DISCUSSION PAPER

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THE Brattle GROUP

Coal Plant Retirements

Feedback Effects on Wholesale Electricity Prices

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Contents

Summary

This paper describes the likely causes and magnitudes of feedback effects of coal plant retirements on short- and long-term wholesale electricity prices, investigating these issues through a case study and various sensitivity analyses. The primary drivers for feedback effects will be the reduced supply for electricity generation and increases in the cost of natural gas due to increased gas demand from replacing the coal retirements. Increased plant operating costs at retrofit units also will tend to raise prices, while there could be partially offsetting impacts on the cost of coal. Capacity markets, where they exist, may show a short-term increase due to reduced reserves, then a longer-term reduction due to net CONE changing under higher energy prices.

More specifically, in eastern PJM Interconnection LLC (PJM) considering only the impacts of retirements on power supply curve, we estimate the increase in energy prices to be around $3-4/MWh for on-peak hours and $1-2/MWh for off-peak hours. If incremental gas-fired generation were to replace essentially all of the retired coal (a strong assumption, as some of it could go to existing coal and new renewables), then we would expect 10-15% higher gas prices that would further push PJM electric prices to as much as $9-11/MWh for on-peak hours and $5-6/MWh for off-peak hours. However, we expect that both of these effects would attenuate after 5 to 10 years, as a result of markets adding new resources. These increased energy margins are not likely to be large or persistent enough to alter the extent of overall plant retirements. We estimate their present value to be around $100-300/kW, depending on how much gas prices are affected.

These effects may already be partly reflected in forward prices, but likely not with perfect certainty, because the environmental policies and market participants' responses are not yet fully known. Thus, there may be a few $/MWh of risk in forward prices which could move either way depending on pending rule resolutions and market responses.

Introduction

Although there are many studies that have projected the amount of likely coal plant retirements and control retrofits in the United States due to recent environmental regulations, the implications of such retirements and retrofits on wholesale energy and capacity prices and the related market feedback effects on plant economics have been investigated in only a small number of studies.[1] It is likely that reduced supply for electricity generation, increased operating costs, and shifts in fuel demands due to retirement and retrofitting of coal plants will drive up market prices. It is also likely that, because of their complexity and time frames for impact, not all of these impacts are reflected in public forecasts or market forward prices.

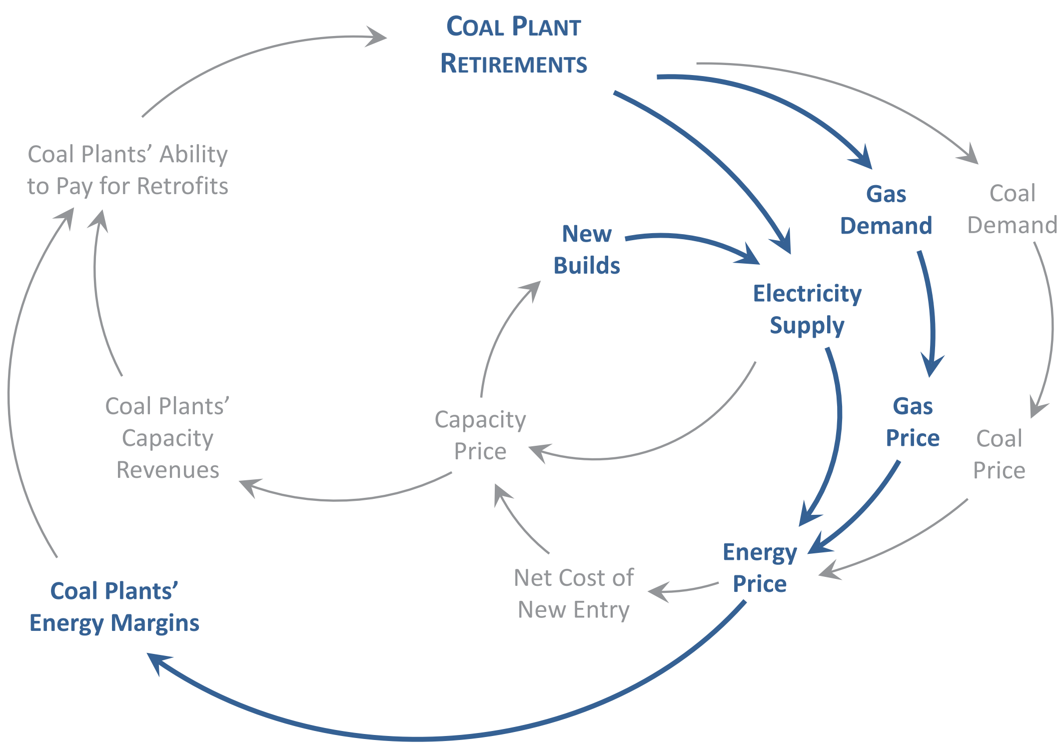
Even if they are partially or largely reflected, the uncertainty about ongoing changes in environmental policies towards coal plants and the uncertainty about plants' responses to such changes make it instructive to know how large such feedback effects could be. The retirement risk is also not unique to coal plants, though that prospect presents a strong example for demonstrative analysis. For instance, it is possible that a material portion of the nuclear fleet in the U.S. will shut down if gas prices and resulting wholesale power prices continue to be low. And gas usage itself could increase sufficiently that it begins to dampen its own attractiveness.

Finally, if feedback effects are already impounded into market expectations, but then environmental rules should become softer or deferred to a later period than was anticipated, we should expect a reverse feedback effect. Thus, the magnitude of market supply and demand feedback interactions is an important source of risk to understand in various analyses including asset valuation and assessment of potential retirements. This paper explores that sensitivity.

The current forwards and futures contracts for electricity delivery, as well as forward market prices for capacity resources, do not typically go beyond 2016, the period when the majority of the retirement and retrofit decisions triggered by the U.S. Environmental Protection Agency's (EPA's) emerging regulations on hazardous air pollutants, combustion residuals, and cooling water are expected to take place. What happens to energy prices is important for all generators, but especially for coal plants that could change their plans to retire or retrofit as a result of potentially higher energy prices.

