Northwest Power and Conservation Council

April 3, 2008

MEMORANDUM

TO: Power Committee

FROM: Maury Galbraith

SUBJECT: Forecasts of the Northwest Power System's Marginal Carbon Dioxide Production Rates

Staff has developed new forecasts of the Northwest power system's marginal carbon dioxide (CO2) production rates. A draft paper describing the forecast methodology and results is included in the Power Committee packet.

The Council and the Regional Technical Forum use the marginal CO_2 production rates to quantify and evaluate the CO_2 offset benefits of energy efficiency measures and other resources with low CO_2 emissions. The methodology used to estimate the Northwest power system's marginal CO_2 production is an extension of the modeling described in the Council's recent Interim Wholesale Power Price Forecast paper.

Staff will describe the forecast results during the Power Committee meeting. Some of the major findings and conclusions of this new analysis are:

- For the Northwest power system, with its large amount of hydroelectric generating resources and increasing amount of wind generating resources, the *marginal CO_2 production rate* is considerably higher than the *average CO_2 production rate*.

- The region's marginal rate of CO_2 production and its total amount of CO_2 production tend to move together, but in opposite directions.

- The type and amount of generating resources added to the Western power system outside our region influence the Pacific Northwest's CO_2 production.

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Northwest Power and Conservation Council

April 15, 2008

DECISION MEMORANDUM

TO: Council Members

FROM: Terry Morlan, Director, Power Planning Division
Wally Gibson, Manager, System Analysis and Generation
John Fazio, Senior System Analyst

SUBJECT: Adoption of a Resource Adequacy Standard for the Northwest

PROPOSED ACTION: Accept the proposed changes to Council document number 2008-01, "A Resource Adequacy Standard for the Northwest" and adopt the language as provided in the amended document.

SIGNIFICANCE:

- Adoption of the energy bill in 2005 gave the Federal Energy Regulatory Commission (FERC) authority to assess the adequacy of the nation's power supplies. We expect that the Western Electricity Coordinating Council (WECC) will be designated to assess the adequacy of the western power supply. This proposed standard and the corresponding adequacy assessment for the Pacific Northwest power supply will aid WECC's efforts.
- The Bonneville Power Administration (BPA) has been a joint sponsor of the Resource Adequacy Forum and intends to incorporate the standard in its Regional Dialogue and the ensuing contracts.
- The establishment of a regional resource adequacy standard will provide a consistent context to utilities, regulatory commissions and public utility boards in their assessment of individual utility resource plans. This standard will also be incorporated into the Council's next power plan.
- The adoption of this standard effectively completes action items ADQ-1 and ADQ-2 in the Council's fifth power plan.

BUDGETARY/ECONOMIC IMPACTS:

- There are minimal effects on the Council's budget. An assessment of the adequacy of the Northwest's power supply will be made annually by Council staff, aided by members of the Forum. In addition, the methodology used to develop this standard and its targets will be reviewed whenever it is deemed to be appropriate. At this time, there remain some details related to the counting of resources and loads that must be resolved prior to the next assessment. Some of this work will be provided by contractors. The total cost for this work should not exceed $25,000 for this fiscal year. There is no anticipated contract work on this issue for the next fiscal year.

- The regional economic benefits of establishing a resource adequacy standard could be significant. Historically, the region has experienced periods of surplus and deficit energy supplies. Neither situation is desirable from an economic point of view. The establishment of an adequacy standard will not only help reduce the risk of unexpected curtailments and but also minimize the number of times the region finds itself in a costly situation of too little or too much energy supply.

BACKGROUND:

Recent events such as the Western energy crisis of 2001, which led to both curtailments in California and to West-wide electricity price spikes, have forced utilities and regulators to rethink their approach to planning and operating the power system. In that year, the Northwest experienced its second-lowest water year (based on historical records since 1929). Also, few new resources were developed during the late 1990s, leading to areas of resource deficiency throughout the West. These factors, combined with a flawed electricity market design in California and apparent market manipulation, led to the undesirable events of 2001. The Northwest is still recovering from the economic recession following that crisis.

The crisis demonstrated that the public has little tolerance for high and volatile market prices over a prolonged period. It also became clear that the financial community will not lend money for power-plant construction unless developers have power contracts in hand and/or utilities have included the costs of those contracts in their rates.

In an environment where an increasing number of parties will be taking on the responsibility for acquiring resources to serve regional load, a resource adequacy standard is key to ensuring overall regional sufficiency of resources to meet load at reasonable costs. The Pacific Northwest is unique, not only in the predominately hydroelectric nature of its resources, but also in the ratio of public utilities to investor-owned utilities (IOUs). Resource adequacy is more difficult to achieve in the Northwest for the following reasons:

- The ability to rely on wholesale electricity markets and surplus hydroelectric generation (in most years) can mask a condition of resource deficiency.
- The capital risk of constructing new resources in a market with substantially varying supply levels from year to year may be deemed too great for many developers.
- There is a continuing lack of clarity about the responsibility for resource acquisition among public utilities, BPA and independent power producers.

One way to alleviate the problem is to develop a regional resource adequacy standard and implementation framework. Such a standard would help utilities and their regulators gauge whether they have enough resources to meet their loads under a regionally accepted measure of generation sufficiency. A framework for implementing the standard would lay the foundation for those entities to plan for and acquire sufficient resources to meet load.

In its Fifth Power Plan, the Council recognized the importance of developing a resource adequacy standard and implementation framework. Action items ADQ-1 and ADQ-2 in the plan call for the establishment of resource information-gathering protocol and for the development of a resource adequacy standard for the Pacific Northwest. To achieve these goals, the Council and BPA instigated the Pacific Northwest Resource Adequacy Forum (Forum), with the intention that this group would develop a resource adequacy standard for the northwest.

ANALYSIS:

The Resource Adequacy Forum has been working on this task since June of 2005. Analysis and documents, including meeting notes, are posted on the Council's web site at http://www.nwcouncil.org/energy/resource/Default.asp. The Forum is comprised of a technical work group and a policy steering committee.

The proposed standard consists of a metric (something that can be measured) and a target (an acceptable value for that metric) for both energy (annual) and capacity (hourly) capabilities of the system. The standard is designed to be transparent and simple to understand.

For the energy metric, an annual load/resource balance is proposed and for the capacity metric, a reserve planning margin (or surplus sustained-peaking capability) is proposed. The targets for both the energy and capacity metrics are based on a more detailed and sophisticated analysis of the power system, which includes hourly as well as seasonal analysis.

This standard is expected to be dynamic, in that the targets will be adjusted as conditions in the power supply or demand change and as the region's ability to measure and analyze its capability improves.

ALTERNATIVES:

- One alternative is to not adopt a Northwest resource adequacy standard. This means that the region would continue to develop resources without the benefit of an overarching strategy. The likely outcome of this alternative is a greater possibility of periods of over- or under-building for the needs of Northwest consumers. Quantifying the potential regional cost of this alternative is difficult but based on past experiences could be significant.
- A second alternative is to allow the WECC to establish a West-wide adequacy standard, which would also apply to the Northwest. The drawback to this alternative is that WECC has little or no expertise in planning for systems that are energy-limited (as opposed to capacity-limited regions such as in California). The WECC standard would not likely address Northwest needs in an appropriate way.
- A third alternative is to delay the adoption of a Northwest resource adequacy standard until further review and analysis is complete. Delaying this decision would affect the WECC process of assessing west-wide resource adequacy and it clearly will affect BPA's efforts in its regional dialog. Because this standard is designed to be dynamic, there appear to be no significant analytical reasons for delaying this decision.

ATTACHMENTS:

The proposed regional resource adequacy standard language (Council document 2008-01) was released for public comment on February 14, 2008. A summary of comments and staff response is attached along with a red-lined version of the draft language that includes proposed minor amendments. In addition, a background paper that provides a greater in-depth description of the adequacy standard is attached.

