LIMITATIONS ON NATURAL GAS COMBINED CYCLE (NGCC) CAPACITY UNDER DEEP CO_2 REDUCTION SCENARIOS

Donald A. Hanson, Argonne National Laboratory, 630-252-5061, dhanson@anl.gov
David K. Schmalzer, Argonne National Laboratory, 703-622-2431, schmalzer@anl.gov
Christopher Nichols, National Energy Technology Laboratory, 304-285-4172, Christopher.Nichols@NETL.DOE.GOV

Overview

Currently low gas prices and renewable mandates and subsidies have already resulted in capacity factor reductions for existing coal-fired power plants (CFPP). These older plants were not designed for cycling operations. We find that adding a CO_2 price (or CO_2 regulations which induce a shadow price on CO_2 emissions) would result in dramatically changing gas and coal markets. Almost all existing CFPP would retire by 2035 (except for the best existing plants that are economic to retrofit with CCS) with an associated doubling (or more) of gas-fired power generation. Advanced NGCC units will have lower variable costs than most existing coal units when there is a price on CO_2 emissions. Dispatching units in order of variable costs pushes the CFPP lower in the loading order. CFPP gradually retire and are replaced with gas and renewable capacity, which further push remaining CFPP down the loading order. It is a dynamic process; a sort of viscous circle in which the replacement capacity for retiring CFPP in a given year contributes to further CFPP retirements in the next year.

Methods

The dynamic process of endogenous retirements due to cycling and replacements requires modelling to better understand. We use the Electricity Supply and Investment Model (ESIM) which is the electric power sector module of the AMIGA Integrated Assessment Model. ESIM includes seven state-based US regions – Northeast, Mid-Atlantic, Southeast, Midwest, Central US, Texas, and Western states. This state grouping corresponds to a current Stanford University Energy Modeling Forum study (EMF-32) of CO_2 price impacts on the electric power sector. We did a thorough literature review of cycling damages, which are mostly due to the interaction of creep (time-dependent deformation below tensile yield) and fatigue (defect growth from cycling-induced changes in stress). We then constructed a damage function and installed code in the ESIM model to account for cumulative cycling damage over time for each coal unit in the model's unit inventory. The ESIM model also represents gas supply functions which were identified from several AEO sensitivity runs. The ESIM model calculates gas prices consistent with gas supply and demand equilibrium.

Results

Figure 1 shows a more than doubling of gas demand added over regions as existing coal plants are retired.

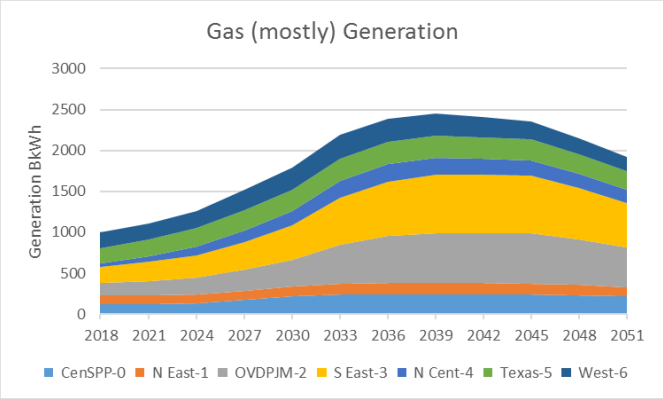

Figure 1. Stacked graph of gas generation by US region due to NGCC replacement for coal.

Figure 2 shows an acceleration of coal unit retirements as cycling damages accumulate in the fleet. Only coal units retrofitted with CCS survive after year 2035. This is in spite of higher gas prices shown in Figure 3 driven mainly by gas demand increases. The resulting CO_2 emission reduction is shown in Figure 4.

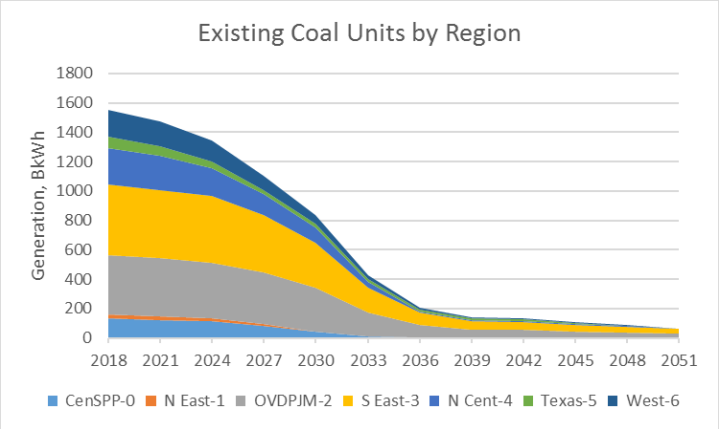

Figure 2. Stacked graph of coal generation by US region due to cycling-related retirements

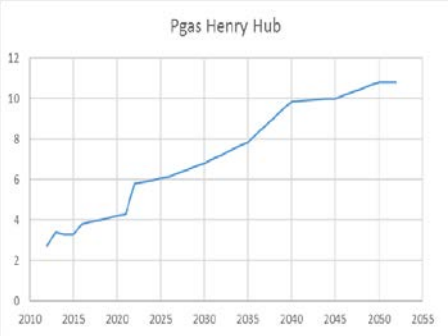

Figure 3. Equilibrium gas price path reflecting increased gas demand

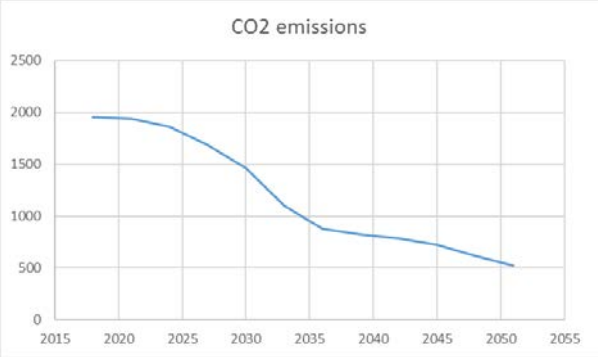

Figure 4. Resulting CO_2 emissions decline based on price of CO_2 at \$15/t in 2025 rising to \$50/t in 2050.

Conclusions

So many new NGCC units projected to be built under the scenario described here will make it difficult to meet 80% CO_2 reductions by 2050 unless the gas units are retrofitted with CCS. Another option is to save more of the best CFPP from cycling modes, thereby reducing the build-up of NGCC capacity prior to the 2050 reduction target.

References

1. Damage to Power Plants Due to Cycling, EPRI, Palo Alto, CA, 2001 No. 1001507, Page ix
2. Kumar, N. et al, Power Plant Cycling Costs, Intertek AIM (formerly APTECH), Subcontract Report No. NREL/SR-5500-55433, NREL, Golden, CO, July 2012