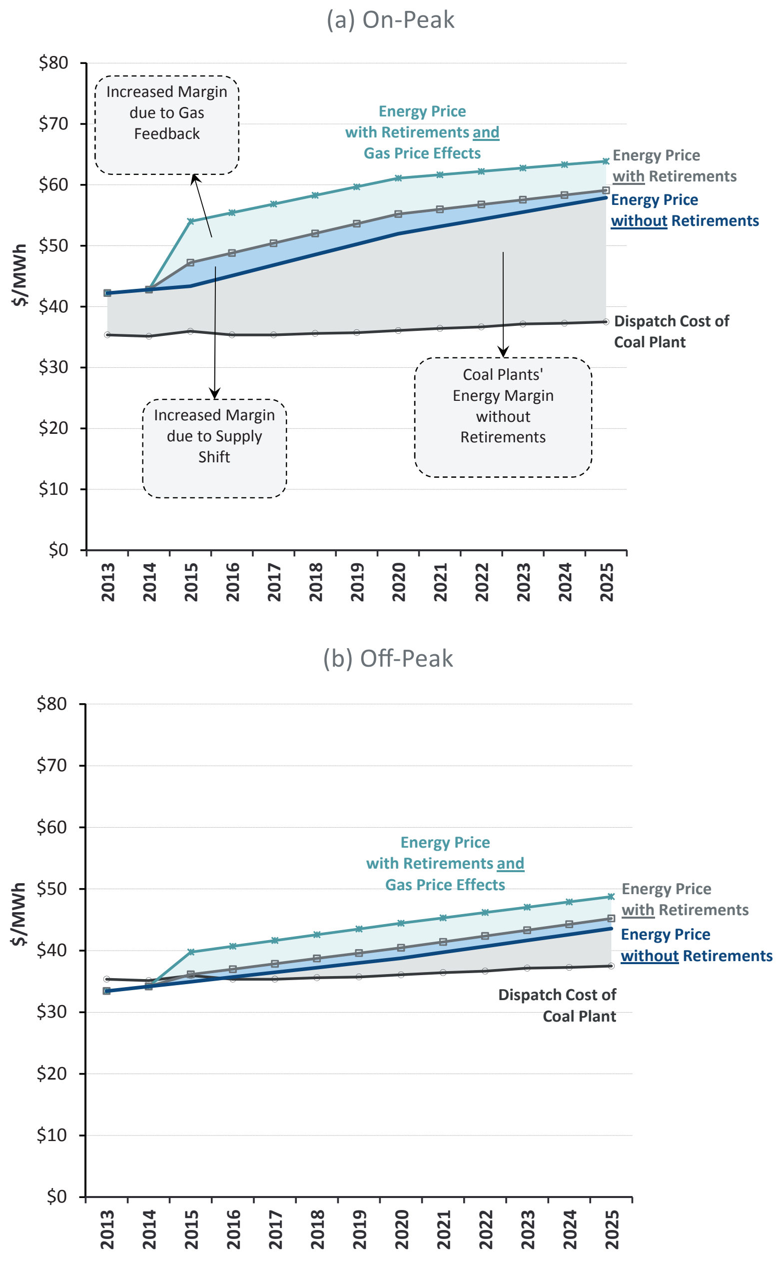
Figure 1 shows the major feedback loops between coal plant retirements and energy markets. This paper describes our general approach and explains the price effects we foresee in the PJM's Mid-Atlantic (MAAC) region as a case study, in relation to the forward prices that prevailed for power at the PJM-West hub as of summer 2012. (As of the end of October 2013, gas forwards were about the same as in summer 2012, but PJM-West forwards were about \$5/MWh lower. Therefore, price impacts of retirements could be larger than a few dollars relative to the most recent PJM-West forwards.)

Figure 1 Feedback Loops between Coal Plant Retirements and Markets



At The Brattle Group, we have developed a market simulation model to estimate the impacts of coal plant retirements on short- and long-term wholesale energy prices, and investigate a range of issues through sensitivity analysis. This paper describes our general approach and explains the price effects we foresee in the PJM's MAAC region as a case study, in relation to the forward prices that prevailed for power at the PJM-West hub as of summer 2012. As shown in Figure 2, retiring coal plants could lead to significantly higher prices — by as much as $10-15/MWh or about 25%, especially in the near term — so they could meaningfully impact coal and other infra-marginal plants' energy margins.

Figure 2 Potential Energy Price Increase due to Coal Plant Retirements and Impact on Coal Plants' Energy Margins in PJM's MAAC Region



Notes:

[1] All prices are in 2012 dollars.

[2] Projections reflect market outlooks as of mid-2012. The forward gas and coal prices have been relatively stable over the past several months, so we do not expect them to be drastically different under the current market outlooks.

[3] Dispatch cost of coal plants assumes an 11,500 Btu/kWh of heat rate.

The magnitude of price effects depends on several factors, including the amount of plant retirements, relative fuel prices for gas- and coal-fired plants, types of resources that would eventually replace the retired coal capacity (peaking, intermediate, or baseload) and the timing of the replacements. Coal plant retirements could also change incentives for renewable generation and new transmission projects, which may have additional impacts on electricity prices (not analyzed in this paper).

We find that two factors are approximately equally important in feedback effects: (1) the reduction of electric supply (shift to the left in a conventional supply curve depiction) from retirements, and (2) the increase in gas demand resulting in higher gas prices. Because the producers in both power and natural gas markets will respond to those changes, the magnitude of both of these effects will attenuate after 5 to 10 years with new entry. We project the changes in energy prices to be bigger in on-peak hours than in off-peak hours, but this will also depend on other factors, as discussed later. The increased energy margins could cover the costs of a modest portion of coal plant emission control technologies of coal plants in PJM's MAAC region (at around $100-200/kW), but they are unlikely to be enough to radically alter the extent of overall plant retirements.[2] With higher gas prices driven by increased gas demand, the total present value of the incremental energy margins for non-retiring coal plants could reach $300/kW.

While not presented here, Brattle has also examined the feedback effects of retirements in other regions. We found that the energy prices in other electric Regional Transmission Organizations (RTOs) and market regions can be more or less sensitive to these feedbacks, depending on how many affected units there are in the supply curve and how steep that curve becomes when the retired units are removed. For example, in coal-heavy regions like the Midcontinent Independent System Operator (MISO), retiring the same percentage of coal plants as in PJM MAAC would translate into a larger share of total capacity across all fuel technologies. In testimony filed at a regulatory proceeding in Wisconsin, we estimated that 11 GW of coal plant retirements in MISO and the impact of nationwide retirements on gas prices could increase energy prices in the MISO region by $8/MWh on-peak and $4/MWh off-peak in 2017.[3]

Section 1 Range of Potential Coal Plant Retirements

In October 2012, Brattle published a discussion paper examining the impact of emerging EPA air regulations on coal plants.[4] In that report — an update to a similar Brattle analysis conducted in 2010 — we revised our retirement projections somewhat upwards to reflect the recent market and regulatory outlook facing coal-fired power plants. On the market side, the expectations on the size of future energy margins for coal plants have decreased due to reductions in forward gas prices, and the need for new capacity has been deferred under the lower load forecasts. On the regulatory front, EPA finalized Mercury and Air Toxics Standards (MATS) in December 2011 with less restrictive requirements on the compliance deadlines and equipment than previously predicted. On the other hand, the future of the recently vacated Cross-State Air Pollution Rule (CSAPR) is largely uncertain.[5]

In our October 2012 study, we found that 59 to 77 GW of coal plant capacity are likely to retire over the next 5 years, which is approximately 25 GW more than we previously estimated in 2010 despite somewhat more lenient environmental regulations in 2012. Our predictions have been very sensitive to the assumed future market conditions and potential future climate policy. For example, the projected coal plant retirements would drop to 21 to 35 GW if gas prices increase by $1/MMBtu relative to forward prices. Similarly, our projected coal plant retirements would increase to 115 to 141 GW if gas prices were to decrease (for independent reasons) by $1/MMBtu. Our projections for the retire/retrofit decision of coal units under the base market scenario matched the actual decisions and announcements made by about 70% of the coal units.