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MARGINAL CARBON DIOXIDE PRODUCTION RATES OF THE NORTHWEST POWER SYSTEM

APRIL 3, 2008

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Marginal Carbon Dioxide Production Rates of the Northwest Power System

INTRODUCTION

This paper forecasts marginal carbon dioxide (CO_2) production rates for the Pacific Northwest power system. Power system planners and resource analysts can use the marginal CO_2 production rates to evaluate the cost of future CO_2 emissions and the relative benefits of energy efficiency measures and other resources with low CO_2 emissions. The cost of future CO_2 regulation is a significant risk factor in utility resource planning. Failing to properly account for this risk in resource evaluation can result in a poor resource decisions and higher costs for the region's ratepayers.

SUMMARY

During any given hour of the year, there are numerous generating units supplying power to the Pacific Northwest power system. Some of these units will be hydroelectric units or wind generating units that do not emit CO_2 into the atmosphere. At the same time, some of these units will likely be coal-fired or natural gas-fired generating units that do emit CO_2 into the atmosphere. Each type of generating unit has a distinct rate at which it emits CO2. For example, a contemporary natural gas-fired combined cycle unit emits roughly 0.8 pounds (lbs.) of CO_2 per kilowatt-hour. A typical conventional coal-fired steam unit emits roughly 2.3 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, generating resources are typically brought on-line in order of their operating costs. In other words, resources with low operating costs are used before resources with higher costs. In general, hydroelectric and wind generating units will be brought on-line before coal-fired or natural gas-fired generating units. It is the CO_2 emissions of the marginal resource that can be avoided by adding energy efficiency measures to the system. Power system planners and resource analysts should use the marginal CO_2 production rates to evaluate the CO_2 cost associated with future purchases of power from the wholesale power market and the relative benefits of energy efficiency measures and other resources with lower CO_2 emissions.

In this paper, we estimate the Pacific Northwest power system's marginal resource, and its CO_2 production rate, during each hour for four separate years, 2010, 2015, 2020, and 2025. Because there are typically 8,760 hours during a year, we summarize our results by providing *average marginal CO_2 production rates* for each year. 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.

The major findings and conclusions of this new analysis are:

- For the Northwest power system, with its large amount of hydroelectric generating resources and increasing amount of wind generating resources, the *marginal CO_2 production rate* is considerably higher than the *average CO_2 production rate*. Power system planners and resource analysts should use the marginal CO_2 production rates to quantify and evaluate the CO_2 offset benefits of energy efficiency measures and other resources with low CO_2 emissions.

- Marginal CO_2 production rates for the Northwest power system, under our Interim Base Case assumptions, are forecast to range between 0.7 pounds (lbs.) of CO_2 per kilowatt-hour (kWh) and 0.9 lbs. of CO_2 per kWh over the period 2010 through 2025.

- The region's average marginal rate of CO_2 production and its overall level of CO_2 production tend to move together, but in opposite directions. For example, under our combined High Capital Cost and High CO_2 Price Case assumptions, the region's marginal CO_2 production rate is forecast to jump as high as 1.8 lbs. of CO_2 per kWh. Importantly, however, the dramatic increase in the region's marginal CO_2 production rates is accompanied by the intended result of carbon regulation -- a large decrease in overall CO_2 emissions.

- The type and amount of generating resources added to the Western power system outside our region influence the Pacific Northwest's CO_2 production. For example, although the Interim Base Case and the High Capital Cost Case forecasts have essentially the same resource mix for the Pacific Northwest, the High Capital Cost Case forecasts less overall new plant development, and no new conventional coal-fired plant development, in the Western power system over the planning period. This results in lower annual CO_2 emissions for the Western power system. At the same time, however, annual CO_2 production increases in the Pacific Northwest (and marginal CO_2 production rates decline) as Northwest resources are operated more intensely to meet loads both inside and outside the region.

METHODOLOGY

The methodology we use to estimate the Pacific Northwest power system's marginal resource is an extension of the modeling described in the Council's recent Interim Wholesale Power Price Forecast paper.[1] In this paper, we provide further analysis of two scenarios presented in the interim forecast paper: the Interim Base Case and the High Capital Cost Case. Each of these cases incorporates the same fuel price forecasts, estimates of the future costs of CO_2 allowance prices, and schedule of renewable resource additions to achieve state renewable portfolio standards. The only difference between these cases is the estimated costs of constructing new

[1] The Interim Wholesale Power Price Forecast paper (Draft) is available at: http://www.nwcouncil.org/library/2007/2007-20.htm

generating resources.[2] The Interim Base Case assumes construction costs from the 2006 Biennial Monitoring Report of the Fifth Power Plan. Since the release of the monitoring report, there has been a significant increase in construction costs. The High Capital Cost Case was developed to better reflect current estimates of the future cost of building new generating resources and is being used in the preliminary studies for the Sixth Power Plan. We also present new results for a combined High Capital Cost/High CO_2 Price Case. The resource mix underlying each of these forecasts affects the determination of the marginal market-clearing resource, and therefore, the marginal CO_2 production rate for the Pacific Northwest power system. These effects are discussed in the results section of this paper.

Council staff uses the AURORA^xmp®^ Electric Market Model to develop its wholesale power price forecasts.[3] 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 AURORA^xmp^ uses 18 load-resource zones to represent the Western power system. The Pacific Northwest power system is represented by 6 of these zones.[4] Therefore, for each hour of a simulation period, AURORA^xmp^ identifies 6 marginal resources for the Pacific Northwest, one for each zone.[5]

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 AURORA^xmp^ hourly output databases. The hourly output databases contain statistics summarizing the simulated operation of each generating unit located in the Pacific Northwest.[6] 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 are those that are operated regardless of wholesale power market prices. For the Northwest, must-run resources include: wind plants, municipal solid waste facilities, industrial co-generation facilities, geothermal steam plants, and landfill gas energy recovery and other biogas facilities. Second, for each hour, any unit that did not generate electricity was removed from consideration. Finally, of the remaining units, the unit with the highest dispatch cost was selected as the region's marginal resource for each hour.[7] This process resulted in a single marginal resource for the Pacific Northwest for each hour of the simulation period.[8]

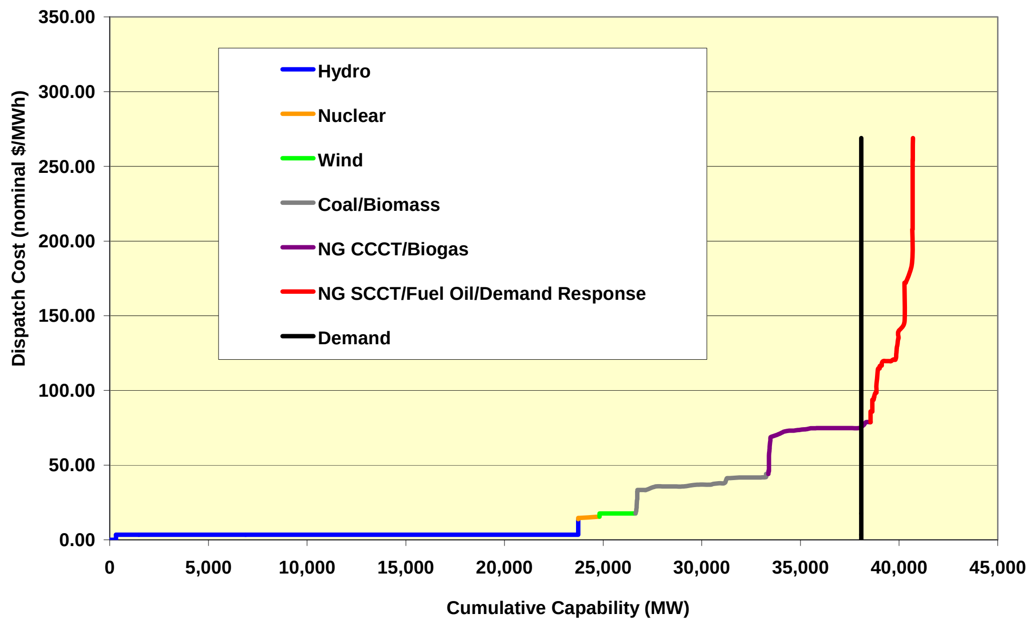
This methodology for identifying the region's marginal resource is analogous to the resource stacking approach depicted in Figure 1. The figure is a snapshot of our forecast of the region's supply and demand during the peak hour of demand in 2020.[9] The vertical axis of the figure is dispatch cost -- the cost that can be avoided by curtailing operation of a resource. For any resource, the dispatch cost is comprised of the variable operating and maintenance costs

