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A brief history of carbon emissions from the Northwest power system[☆]

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ABSTRACT

The Pacific Northwest power system emits carbon but it is difficult to identify long-term trends or short-term events because of high year-to-year variation related to hydropower. However, it is possible to normalize CO_2 emissions, essentially estimating what emissions would have been each year if runoff had been average. The method is relevant for identifying trends as well as setting CO_2 emissions targets and verifying their achievement.[1]

1. Northwest carbon emissions

The power system in the Pacific Northwest region of the United States is one of the cleanest in the country and emits about half as much carbon per megawatt-hour as the United States as a whole, 0.23 metric tons compared with 0.47 metric tons. The Northwest Power and Conservation Council has estimated the total carbon emissions from the power system associated with meeting Northwest loads and the results are presented in Fig. 1. The data includes the emissions from thermal plants that are committed to providing power to customers in Washington, Oregon, Idaho, and Montana, some of which are located outside the Northwest.[2]

As Fig. 1 shows, the pattern is erratic largely because emissions are depressed in high-water years (2006, 2011, and 2012) and elevated in low-water years (2001, 2003–5, 2010, 2015), especially 2001, a year of record drought. In high-water years, hydro generation displaces some thermal generation and the opposite occurs in dry years.

2. Adjusting CO_2 emissions

The basic idea for adjusting emissions starts with water because it contributes to hydro generation which in turn reduces thermal generation and CO_2. The amount of water available to generate hydropower in the Northwest varies from year to year and can be approximated by the annual water flowing past the Dalles dam on the lower Columbia River. This is an approximation because not all Northwest dams are in the Columbia drainage, but there is a high correspondence between precipitation in the Columbia and adjoining locations where other Northwest dams are located. The relationship between hydro generation in average megawatts (aMW) and runoff at the Dalles dam is illustrated in Fig. 2.

While higher hydro generation leads to lower thermal generation, the response is not a one-to-one relationship. Separate analysis shows that when hydro generation falls by 100 aMW, coal generation increases by about 17 aMW, gas by 32 aMW, and net exports decrease by 51 aMW. In other words, the Northwest exports less power when hydro generation is low. As a result the annual change in hydro generation causes only about half as much change in thermal generation for the Northwest.[3]

Using these results it is possible to calculate a water-normalized level of coal and gas generation. These adjusted series, presented in Fig. 3, represent the amount of coal and gas generation in the Northwest that would have been expected if water had been at average levels.

There is still some variation from year to year but the pattern is clear: coal generation was flat from 2000 to 2008 and declined gradually after that, while gas rose steadily after the 2001 West Coast energy crisis, with a lapse during the recession from 2008 to 2012.

Three other important factors account for some of the changes in

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[1] A technical appendix that describes the calculations used in this article is available from the authors.
[2] Out-of-region coal plants include 100% of Jim Bridger Power Plant in Wyoming and 50% of North Valmy Generating Station in Nevada. Emissions data were obtained from SNL derived from the Energy Information Agency.
[3] An increase in exports, of course, will likely displace other generation somewhere else, most likely thermal. Consequently the carbon variation observed in the Northwest due to hydropower is a subset of the larger variation that would be observed if we measured West-wide carbon emissions.

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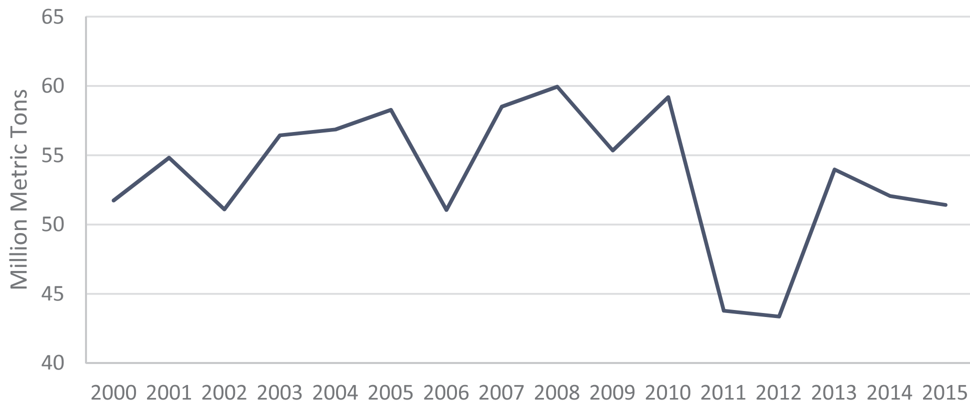

Fig. 1. Carbon Emission NW Power System for NW Loads.