Figure 3 Announced and Projected Coal Retirements by ISO/RTO Region

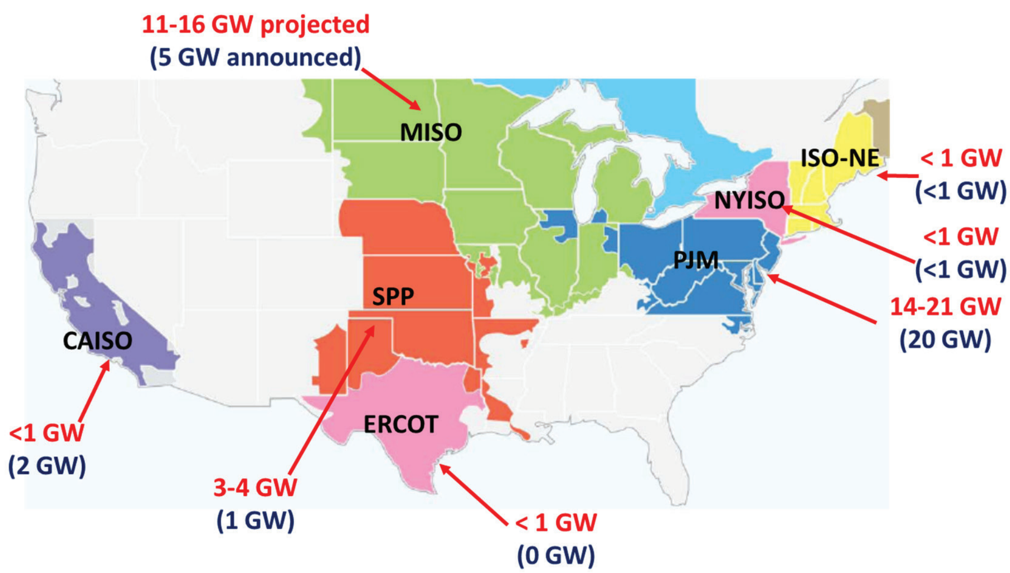


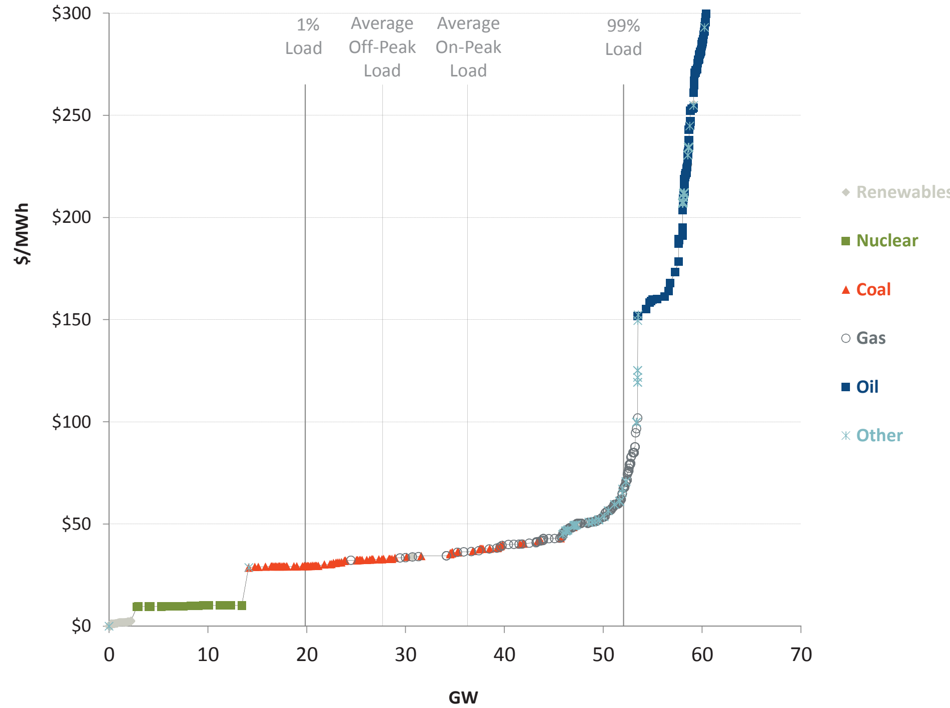
Figure 3 summarizes the results from our October 2012 study by the RTO regions. Overall, we projected PJM and MISO to have the largest amounts of coal plant retirements. In the PJM region, we estimated 14 to 21 GW of coal capacity to retire in the next 5 years or so, compared to about 20 GW of capacity that has already announced retirements. This is largely consistent with PJM's estimated 11 to 25 GW range for the coal capacity "at risk" of retirements in its August 2011 study.[6] Our projections correspond to 18-27% of existing coal capacity and 8-11% of total generation capacity in PJM. Up to 2.5 GW of these projected retirements is in PJM's MAAC region, reflecting about 15% of the existing coal capacity.

These results were derived assuming the projected decisions by coal plant owners are based solely on their direct costs and resulting financial pay-back (returns) from controls versus retirement choices. All market prices were assumed to be invariant to the retirements themselves, though we acknowledged that was a strong assumption. In this paper, we investigate the effects of those retirements on the market prices.

Section 2 Feedback Modeling Approach

Our feedback estimation model uses historical hourly load data to characterize the electricity demand in the modeled region, and applies a demand growth rate for future years consistent with recent load forecasts. It then constructs energy supply curves based on the variable costs of all of the individual generators in the region that are in-service. The hourly intersection of these supply and demand curves is equivalent to a dispatch analysis, in terms of estimating the energy prices as the cost of the most expensive generator that needs to run to meet the demand in that hour. Figure 4 illustrates the relationship between system demand, the marginal generator at various load levels, and the resulting energy prices in PJM's MAAC region for 2015 (reflecting July 2012 forwards for gas price and AEO2012 projections for coal price).

Figure 4 Illustration of Supply Curve Used to Estimate Energy Prices (PJM MAAC, 2015)



Sources and Notes:

[1] Supply curves reflect 2015 summer capacity based on unit-specific data compiled by Ventyx, the Velocity Suite (as of August 2012).

[2] Capacity numbers are de-rated for forced outages and scheduled maintenance. Generic regional capacity factors are used for renewable generation resources.

[2] Gas prices based on NYMEX futures for Henry Hub as of July 2012, plus ~$1/MMBtu for basis differentials and local delivery charges.

[3] Delivered coal prices are based on EIA's projections in AEO2012 Reference Case.

[4] Load assumptions from PJM's 2012 Load Forecast Report, reduced by the amount of average net imports for the summer period. Historical load shape for 2011 is used to develop hourly load data.

