The Brattle Group

Potential Coal Plant Retirements Under Emerging Environmental Regulations

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The Brattle Group

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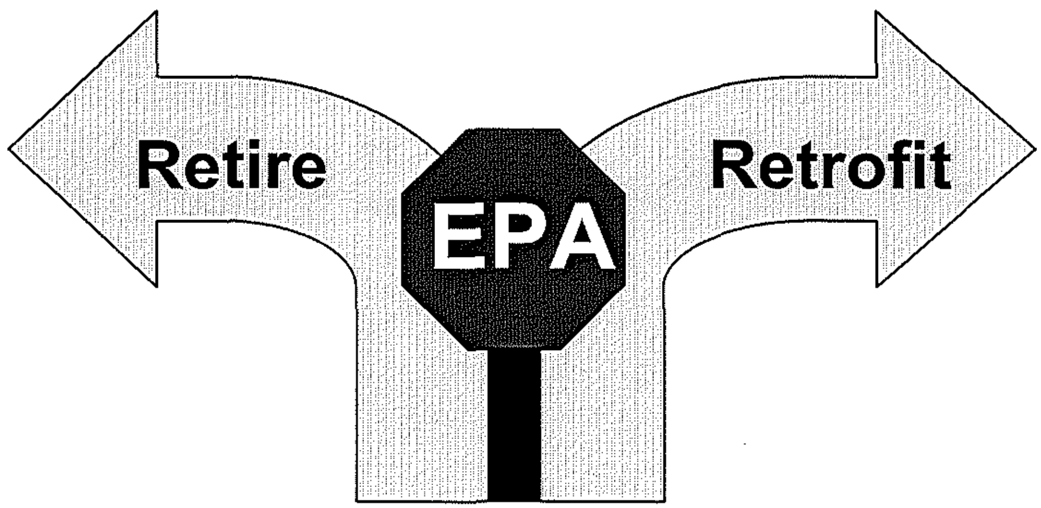
Coal plant retirements under EPA regulations

Emerging EPA regulations on air quality, water use and ash disposal will likely require existing coal units to choose between installing expensive control equipment and retirement.



Continuation of current low electricity prices in the next five years will also increase the pressure to retire.

Analysis of coal plant retirement exposure

Developed a tool to analyze economics of retrofit vs. retirement for every coal unit in the U.S. under various scenarios of environmental regulation.

- Estimate future capacity factor for each unit by dispatching against projected hourly power prices

- Decide each year whether to retire based on comparing 15-year projected avoidable costs of retrofit against:
  - revenues from energy and capacity markets for merchant units (on an after-tax basis),
  - cost of replacement power from gas CCs or CTs for regulated units.

Brattle coal plant retirement screening tool

Economic Drivers (by region)

- Hourly power prices
- Capacity prices
- Unit-specific VOM cost, heat rate, and coal prices
- FOM cost by age
- Cost of replacement power from gas CC/CTs

Retirement Analysis

Environmental Drivers (by region)

- Regulation scenarios
- Existing control equipment
- CapEx for retrofit Additional FOM for each retrofit
- Compliance year

Results

- Retired coal capacity
- Compliance costs
- CO_2 emissions
- Regional reserve margins
- Gas and coal demand

Note: The version of the tool presented here does not consider potential feedback effects of retirements on wholesale electricity or fuel prices.

Uncertainties and contingencies

These results present a <u>retirement exposure</u> analysis, identifying which units become uneconomic under current market projections.

- Where the local effects of potential retirements are severe, it is likely that market responses, regulatory allowances, or perhaps even environmental policy adjustments would occur that would mitigate some of the impacts, especially where reliability is at risk.
- On the other hand, there are also frictional effects of making numerous, industry-wide retrofits and capacity replacements, which would tend to increase the difficulties of meeting the new environmental regulations. These have also not been modeled.

This analysis describes just one particular set of region-specific market conditions.

- This is only one possible view of the future – There are major uncertainties surrounding long run market circumstances and regulatory policy that would affect these projections.

The modeling capability behind this presentation would allow us to explore unit-specific impacts of other potential future market conditions, investment decision criteria, and more detailed circumstances faced by individual companies or generating units.