[2] For a description of our current estimates of new resource capital costs see the Interim Wholesale Power Price Forecast paper (pp. 10-13).
[3] Available from EPIS, Inc. (www.epis.com).
[4] The Pacific Northwest zones are identified as PNW Westside North, PNW Westside South, PNW Eastside North, PNW Eastside South, Idaho South, and Montana East.
[5] This is equivalent to 52,560 marginal resources in the Pacific Northwest on an annual basis (8,760 hours * 6 load-resource zones = 52,560 marginal resources).
[6] The annual databases contain rough 7.4 million records (844 generating units * 8,760 hours = 7.4 million records)
[7] If two unit or more units tied for the highest dispatch cost in an hour, the unit operating farthest from its maximum capability (or closest to its minimum capacity) was chosen as the marginal resource.
[8] For an annual simulation period, this results 8,760 marginal resources in the Pacific Northwest.
[9] The snapshot shown is for hour ending 7:00 P.M. on January 15, 2020.

(including integration costs for intermittent resources), variable fuel cost, CO_2 allowance cost, any unit cycling premium, and a dispatch premium representing the "profit" over cost demanded by a plant owner to dispatch the resource.

The horizontal axis represents cumulative generating capability for the hour. The supply curve for this hour starts with the region's lowest cost resource, hydroelectric generation, and adds additional segments of supply in order of increasing dispatch cost. The forecast demand for electricity in this hour is 38,081 megawatts, shown as the vertical black line. The region's marginal resource for this hour is the generating unit that is situated at the intersection of the region's supply and demand curves.

Figure 1: Illustration of the marginal resource selection methodology (High Capital Cost Case)



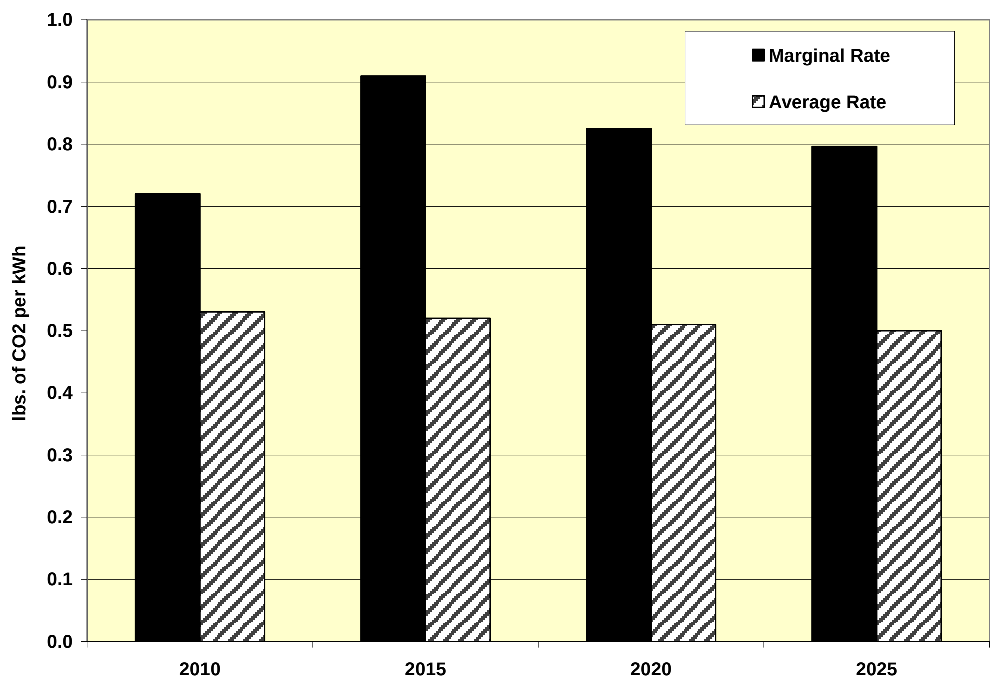
The region's marginal resource will change not only from season to season as the region's water supply, loads, fuel prices, and resource availability varies, but also from hour to hour as demand changes. The filtering methodology described in the previous paragraph is roughly analogous to performing this resources stacking for each hour of the forecast year.

RESULTS

Interim Base Case

For the Northwest power system, with its large amount of hydroelectric generating resources and increasing amount of wind generating resources, the *marginal* CO_2 *production rate* is considerably higher than the *average* CO_2 *production rate*. Figure 2 compares these two rates for the Interim Base Case.

Figure 2: Northwest marginal and average CO_2 production rates (Interim Base Case)



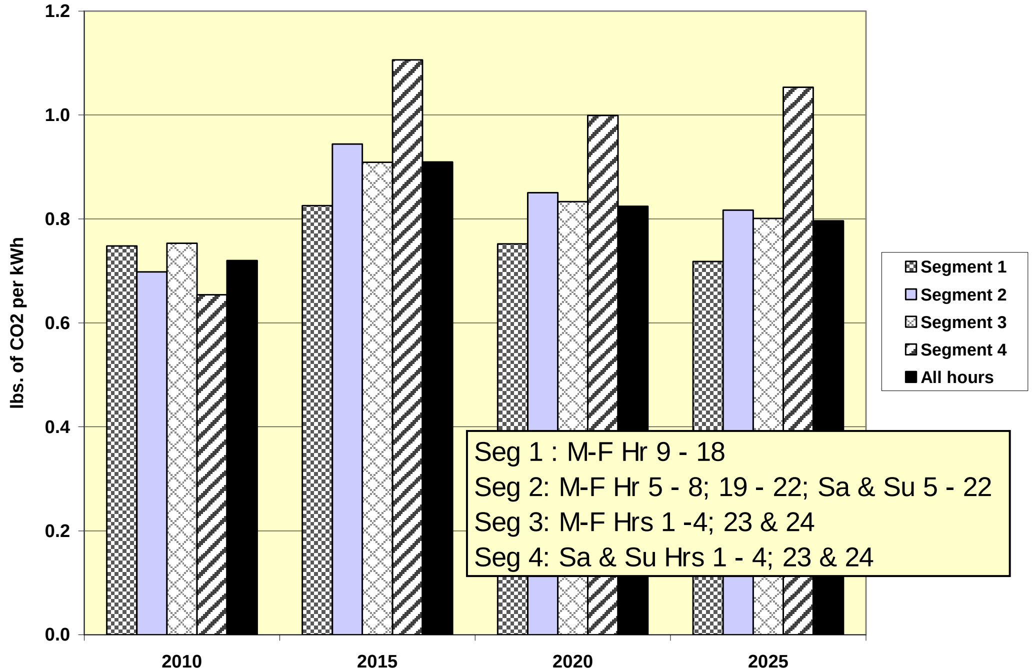
Power system planners and resource analysts should use the marginal CO_2 production rates to evaluate the CO_2 cost associated with future purchases of power from the wholesale power market and the relative benefits of energy efficiency measures and other resources with lower CO_2 emissions. For example, given the Council's current interim forecast of future CO_2 emissions prices (i.e., $11.12 per ton in 2015, $12.55 per ton in 2020, and $14.15 per ton in 2025), the estimated CO_2 cost included in future purchases from the wholesale power market would be $5.06 per megawatt-hour (MWh) in 2015, $5.17 per MWh in 2020, and $5.63 per MWh in 2025.[10]

Marginal CO_2 emission rates (pounds of CO_2 per kWh) vary by time of day and day of week because the marginal generating resource changes with load. Gas-fired power plants with relatively high variable costs are typically on the margin during heavier load hours, whereas coal-fired plants with lower variable costs can be on the margin during nighttime and weekend light load hours. Therefore, both the physical quantity, and dollar value, of avoided CO_2

[10] The calculation of the market CO_2 cost in 2015 is: (0.9 lbs. of CO_2 per kWh) / (2000 lbs. per ton) * (1000 kWh per MWh) * ($11.12 per ton of CO_2).

emissions vary with time. The Council and the Regional Technical Forum use four load segments to assess the cost-effectiveness of conservation measures. Figure 3 shows the average marginal CO_2 emission rates for the four segments for the four future years.