To assess the price effects of potential coal plant retirements, we compared the results for a system without any coal plant retirements to the results for a system with various levels of retirements considering the replacement capacity that may be needed to maintain the required reserve margins.

Our model creates supply curves on a monthly basis, using monthly fuel prices and generation outage schedules. It assumes that the energy imports and exports would remain constant at recent historical levels, using average monthly data for on-peak and off-peak periods. It does not analyze the transmission flows and locational price differences that could be seen due to congestion. For load, our model starts with an hourly shape from a recent historical year and scales it up (or down) to match weather-normalized load forecast. As part of our validation effort, we used our model to project energy prices for PJM's MAAC region in 2013. We estimate the average prices to be about $42/MWh for on-peak period, and $33/MWh for off-peak period. These results generally line up with the futures prices traded for the PJM-West hub as of summer 2012.

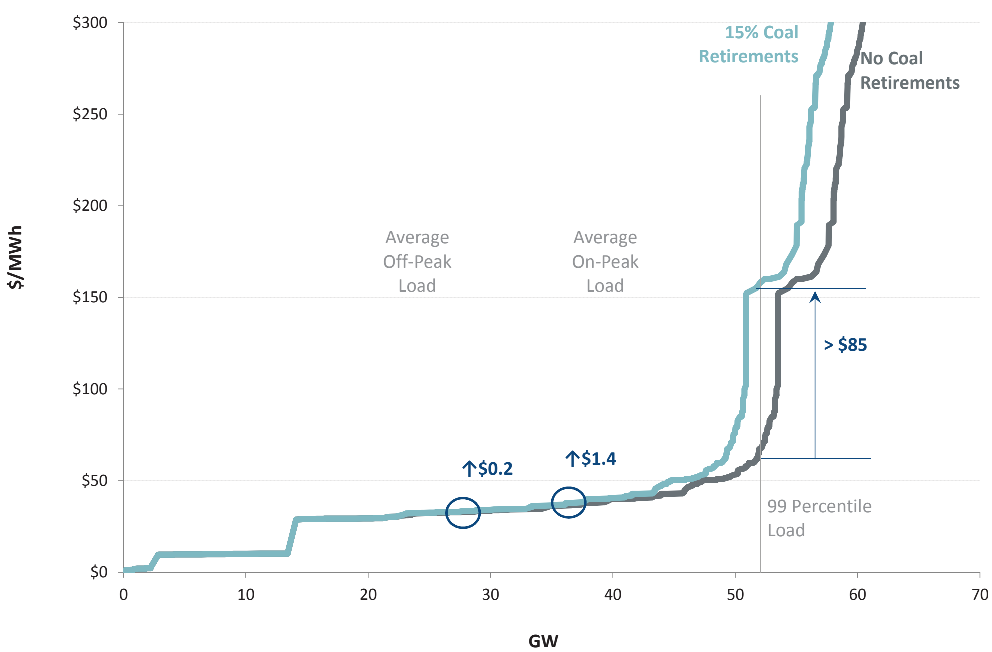
Section 3 Energy Price Effects of Retirement

NEAR-TERM EFFECTS (LIMITED/NO REPLACEMENT)

Given the existing capacity surplus in most regions in the U.S., the amount of coal plant retirements would not likely require new replacement capacity in the near term. Therefore, the energy supply curves will initially shift to the left as some of the coal plants are removed from the supply stack, with little replacement. Existing gas plants and the inefficient coal plants that do not retire will set the prices more often, yielding to higher energy prices than in the "no retirements" case. The shift in the energy supply curve mostly impacts the high-load hours where the supply curve is steeper. As a result, we expect the price effects will typically be higher during the on-peak period.

Figure 5 below plots the energy supply curves for PJM's MAAC region in 2015 using forward fuel prices. It illustrates the impact of retiring 15% of existing coal capacity in the region, which corresponds to approximately 2.8 GW (this is at the high end of the estimated range of retirements we projected in the October 2012 Brattle study discussed in Section 1). For 2015, we assumed that no additional capacity will be needed to replace the retired coal capacity. As shown in Figure 5, the price effects are likely to be less than a few dollars per MWh in most of the hours, but could be substantial during the on-peak period when the system demand is relatively high.

Figure 5 Illustration of the Near-Term Impact of Coal Plant Retirements on Energy Supply Curves (PJM MAAC, 2015)

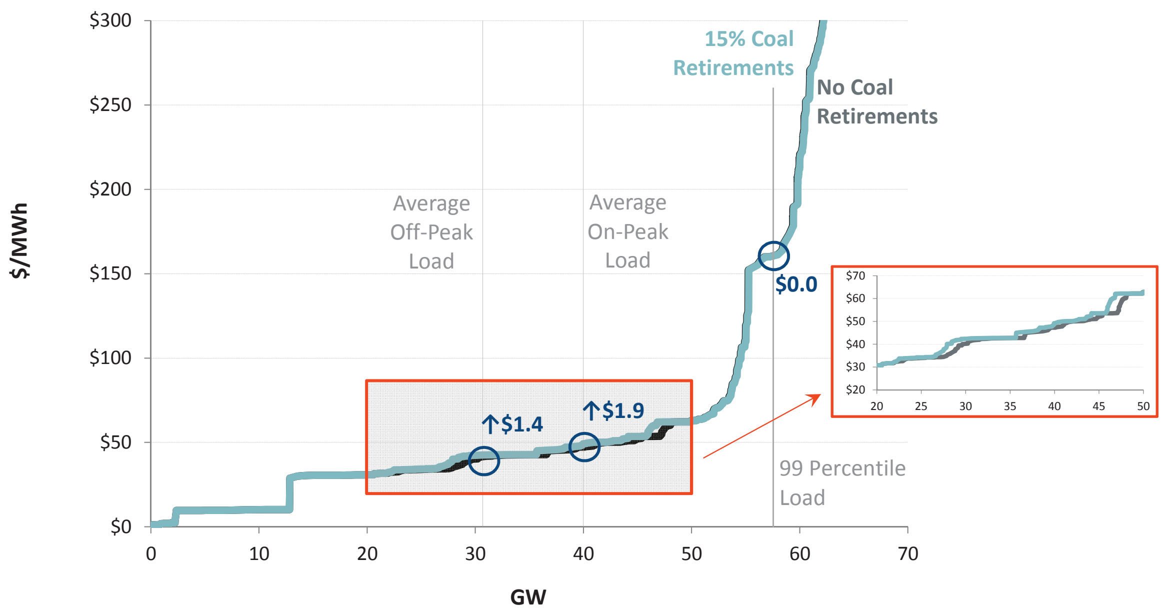


LONGER-TERM EFFECTS (PARTIAL/FULL REPLACEMENT)

The retired coal plants will accelerate the need for new resources in order to maintain required reserve margins. This will occur with a lag, and it then could, at least partially, offset the energy price increases associated with the potential coal plant retirements, depending on the economics of the new units. The magnitude of this offset will depend on the type of the new capacity added to replace the retired coal plants and also relative fuel prices. We explore this under alternative assumptions about what the replacement capacity might eventually be.