Key conclusions – coal plant retirements

A requirement to install scrubbers and SCRs on coal units by 2015 would result in 40-55 GW of economic retirements

- **Another 11-12 GW** of coal units would retire if **cooling towers** (@ $200/kW) are also mandated
- Higher-end of range based on doubling the retrofit costs due to potentially increasing demand for labor and control equipment or due to site-specific constraints

$70-130 billion investment on scrubbers and SCRs (for 187 GW coal capacity) would be needed to comply with the EPA mandates

- **An additional $30-50 billion** compliance investment would be needed if **cooling towers** are also mandated.

Most of the economic retirements are with merchant units (which rely on market revenues), in contrast to regulated units whose retirement decisions are based on the cost of replacement power.

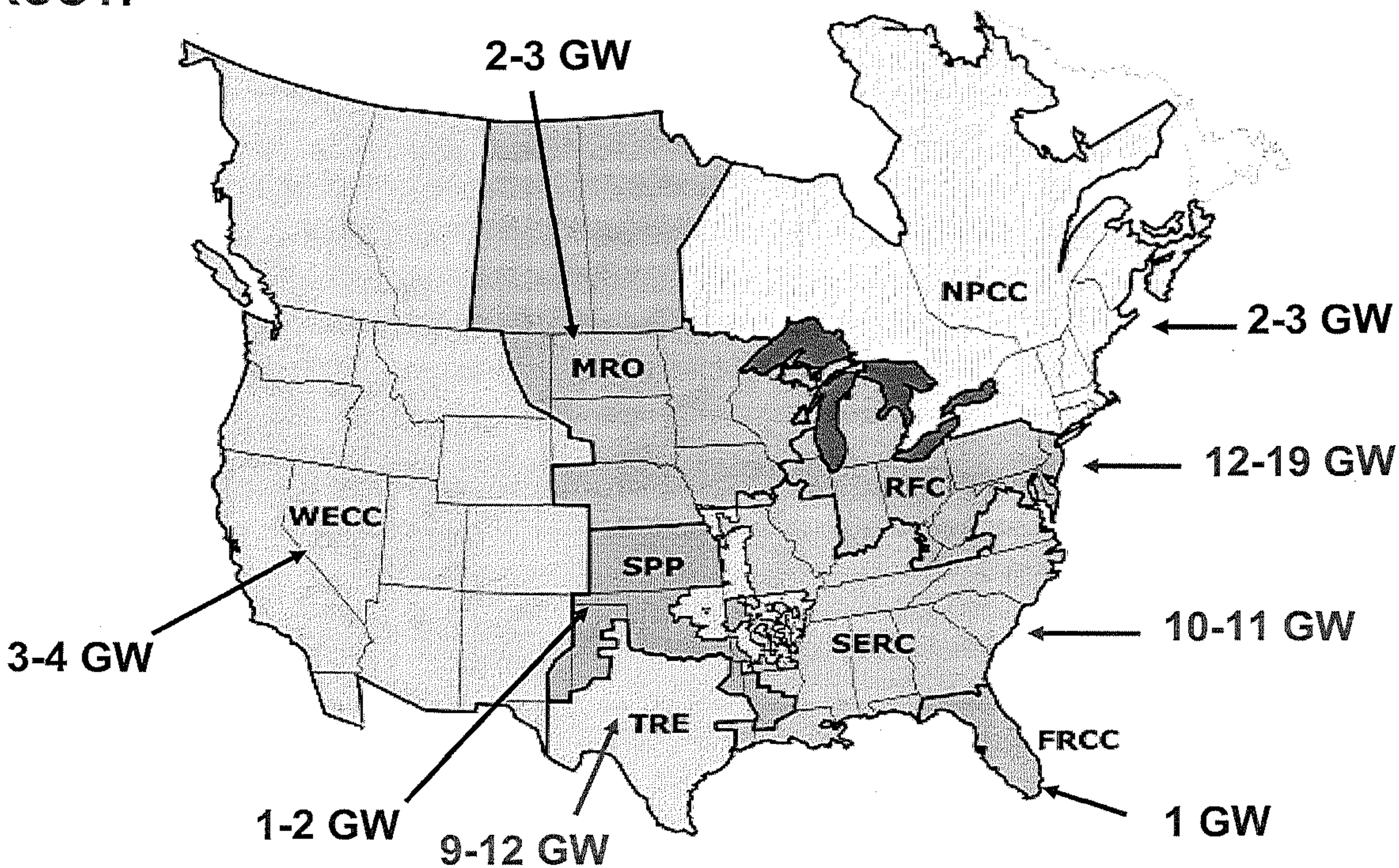
- We analyzed merchant units against wholesale spot conditions, not considering any LT PPAs