Figure 3: Northwest marginal CO_2 production rates by load segment (Interim Base Case)

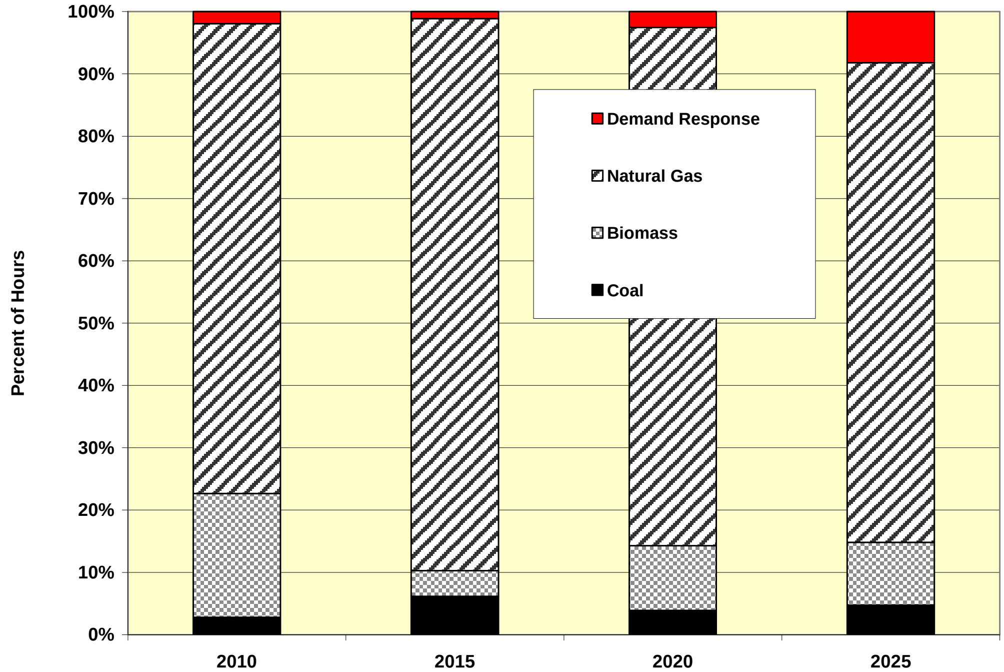


The pronounced increase in the marginal CO_2 production rate during weekend nighttime hours (i.e., during Segment 4 hours) is due to coal-fired units being the marginal resource during these low load hours. This is consistent with the recent and expected addition of significant amounts of wind generation to the Northwest power system, which pushes coal-fired resources up toward the margin.[11] After 2015, there is a slight downward trend in the Northwest's marginal CO_2 production rates. This downward trend reflects the changing fuel mix of the region's marginal resources over time.

Figure 4 shows the percentage of hours in each year that resources of various fuel types are on the margin. The percentage of hours that coal-fired resources are the marginal resource declines from 6.2 percent in 2015 to 4.7 percent in 2025. As regional loads continue to grow, there is also an increase in the number of high load hours during which demand response is the region's marginal resource. Both of these changes have the effect of lowering the region's marginal CO_2 production rates.

[11] An open issue at this time is whether the coal-fired resources operating at the margin during these light load hours can provide the operational flexibility needed to integrate intermittent resources into the power system.

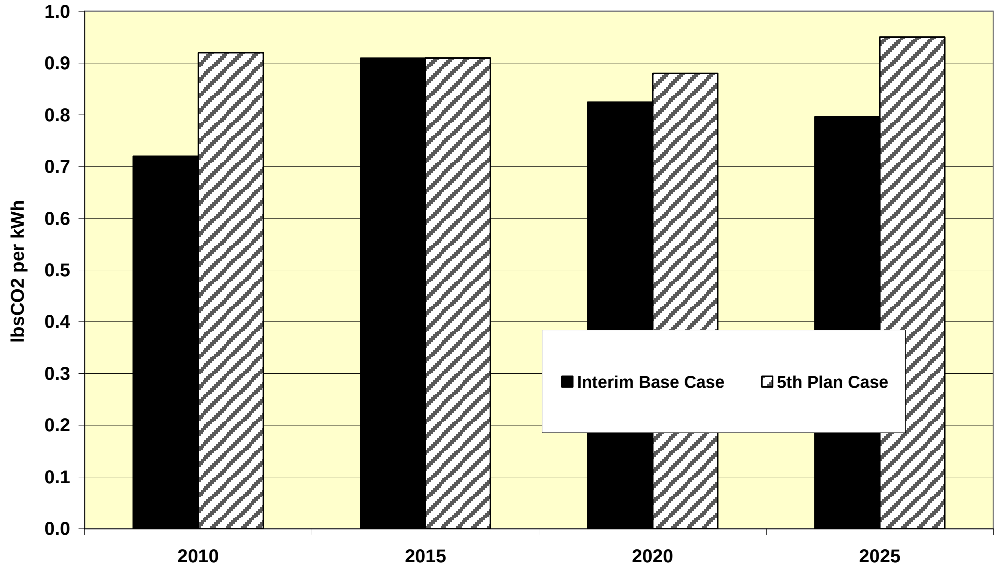
Figure 4: Percentage of hours resources of various fuel types are the marginal resource (Interim Base Case)



The low percentage of hours that coal-fired resources are the region's marginal resource is a significant change from the Council's previous forecast of the marginal rate of CO_2 production in April, 2006.[12] At that time, coal-fired resources were forecast to be the marginal resource in 16 percent of the hours in 2010, declining to 12 percent of the hours in 2025. This difference in marginal resource mix is evident in a comparison of the two forecasts of marginal CO_2 production rates (see Figure 5).

[12] Staff presented, "Power System Marginal CO_2 Production Factors" to the Council's Power Committee on April 11, 2006, in Whitefish, Montana.

Figure 5: Comparison of marginal CO_2 production rates (Interim Base Case vs. 5th Plan Case)



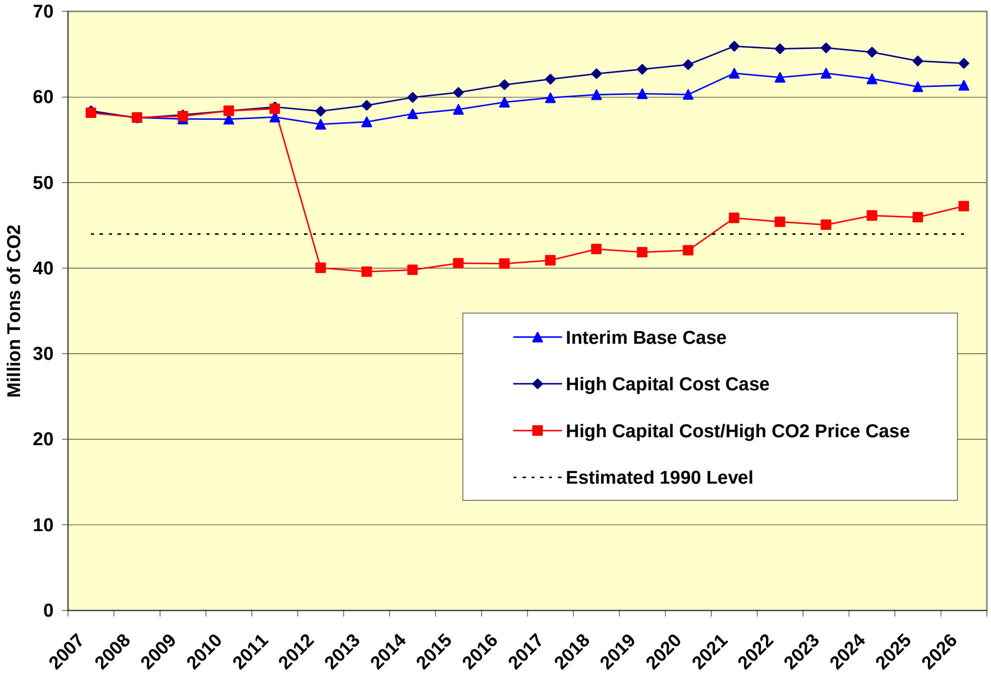
The decrease in coal-fired generation on the margin can be partly attributed to the improved methodology for selecting the region's marginal resource.[13] However, this difference is also partly explained by differences in forecast assumptions and the forecast, or recommended, resource mix for the Pacific Northwest. For example, the Interim Base Case uses higher CO_2 allowance prices than the 5th Plan Case.