Figure 6 plots the energy supply curves for PJM's MAAC region in 2025 (10 years later), and illustrates the impact of retiring 15% of existing coal capacity and replacing most of that with gas plants to maintain the required reserve margins (half replaced starting in 2020 with an equal mix of combined cycle (CC) and combustion turbine (CT), and the rest by 2022).

Figure 6 Illustration of the Long-Term Impact of Coal Plant Retirements on Energy Supply Curves (PJM MAAC, 2025)



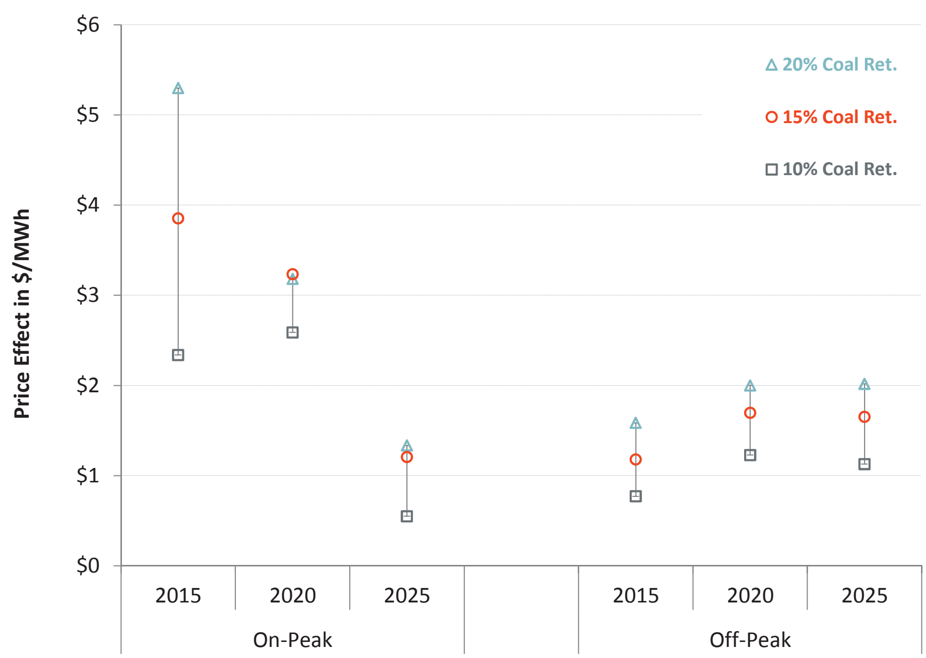
The energy supply curve with the coal plant retirements (and the associated replacement capacity) looks almost identical to the supply curve without the retirements, except for the middle section where the additional gas plants replace the retired coal plants. As a result, unlike the near term, we find the price effect to be very small or none in high load hours. The price effect in other hours will depend on the relative dispatch cost of coal plants that could potentially retire and the new resources that will replace them. The dispatch cost of a coal plant would be around \$35-40/MWh assuming a \$3/MMBtu for delivered coal and 11,500 Btu/kWh of heat rate. This is not much different than the dispatch cost of a new gas-fired CC plant, assuming a \$6/MMBtu for delivered gas and 7,000 Btu/kWh of heat rate. This means that if the retired coal plants are replaced by efficient gas CCs, then the price effect will be minimal, because the changes in the middle section of the energy supply curve will likely be very small. On the other hand, under the same \$6/MMBtu assumed for delivered gas, the dispatch cost of a new gas-fired CT with a 10,000 Btu/kWh heat rate would be approximately \$60/MWh, which is significantly higher compared to the dispatch cost of the coal plants that could potentially retire. As a result, the price effects could be much larger if the retired coal plants are replaced by peaking gas CTs.

KEY DRIVERS OF FEEDBACK EFFECTS ON ENERGY PRICES

The Amount of Plant Retirements

As should be expected, we find that retiring more coal capacity would further increase the energy prices, but not to the same extent in every year, and not as much off-peak as on-peak.

Figure 7 Estimated Energy Price Effects of Various Levels of Coal Plant Retirements in PJM MAAC (including Replacement Capacity to Maintain Planning Reserve Margins)



Note: All prices are in 2012 dollars.

Figure 7 above illustrates the impact of various levels of coal plant retirements on average energy prices in PJM's MAAC region. The price effect is larger for the on-peak period, especially for the near term, and declines over time as more replacement capacity is added. On the other hand, the price effect during the off-peak period is smaller since the bottom of the energy supply curve does not change as much. That is, the replacement capacity does not impact the marginal units setting the energy prices for the off-peak period; therefore, the price effects remain relatively stable over time. Overall, we estimate that retiring 15% of existing coal capacity by 2015 would increase on-peak prices by $3-4/MWh between 2015 and 2020, with price effects declining to $1/MWh by 2025. The off-peak prices would increase by approximately $1.5/MWh.

If we extrapolate the results between the study years and assume that the price effects remain constant for five years after 2025, then the value of increased energy margins under 15% of coal plant retirement scenario could be worth approximately $100/kW over a 15-year period between 2015 and 2030 for a representative coal plant that runs at 50% capacity factor (80% on-peak, 25% off-peak). This could pay for up to about half of the retrofit costs for installing a baghouse on a large coal unit. Price effects and related energy value could be much higher or lower, depending on the level of retirements.

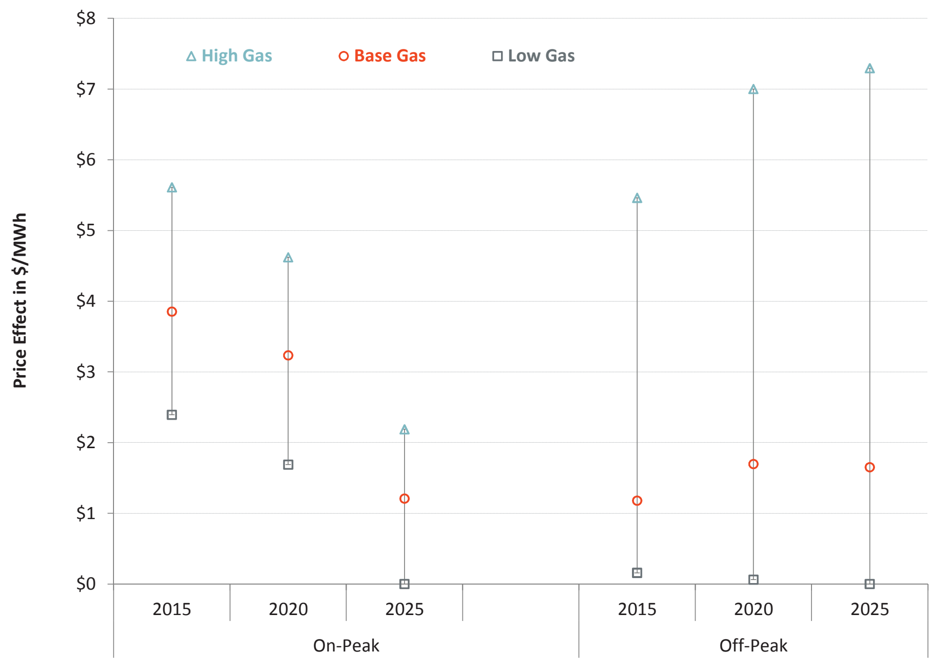
Natural Gas Prices

The spot prices and long-run expectations on gas prices have dropped considerably from a few years ago, due to demand reduction and the development of shale gas resources. For our illustrative simulations, we assumed a delivered gas price of $5-6MMBtu for the 2015-2025 period, consistent with the Henry Hub forward prices as of July 2012. While this reflects a modest increase from the current spot prices, it is still well below the gas prices observed just a few years ago.