U.S. COAL PLANT CAPACITY VULNERABLE TO RETIREMENT BY 2020

	Retirements with Scrubber & SCR Mandate GW	Additional Retirements with Cooling Tower Mandate GW	**Total Retirements GW**	Percentage of Coal Capacity	Percentage of Total Capacity	Retrofit Capital Costs for Compliance $ Billion
Nationwide Total	**40-55**	**11-12**	**50-66**	**16-21%**	**5-7%**	**$101-181**
Merchant	37-48	8-10	**47-56**	64-76%	11-14%	$5-7
Regulated	3-6	1-4	**3-10**	1-4%	1-2%	$94-177

Key conclusions – coal plant retirements (cont'd)

Most of the retirements would be in NERC regions RFC, SERC and ERCOT.



Key conclusions – coal plant retirements (cont'd)

Market areas with the largest retirements would be Midwest ISO, ERCOT, and PJM.

- Retirements represent large portions of existing total regional capacity: 15% in ERCOT, 11-14% in Midwest ISO, and 6-11% in PJM
- All merchant coal plants in ERCOT would retire if scrubbers, SCRs, and cooling towers are mandated

COAL PLANT CAPACITY VULNERABLE TO RETIREMENT BY 2020 - SELECTED REGIONS

	Retirements with Scrubber & SCR Mandate GW	Additional Retirements with Cooling Tower Mandate GW	**Total Retirements GW**	Percentage of Coal Capacity	Percentage of Total Capacity	Retrofit Capital Costs for Compliance $ Billion
Midwest ISO Total	**12-15**	**3-5**	**16-20**	**21-28%**	**11-14%**	**$27-48**
Merchant	11-12	2-3	**14**	93-94%	30-31%	$0
Regulated	1-3	0-3	**2-6**	3-11%	2-6%	$27-48
ERCOT ISO Total	**9-12**	**1-3**	**13**	**72**	**15%**	**$3-5**
Merchant	9-12	1-3	**13**	100%	18%	$0
Regulated	0	0	**0**	0%	0%	$3-5
PJM ISO Total	**8-15**	**3-5**	**12-19**	**15-26%**	**6-11%**	**$19-29**
Merchant	8-15	3-4	**12-19**	33-54%	10-16%	$4-6
Regulated	0	0	**0**	0-1%	0-1%	$13-25

Key conclusions – coal plant retirements (cont'd)

About **1/3rd of the economic retirement capacity are younger (< 40 years) and larger (> 500 MW) units**, highlighting the importance of considering regional market conditions in addition to unit age and size in retirement decisions.

Capacity revenues are moderately important, reducing them by half would add another 7 GW of retirements under the EPA mandate to install scrubbers and SCRs

Another 8 GW of regulated units would retire under scrubber and SCR mandates (~ half of them in the MRO region) **if a 20% discount is applied to the cost of replacement power** as a proxy for potential externality penalties imposed by regulators (such as "Probable Environmental Cost" assessments)

Key conclusions – other impacts

Retirements would reduce **reserve margins** in 2020 below targets in ERCOT and RFC in the absence of additional new resources coming online:

- ERCOT: from 10% to 1%, compared to target of 13%
- RFC: from 19% to 13%, compared to target of 15%
- Most retirements occur in 2015 (beginning of assumed mandates)

Coal demand falls by about 15% relative to base case in 2020 (due to retirements and lower CFs for the remaining units that installed scrubbers and SCRs).