It is important to place the declining trend in the Northwest power system's marginal CO_2 production rates, and the underlying changes in its marginal resource mix, within the wider context of the overall increase in the system's CO_2 production. In our Interim Base Case, Northwest power system CO_2 emissions are forecast to total 57 million tons in 2010, and to increase to 61 million tons in 2025. For comparison, we previously estimated that the Northwest power system's CO_2 production was 44 million tons in 1990 and that it would have been 57 million tons in 2005 (had normal hydro conditions prevailed).[14] Figure 6 shows our CO_2 emissions forecasts for the Northwest power system under the three future scenarios discussed in this paper.

[13] The previous methodology selected a single regional marginal resource during each hour of the year by starting with the units that AURORA[xmp] identified as the marginal resource in each of the six Northwest load-resource zones. Starting with only one resource in a load-resource zone, and then removing it from further consideration if it is a must-run resource, has the effect of removing all the resources in that zone from consideration as the region's marginal resource. In some hours, this method could erroneously select an intra-marginal resource as the region's marginal resource. The prior method had the potential to overstate the occurrence of coal-fired units and hydroelectric units as the region's marginal resource. The methodology presented in this paper avoids this problem by starting with all of the generating units dedicated to serving loads in the Pacific Northwest.

[14] We also estimated that with implementation of the recommended resource portfolio of the 5th Power Plan, CO_2 emissions would total 67 million tons in 2024. These estimates are from the Council's paper titled, "Carbon Dioxide Footprint of the Northwest Power System." This paper is available at: http://www.nwcouncil.org/library/2007/2007-15.htm

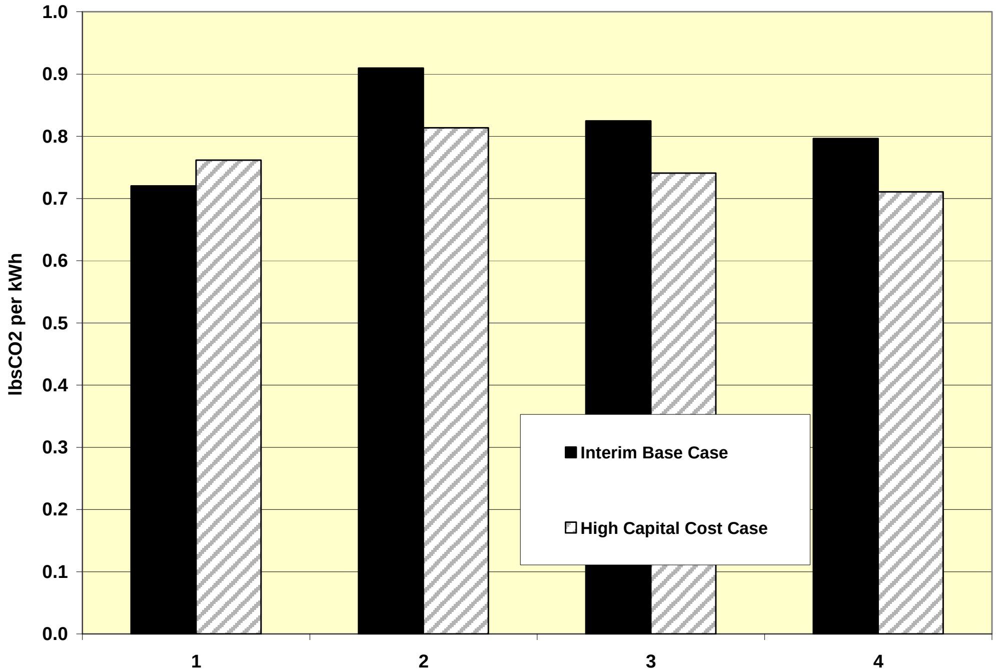
Figure 6: Forecasts of the Northwest power system's CO_2 emissions



High Capital Cost Case

It is also important to describe the sensitivity of our results to changes in key input assumptions. Figure 7 shows the effect on marginal CO_2 production rates of our revision in the forecast construction costs of new generating resources. The higher construction costs in the High Capital Cost case reduce the level of forecast resource additions in other regions of the Western Electricity Coordinating Council (WECC) area. This leads to more intense use of power resources in the Pacific Northwest, and to lower marginal CO_2 production rates.

Figure 7: Comparison of marginal CO_2 production rates (High Capital Cost Case and Interim Base Case)



The portfolio of Northwest generating resources is essentially the same in both the High Capital Cost Case and Interim Base Case. In both cases, Northwest generating resources consist of existing resources and the forecast addition of renewable resources to meet state renewable portfolio standards. The reduction in marginal CO_2 production in the Northwest is primarily driven by a change in the amount and type of new resources added to meet load in areas outside of the Northwest. The High Capital Cost Case results in more new natural gas-fired resources and fewer new coal-fired resources being added to the Western power system over the planning period.[15] This change in incremental resource mix, results in Northwest resources being dispatched more often to serve loads, both inside and outside the region. This increase in the dispatch of regional resources increases the occurrence of natural gas-fired resources on the margin and reduces the Northwest's marginal CO_2 production rates.

Although the increase in new resource construction costs results in higher total CO_2 production in the Northwest (e.g., 64 million tons in 2025 in the High Capital Cost Case compared to 61 million tons in 2025 in the Interim Base Case), it results in lower total CO_2 production in the WECC (e.g., 461 million tons in 2025 in the High Capital Cost Case compared to 519 million tons in the Interim Base Case).

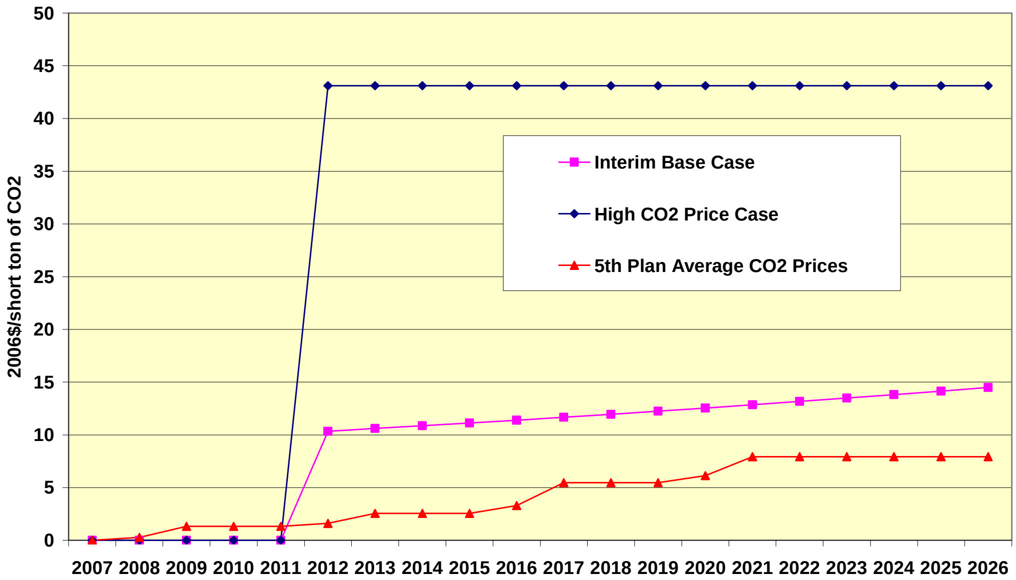
Combined High Capital Cost and High CO_2 Price Case

The following figure shows the difference between the CO_2 allowance prices used in the Interim Base Case (and High Capital Cost Case), and the higher CO_2 allowance prices used in the High

[15] See Interim Wholesale Power Price Forecast paper (at page 26) for a detail description of this change in incremental resource mix.