We ran sensitivities to determine how the impact of retiring 15% of coal capacity would change under different sets of gas prices. As shown in Figure 8 below, if the delivered gas prices stayed at current levels of $3-4/MMBtu (i.e., "Low Gas" sensitivity) then the price effects would be very close to zero except for the on-peak period in the near-term. This is not surprising because the coal plants that would potentially retire are the less efficient ones and they would not run a lot under such low gas prices if remained in-service. Thus, the marginal units that set the market prices would stay the same whether or not the coal plants retire.

On the other hand, the price effects of coal plant retirements could be significantly higher if the delivered gas prices reach at $8-10/MMBtu (i.e., "High Gas" sensitivity). (Admittedly, this looks very unlikely, given the persistent lower cost of shale gas. However, it is instructive because this assumption eliminates a significant amount of feedback dampening that is inherent when the supply curves are quite broad and flat.) We estimate that if 15% of existing coal capacity retires in 2015 under such high gas prices, then the on-peak energy prices would increase by $5-6/MWh in the following five years or so, with the price effects declining to $2/MWh by 2025. The results for the off-peak period are more sensitive to gas prices and they are persistent over time with price increases at approximately $6-7/MWh range for both near-term and the long-term. This is due to the increased gap in dispatch costs of coal and gas plants.

Figure 8 Energy Price Effects due to 15% Coal Plant Retirements in PJM MAAC Under Different Gas Prices (including Replacement Capacity to Maintain Planning Reserve Margins)



Notes:
[1] All prices are in 2012 dollars.
[2] "High Gas": $8-10/MMBtu, "Base Gas": $5-6/MMBtu, and "Low Gas": $3-4/MMBtu.

The value of increased energy margins under conditions of higher gas prices could be worth up to almost $200/kW for the 2015 to 2030 period, assuming a 50% capacity factor for a representative infra-marginal, non-retiring coal plant. This could pay for the full costs of installing a baghouse — which is close to being significant for some of the coal plants' decision as to whether they should retire or retrofit.

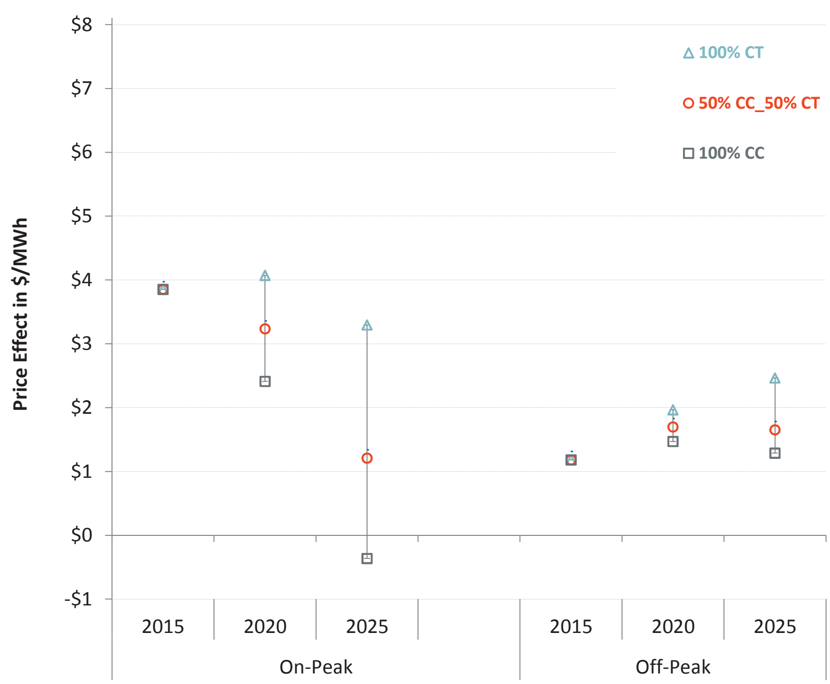
The sensitivity results in Figure 8 assume the same gas prices in both "no retirement" and "15% retirement" cases. Therefore, the impacts of coal plant retirements on gas demand and gas prices are not captured. Our October 2012 study on potential coal plant retirements in the U.S. indicated that the 59 to 77 GW of coal plant retirements could increase the gas demand by up to 6 Bcf/d (nationwide). While not focused on this question, a recent EIA study concluded that an increase of 6 Bcf/d in nationwide gas demand due to LNG exports beginning in the next few years could result in approximately 15% higher gas prices in the near term, and a 10% higher gas prices in the long term.[7] At $6/MMBtu, this would be equivalent to about $0.6 to 0.9/MMBtu increase in gas prices. This would then translate into an incremental $6-8/MWh increase in on-peak energy prices, and $2-3/MWh increase in off-peak energy prices (only in the retirement case).

Combining the effects on supply shift and feedback on gas prices, we estimate that retiring 15% of existing coal capacity would raise the on-peak energy prices by $9-10/MWh for near term and about $6/MWh for long term, and off-peak energy prices by $5-6/MWh for both near term and long term. The value of increased energy margins over the 2015 to 2030 period could add up to $315/kW, assuming a 50% capacity factor for a representative coal plant. This is substantially higher than our estimates for the "base case" runs, which do not include any feedback effects on gas prices, and could be enough to pay for a large portion of the environmental retrofits (depending on the combination of additional equipment necessary to bring a unit to compliance with EPA regulations).

Types of Replacement Capacity

As discussed before, the types of additional capacity added to replace the retired coal plants could make a big difference in terms of the price effects of coal plant retirements. This is especially true for the long term, when the amount of the retired capacity needs to be fully replaced to maintain required reserve margins. In our "base case" runs, we assumed that the replacement capacity is split evenly between gas-fired CTs and CCs. We ran two additional sensitivities to demonstrate the impact of the type of replacement capacity: one with only gas CTs and another with only gas CCs. Figure 9 summarizes the price effects of retiring 15% of existing coal capacity under these sensitivities.

Figure 9 Energy Price Effects due to 15% Coal Plant Retirements in PJM MAAC Assuming Different Types of Replacement Capacity (including Replacement Capacity to Maintain Planning Reserve Margins)



Note: All prices are in 2012 dollars.