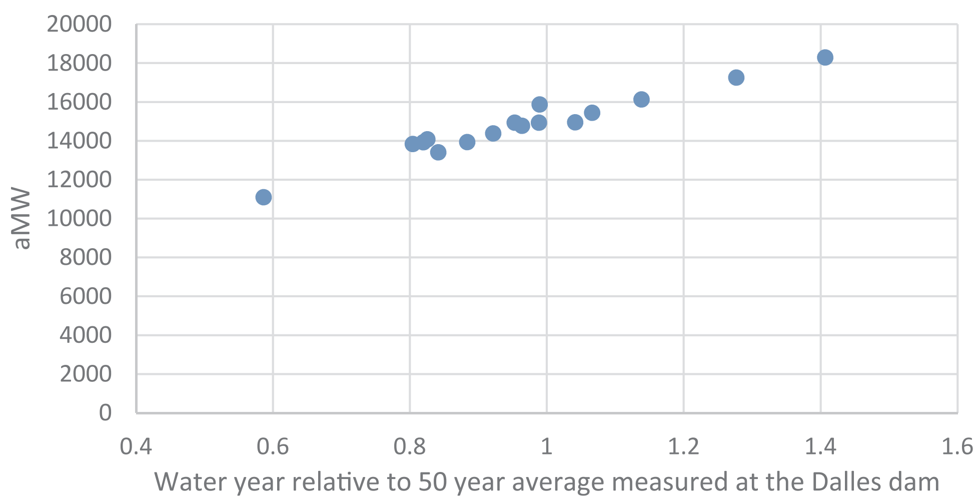

Fig. 2. Hydro Generation and Water Year.

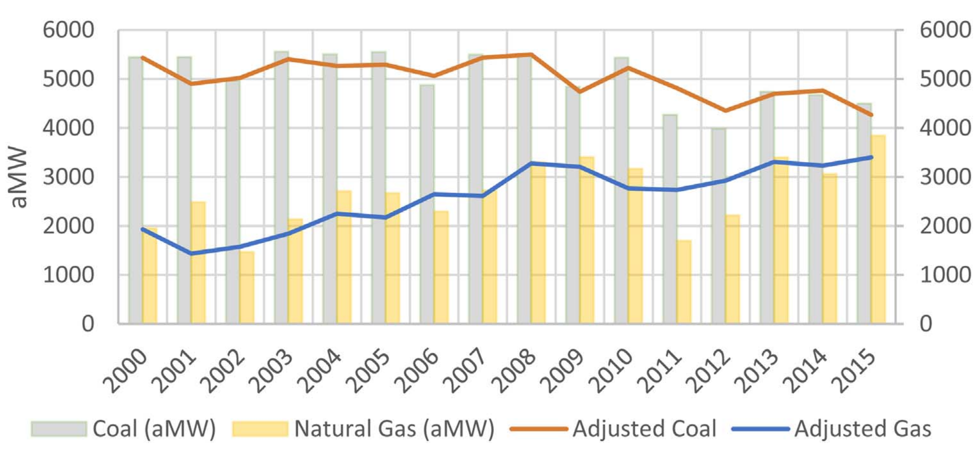

Fig. 3. Coal and Gas Generation Actual and Adjusted for Average Water.

thermal emissions: Northwest loads, represented by regional sales in Fig. 4; annual energy efficiency savings, shown in Fig. 5, and the price of natural gas, represented in Fig. 6. In general, higher loads, lower efficiency, and higher gas prices (which tend to reduce gas relative to coal) result in higher emissions.

3. Adjusted CO_2 emissions

It is easier to see trends in CO_2 emissions if the variability associated with precipitation is removed by normalizing the series to an average water year. The adjusted CO_2 emissions in Fig. 7 were developed by

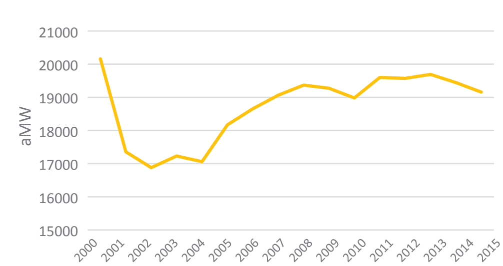

Fig. 4. Total Regional Sales.