Capital Cost/High CO_2 Price case.[16] It also shows the average of the 750 possible future trajectories of CO_2 emissions prices used in the Fifth Power Plan.

Figure 8: Base and high CO_2 emission prices



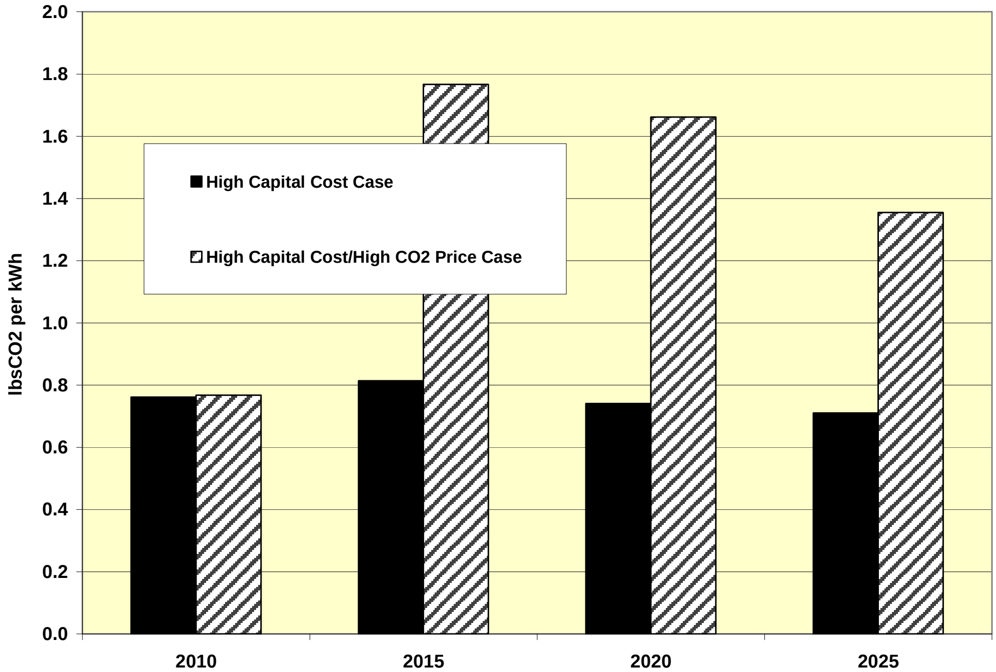
The higher CO_2 emissions prices used in the High Capital Cost/High CO_2 Price Case significantly reduce the forecast annual CO_2 production of the Western power system. Forecast WECC-wide CO_2 production drops from 461 million tons in the High Capital Cost Case to 384 million tons in the High Capital Cost/High CO_2 Price Case. The higher CO_2 emissions prices also drive a dramatic decline in the forecast of annual CO_2 production from the Northwest power system (see Figure 6).[17]

The higher CO_2 prices also have a significant effect on the forecast of the Northwest's marginal CO_2 production rates. These marginal rates are dramatically higher (see Figure 8). This increase occurs because the higher CO_2 prices drive heavy CO_2 producing resources to the less frequently dispatched end of region's supply curve, and put them on the margin during more hours of the year.

[16] For a description of the rationale underlying our CO_2 emission price assumptions see the Interim Wholesale Power Price Forecast paper (pp. 8-10).

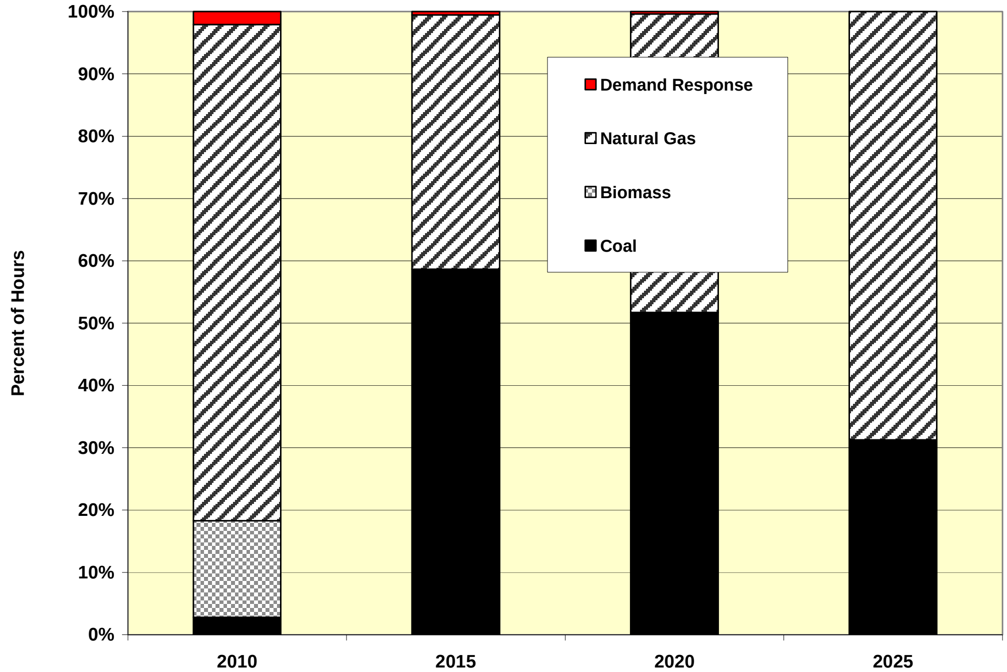
[17] The higher CO_2 emissions prices result in 1,200 megawatts (MW) of new wind resources being added to the Northwest power system over the planning period (i.e., 500 MW in 2016, 200 MW in 2024, and 500 MW in 2025). This is installed wind capacity above the amount forecast to be added to meet state renewable portfolio standards.

Figure 8: Comparison of marginal CO_2 production rates (High Capital Cost Case vs. High Capital Cost/High CO_2 Price Case)



Under the High Capital Cost/High CO_2 Price Case assumptions, coal-fired resources are the marginal resource during 59 percent of the hours in 2010, 52 percent of the hours in 2015, and 31 percent of the hours during 2025. Figure 9 shows the marginal resource mix for this sensitivity case.

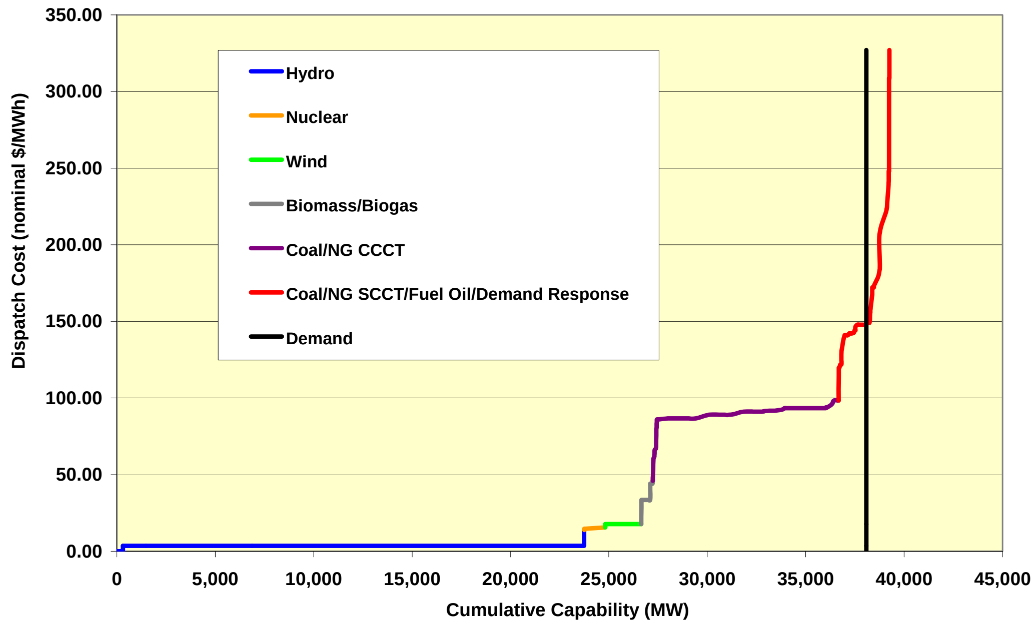
Figure 9: Percentage of hours resources of various fuel types are the marginal resource (High Capital Cost/High CO_2 Price Case)



Again, stated differently, the increase in the percentage of hours that the Northwest's coal-fired resources are on the margin is attributable to the dispatch cost of these generating units increasing to, and in some cases surpassing, the dispatch cost of the Northwest's natural gas-fired combined cycle units. This "leveling" effect of the higher CO_2 emission prices is illustrated in the following snapshot of the region's supply and demand during the peak hour of demand in 2020.[18]

[18] The snapshot shown is for hour ending 7:00 P.M. on January 15, 2020.