The near-term results do not change relative to the "base case" runs, because there is very little replacement capacity needed. However, we find that the long-term implications of the type of replacement capacity could be substantial, especially for on-peak hours. If replaced by gas CCs, the price effects of retiring coal plants would be eliminated to a large degree. On the other hand, if replaced by gas CTs, the price effects expected in the initial years would last longer. The higher energy margins related to the price effects of coal plant retirements could be worth about \$69/kW if the retired capacity is replaced by gas CCs, and \$136/kW if it is replaced by peaking gas CTs (assuming 50% capacity factor, for the 2015 to 2030 period).

Section 4 Implications for Coal Plants

The energy price increase associated with coal plant retirements could translate into higher energy margins, and may impact some of the coal plants' decision on whether to retire or not. Figure 10 summarizes the energy price effects of the potential coal plant retirements in PJM's MAAC region and the value of related increase in energy margins for a plant that run at 50% capacity factor.

Figure 10 Energy Price Effects of Potential Coal Plant Retirements in PJM MAAC and Value of Increased Energy Margins

	Energy Price Effect On-Peak			Energy Price Effect Off-Peak			PV of Increased Margins
	2015 ($/MWh)	2020 ($/MWh)	2025 ($/MWh)	2015 ($/MWh)	2020 ($/MWh)	2025 ($/MWh)	2015-2030 ($/kW)
BASE CASE	**$3.85**	**$3.23**	**$1.21**	**$1.18**	**$1.70**	**$1.65**	**$99**
Sensitivity on Amount of Coal Capacity Retired							
LoRet w/ 10%	$2.34	$2.59	$0.55	$0.77	$1.23	$1.13	$66
HiRet w/ 20%	$5.30	$3.18	$1.33	$1.59	$2.00	$2.02	$116
Sensitivity on Delivered Gas Prices							
LoGas w/ $3-4	$2.39	$1.69	-$0.16	$0.16	$0.06	-$0.25	$37
HiGas w/ $8-10	$5.61	$4.62	$2.19	$5.46	$7.00	$7.29	$197
BaseGas + Feedback	$10.63	$9.13	$5.98	$4.81	$5.69	$5.20	$316
Sensitivity on Type of the Replacement Capacity							
100% gas CC	$3.85	$2.41	-$0.36	$1.18	$1.47	$1.29	$69
100% gas CT	$3.85	$4.07	$3.29	$1.18	$1.97	$2.46	$136

Notes:
[1] All prices are in 2012 dollars.
[2] "Base Case" assumes that 15% of existing coal plants retires, delivered gas prices of \$5-6/MMBtu with no feedback effect, and replacement capacity split equally between gas-fired CC and gas-fired CT.
[3] Value estimates are based on a plant running at 50% capacity factor (about 80% in on-peak hours and 25% in off-peak hours). Results are for the 2015 to 2030 period, where the price effects are linearly interpolated between 2015, 2020, and 2025, and assumed to remain constant between 2025 and 2030. A discount rate of 7% is used.

With 15% of coal fleet retiring under base case projections, the energy prices in PJM's MAAC region could increase by almost $4/MWh on-peak and about $1/MWh off-peak initially. As discussed previously, we find that the on-peak price effects decline over time as replacement capacity is added, but the off-peak price effects remain relatively constant. Over a 15-year period, the increased energy prices could provide about $100/kW of additional energy margins for a coal plant. Depending on the amount of retirements, the results vary: retiring 10% of coal capacity could increase coal plants' energy margins by $66/kW, while retiring 20% of coal capacity could be worth about $116/kW.

Changes in future gas prices have a substantial impact: if gas prices stay at around $3-4/MMBtu, then the increase in coal plants' energy margins due to retirements would be $37/kW, much smaller than our estimates based on forward gas prices. On the other hand, if gas prices were to reach at $8-10/MMBtu, then the increase in coal plants' energy margins could be worth $197/kW. The feedback effects on gas demand could amplify the price effects, increasing the 15-year present value (PV) of energy margins to $316/kW under base gas prices at $4-5/MMBtu.

As discussed before, it also matters whether the replacement of the retiring coal units comes from gas CTs or gas CCs, because the less-efficient gas CTs do not typically provide replacement power during off-peak and shoulder periods. If the retired coal plants were to be replaced by peaking gas CTs, then the energy price impacts would be larger with $136/kW increase in energy margins, compared to gas CCs providing the replacement with about $69/kW increase in energy margins.

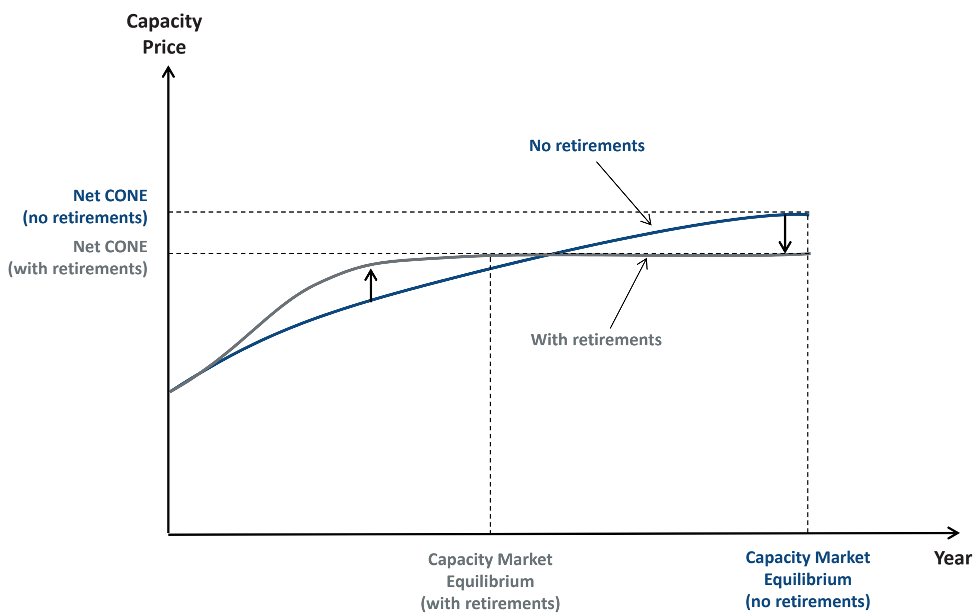
Section 5 Capacity Price Effects

In regions with organized auction-based capacity markets (such as in PJM, ISO-NE, and MISO), suppliers of capacity resources offer their capacity, and the auction manager (RTO) procures from the suppliers with the lowest offer prices such that the total capacity procured matches the demand for capacity. In long-run equilibrium, these markets would be expected to yield capacity prices that are sufficient to support needed new entry. Assuming that new gas CCs or CTs would be part of the equilibrium mix of technologies to meet load growth and retirements in the long-run, this equilibrium price would be net Cost of New Entry (net CONE), which is the annualized costs of capital and fixed costs net of expected margins from energy and ancillary services markets. In the short-term, capacity prices could be lower or higher than net CONE depending on whether the market is in an excess supply or capacity deficiency condition.