Figure 10: Illustration of the change in the regional supply curve (High Capital Cost/High CO_2 Price Case)[19]



With the high CO_2 emissions prices, most of the region's coal-fired units move up to share the same relative position on the region's supply curve with natural gas-fired combined cycle units (some of the less efficient coal-fired units move beyond this level to mix with natural gas-fired simple cycle units and other "peaking" resources). This leveling of the costs of coal-fired generation and natural gas-fired generation creates a "high plateau" in the region's supply curve near $90 per MWh. A quick comparison of Figure 10 and Figure 1 also highlights this effect. The resources lying along this plateau would likely clear the market during many hours of the year.

This analysis confirms that high CO_2 emission prices can drive significant reductions in total CO_2 emissions, both WECC-wide and in the Pacific Northwest. The analysis also shows that high CO_2 emissions prices increase the region's marginal rate of CO_2 production, and therefore, likely increase the CO_2 offset values of energy efficiency measures.

CONCLUSION

This paper forecasts marginal CO_2 production rates for the Pacific Northwest power system of between 0.7 lbs. per kilowatt-hour and 0.9 lbs. per kilowatt-hour for the period 2010 through 2025, under interim base case assumptions. The Council and the Regional Technical Forum can use these marginal CO_2 production rates to quantify the CO_2 emissions avoided by conservation and to evaluate the cost-effectiveness of energy efficiency measures and other resources with

[19] Coal purposefully appears in two places on the legend. With high CO_2 emissions prices most of the Northwest's coal units have dispatch costs similar to natural gas-fired combined cycle combustion turbines (NG CCCT), however, some of the less efficient coal units have even higher dispatch costs, similar to natural gas-fired simple cycle combustion turbines (NG SCCT) and other peaking resources.

lower CO_2 emission rates. These marginal CO_2 production rates are very sensitive to changes in the future regulation, and cost, of CO_2 emissions. Because of this sensitivity, the marginal CO_2 production rates may change significantly if the assumptions regarding CO_2 allowance prices change during development of the Sixth Power Plan.

q:\tm\council mtgs\2008\apr 08\(p4-5)marginal co2 production.doc

Marginal CO_2 Production Rates of the Northwest Power System

Maury Galbraith
Northwest Power and Conservation Council

Power Committee

Whitefish, MT

April 16, 2008

Marginal CO_2 Production Rates

- The CO_2 emissions rate of the last resource (or marginal resource) brought on-line to supply power during a given hour.
- Measured in pounds of CO_2 per kilowatt-hour (lbs. per kWh).
- Power system results are averages of the CO_2 production rate of the marginal resources in each hour of the period (e.g., 8,760 marginal resources per year).

Applications

- Used by the Council, the Regional Technical Forum, the Energy Trust of Oregon, and others.
- Used to quantify avoided CO_2 emissions of energy efficiency or demand response measures.
- Used in estimating the dollar value of avoided CO_2 emissions in cost-effectiveness analysis of energy efficiency measures and other low CO_2 emission resources.

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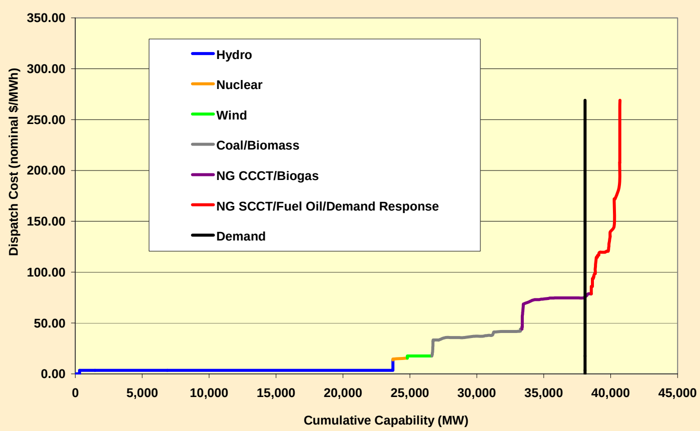
Use AURORA^xmp Hourly Output to Identify the Marginal Resource in Each Hour
(e.g., Jan. 15, 2020 HE 7:00 P.M.)



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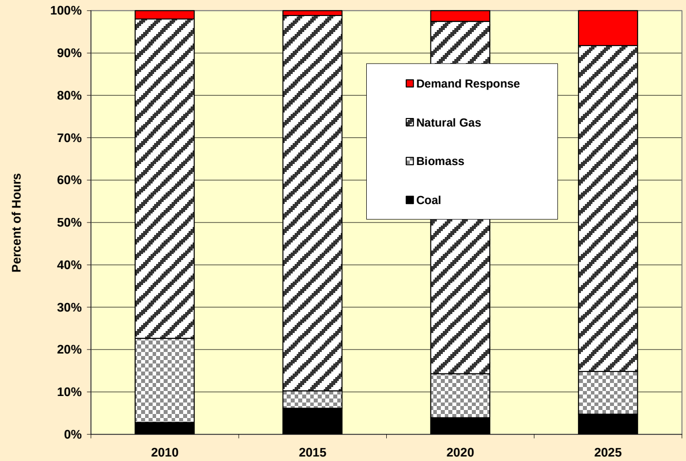
Interim Base Case: Northwest Power System's Marginal Resource Mix



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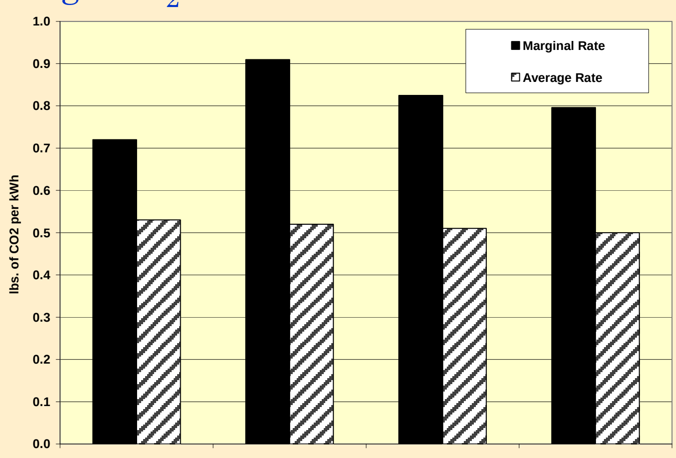
Interim Base Case: Marginal CO_2 Rates Greater Than Average CO_2 Rates



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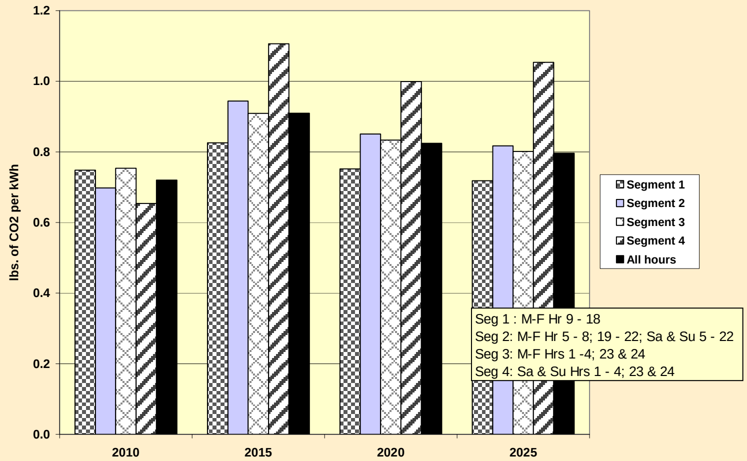
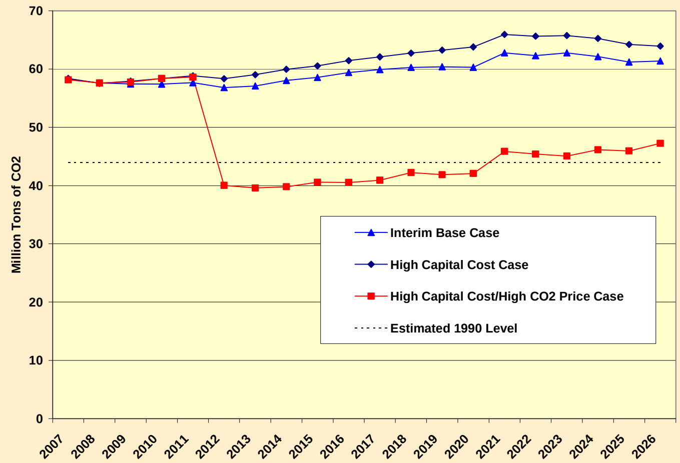
Interim Base Case: Marginal CO_2 Production Rates by Load Segment



Sensitivity Cases:

- High Capital Cost Case
  - Changes the capacity expansion outside the Northwest
  - Primary effect: No new conventional coal-fired resources
  - Detailed description in Interim Wholesale Power Price Forecast Paper
  - Available at: http://www.nwcouncil.org/library/2008/2008-05.pdf
- High Capital Cost/High CO_2 Price Case
  - New combined sensitivity case
  - CO_2 emissions price of $43/ton (constant 2006 dollars) beginning in 2012
  - Primary effect: Changes the dispatch position of coal-fired resources
  - A coal plant is retired in the Northwest
  - Additional (beyond RPS) wind development in the Northwest

Northwest Power System's Annual CO_2 Production



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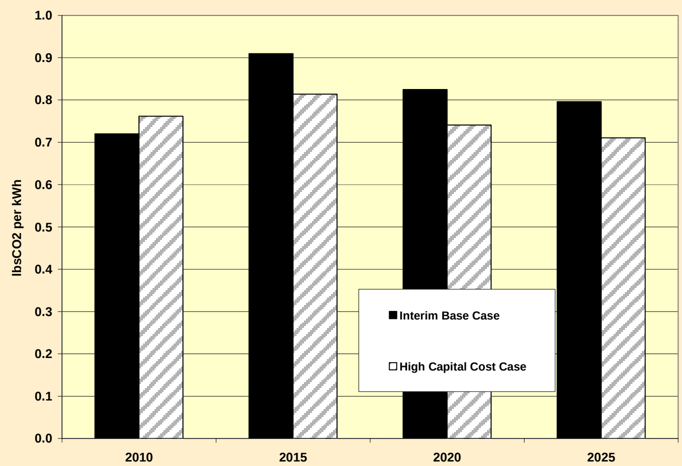
High Capital Cost Case: Lower Marginal CO_2 Production Rates



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High Capital Cost Case: Lower Marginal CO_2 Rates But Higher Annual CO_2 Emissions

- Outside the Northwest:
  - Significantly less coal-fired resource development
  - Slightly more natural gas-fired combined cycle resource development
  - Lower overall capacity expansion
- Inside the Northwest:
  - All resource development is RPS-driven
  - No significant change in Northwest resource mix
  - Greater use of Northwest resources to meet load both inside and outside the region
- Results in:
  - Higher Annual CO_2 Production in the Northwest
  - Lower Marginal CO_2 Production in the Northwest
  - AND Lower Annual CO_2 Production in the WECC

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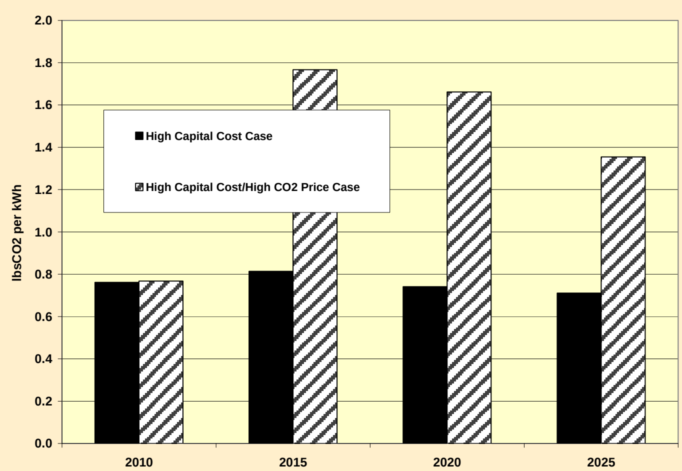
High Capital Cost/High CO_2 Price Case: Higher Marginal CO_2 Production Rates



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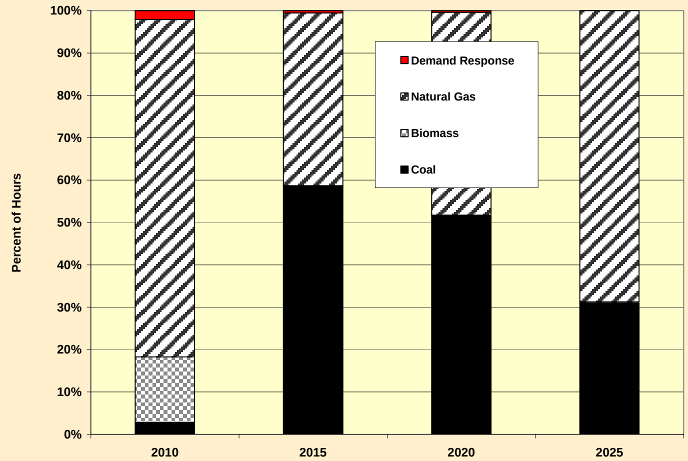
High Capital Cost/High CO_2 Price Case: Northwest Power System's Marginal Resource Mix



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High Capital Cost/High CO_2 Price Case: Higher Marginal CO_2 Rates But Lower Annual CO_2 Emissions

- Higher CO_2 emissions prices increase the dispatch costs of coal-fired (and to a lesser extent natural gas-fired) resources.
- Results in coal-fired resources being the marginal resource during more hours of the year. This increases marginal CO_2 emission rates.
- Also results in less overall reliance on coal-fired resources (and more reliance on natural gas). This reduces annual CO_2 emissions.

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Conclusions

- Under Interim Base Case assumptions, the average marginal CO_2 production rate of the Northwest power system is expected to range between 0.7 -- 0.9 lbs. of CO_2 per kWh.
- Marginal CO_2 production rates vary significantly by hourly load segment (-9% to +33% of all hour average).
- The CO_2 offset value of (flat output) conservation ranges between $0 and $5.60 per MWh under base case CO_2 emission price assumptions (in constant 2006 dollars).

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More Conclusions

- If carbon regulation causes CO_2 emission prices to rise to $50 per ton, then the Northwest's average marginal CO_2 production rate could double to 1.8 lbs. of CO2 per kWh.
- With high CO2 emissions prices and high marginal CO2 production rates, the CO_2 offset value of (flat output) conservation could be as high as $38 per MWh (in constant 2006 dollars).

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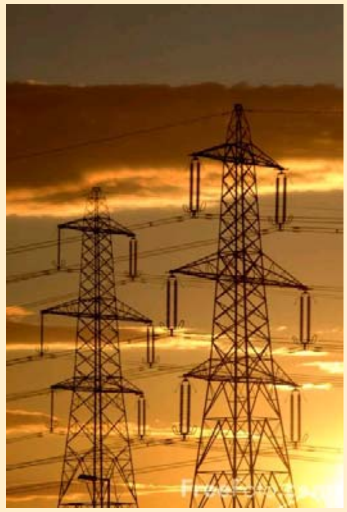

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