Retirement of coal plants would have two major effects on capacity prices. First, retirements would reduce the total supply of capacity in that region until replacement resources come online, hence reducing the reserve margins. This effect will tend to increase the capacity prices in the short/medium-term. Second, retirements would increase the energy prices (as discussed above) and therefore increase the revenue offsets in the determination of net CONE. This effect decreases the long-run equilibrium price of capacity until the energy price impacts of retirements disappear.

Figure 11 illustrates conceptually these two effects on capacity prices over time; of course, many other factors that influence the capacity market are not reflected in this chart. Initially, in this figure, the capacity market is assumed to be in excess supply, hence capacity price lower than the net CONE. The blue line shows a possible time path for capacity prices to increase over time to reach long run equilibrium assuming no coal plant retirements. The gray line shows the likely impact of coal plant retirements in the short and long run. Initially, the coal retirements would increase the capacity prices as a result of tightening supply conditions, and reduce the time needed to reach long-run equilibrium. But the retirements may also decrease the net CONE as a result of pushing up the energy prices; hence, the equilibrium price of capacity could be lower than the case with no coal retirements.

Figure 11 Illustrative Impacts of Coal Plant Retirements on Capacity Prices



This illustration assumes that net CONE remains somewhat depressed in the long-run, because it also assumes energy price impacts of retirements persist. The key uncertainty about persistence is whether the initial increase in gas prices due to retirements remains or disappears after a few years. EIA's LNG export study[8] in 2012 did project that the increased gas demand would have a long-term persistent price impact on natural gas. However, as gas or energy price impacts diminish or disappear completely, retirement of coal plants would have a lesser effect on long-run capacity prices.

Conclusion

We find that future energy prices can be quite sensitive to large, roughly concurrent changes in the power supply curve such as the wave of potential coal plant retirements often projected for the next few years. In eastern PJM, relative to forward price and market conditions prevailing in the summer of 2012, the induced price increases could be a few dollars per MWh or more, due to impacts on the supply curve and gas demand. (As of the end of October 2013, gas forwards were about the same as in summer 2012, but PJM-West forwards were about $5/MWh lower. Therefore, price impacts of retirements could be larger than a few dollars relative to the most recent PJM-West forwards.) The impacts of the supply shift and the increase in gas demand have similar magnitudes, and we expect both affects would attenuate after 5-10 years due to markets responding to higher prices by adding new resources.

For the PJM MAAC region we evaluated, we project the changes in energy prices <u>without accounting for any potential gas price increases</u> to be $3-4/MWh in on-peak hours versus $1-2/MWh in off-peak hours. These resulting increased energy margins in 2015 through 2020 for coal-fired plants could cover the costs of modest emission control technologies at around $100-200/kW, but are not enough to substantially alter the likely extent of overall retirements. However, <u>with gas prices also increasing</u>, the rise in energy prices could be $9-11/MWh on-peak and $5-6/MWh off-peak, having a total present value of increased margins for non-retiring coal plants exceeding $300/kW. This could be enough to influence (and reverse) some retirement decisions, if known with high confidence that very little of that effect was already impounded into forward prices. However, it is more likely that a portion of it is implicit in forward expectations, so the feedback range is more indicative of the uncertainty in how prices will evolve with final retirement decisions than it is a strict source of potential value.

The energy prices in other regions might be more or less sensitive to these feedback effects, especially the supply shifts. For example, in coal-heavy regions like MISO, retiring the same percentage of coal plants would translate into a larger share of total capacity across all fuel types and technologies. However, it may not necessarily result in bigger price effects if the supply curve is relatively flat. The magnitude of the price effects and the value of increased energy margins related to coal plant retirements in a region would depend largely on several key regional factors such as the shape of the supply curve, projected pace of reaching capacity supply-demand balance, expected mix of new resources, and regional fuel prices.

In addition to energy price impacts of coal plant retirements, we have made a qualitative assessment of impacts on capacity prices. The first effect would be to reduce the total supply of capacity in that region until replacement resources come online, hence reducing the reserve margins. This would tend to increase the capacity prices in the short/medium-term. The second effect of retirements would be to decrease net CONE in capacity markets as a result of the higher energy prices. This would tend to decrease the long-run equilibrium price of capacity until the energy price impacts of retirements disappear.

While it is not clear how much, if any, of these effects are already reflected in current forward prices, the price effects are large enough to be a material risk factor for plant economics in the first decade of coal plant retirements. Similar impacts and uncertainties surround possible future broad changes in the supply mix, such as could occur if existing coal plants face strong GHG reduction obligations under the emerging EPA regulations, or if a significant block of nuclear power plants in the same region of the country should shut down due to poor ability to recover fixed costs under a low gas price regime.

Endnotes

1 For example, MISO estimated that the energy prices would increase up to $4.8/MWh in its region due to the EPA regulations (see EPA Impact Analysis: Impacts from the EPA Regulations on MISO, October 2011). Similarly, Exelon's Chairman John Rowe estimated that the energy prices in PJM could increase by $12/MWh in PJM due to EPA's Clean Air Act (see his remarks on Leadership Bipartisan Policy Center, November 9, 2011).

2 This result is consistent with our October 2012 study, which found very little decrease in projected retirements if power prices increased during the 2015-2020 period (by $5/MWh in 2015 decreasing to zero in 2020) as a result of regional coal plant retirements.

3 Pre-filed Rebuttal and Sursurrebuttal Testimony of Metin Celebi on behalf of Wisconsin Public Service Corporation, Docket 6690-CE-197 re: the impacts of pending coal plant retirements and environmental retrofits on energy and capacity prices in the MISO region, December 14, 2012 and January 11, 2013.

4 "Potential Coal Plant Retirements: 2012 Update," by Metin Celebi, Frank C. Graves, and Charles Russell, The Brattle Group, Inc., October 2012, posted at: http://brattle.com/system/news/pdf2s/000/000/095/original/Potential_Coal_Plant_Retirements_-_2012_Update.pdf.

5 The U.S. Court of Appeals for the D.C. Circuit vacated the CSAPR in August 2012 for mostly legal reasons (such as EPA's authority to require individual States to reduce emissions related to significant contributions to non-attainment in downwind States). It is possible some of these legal issues could be cleared with a new proposed rule from EPA, but the EPA's recent petition for rehearing was denied in January 2013.

6 "Coal Capacity at Risk for Retirement in PJM: Potential Impacts of the Finalized EPA Cross State Air Pollution Rule and Proposed National Emissions Standards for Hazardous Air Pollutants," PJM, August 26, 2011.

7 U.S. Energy Information Administration, "Effect of Increased Natural Gas Exports on Domestic Energy Markets," January 2012. Available at: http://www.eia.gov/analysis/requests/fe/pdf/fe_lng.pdf.

8 *Ibid*.

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