The retirements and reduced capacity factors due to scrubber and SCR requirements would increase U.S. **gas demand** by at most 5.8 Bcfd (about 10% of total demand), with significant regional variation

- RFC-MISO gas demand increase about 0.7 Bcfd, compared to 0.1 Bcfd in FRCC.

CO_2 emissions would decrease by 150 million tons in 2020 (~10% of coal CO_2 emissions) if the lost coal generation (due to retirements and lowered capacity factors) is replaced by gas generation (@ 8000 Btu heat rate).

Comparison to other studies

Recent studies estimate <u>10-75 GW coal capacity at risk</u> for retirement.

Study	Projected coal capacity to retire or "at risk"	Criteria to identify coal capacity at risk	Models future revenues from energy and capacity markets?	Models future capacity factors of coal units?	Distinguishes between merchant vs. regulated units?
Brattle, December 2010	50-65 GW by 2020	<u>Regulated units</u>: 15-year PV of cost > replacement power cost from a gas CC or CT; <u>Merchant units</u>: 15-year PV of cost > revenues from energy and capacity markets	Yes, based on dispatch against projected hourly prices	Yes, based on dispatch against projected hourly prices	Yes
NERC, October 2010	10-35 GW by 2018 (in addition to ~20 GW committed/announced retirement, or not relied upon by NERC as a capacity resource)	levelized costs (@ 2008 CF) after retrofitting each unit for the environmental regulations compared to the cost of a new gas-fired unit	No	No	Yes -- uses different cost of capital for regulated vs. merchant units
ICF (October 2010)	75 GW by 2018	unknown	unknown	unknown	unknown
Credit Suisse, September 2010	60 GW	size and existing controls	No	No	No
ICF/INGAAA, May 2010	50 GW	age, efficiency and existing controls	No	No	No
ICF/EEI (May 2010)	25-60 GW by 2015	cost of retrofitting coal plant compared to cost of new gas CC	unknown	unknown	Yes

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Overview of environmental pressures

EPA is in the process of promulgating a series of new regulations to more tightly control all of the following:

- "Criteria air pollutants," especially NOx, ozone, SOx, and particulates
- Hazardous air pollutants (HAPs), especially mercury
- Cooling water discharge
- Coal combustion byproducts

The nature of most of these regulations, and the way states must implement these more stringent air quality standards, is expected to be highly tilted toward command-and-control (i.e., with no choice but to comply or retire on a strict schedule), less toward cap-and-trade of emission allowances that are fungible over space and time.

However, there has been some recent movements that suggest at least the coal ash and water regulations (316b) may be delayed

- a more flexible time table or conditional slate of control options would reduce the economic impacts we find arising under a more strict interpretation of the potential rules

Criteria air pollutants (ozone, NOx, SOx, particulates)

EPA promulgates regulations based on the Clean Air Act: Clean Air Interstate Rules (CAIR), Haze Rules, and National Ambient Air Quality Standards (NAAQS)

- States must file State Implementation Plans to demonstrate commitment to progress towards compliance with NAAQS

EPA Developments Affecting Future Regulations

- Transport Rule – Regulates NOx and SOx emissions in 31 states (Mid 2011)
  - State-specific SOx and NOx budgets starting in 2012/14; restricts interstate allowance trading
  - Reduce SOx emissions by 71%, NOx emissions by 52% (relative to 2005 levels)
- NAAQS – Stricter ozone concentrations likely in place in 2011
  - Will likely cause states to implement command-and-control regulations
- Both of these move away from market-based cap-and-trade and toward command-and-control
- **Many existing units will need to add expensive scrubbers and SCRs or retire**

Hazardous air pollutants (HAPs)

HAPs are pollutants (mercury, phosphoric acid, lead and selenium compounds, etc.) that are associated with cancer or other serious health affects.

EPA has not regulated HAPs from electric generators before.

As soon as EPA does regulate HAPs, the <u>Clean Air Act dictates strict controls by EPA</u> (Maximum Achievable Control Technology -- <u>MACT</u>), with little flexibility for sources to comply.

Coming EPA MACT rulemakings for mercury and other HAPs:

- EPA is expected to **<u>issue rules in March 2011</u>**
- Affects coal and oil units
- **May require <u>scrubbers</u> (ACI may not be enough) <u>on all coal plants in 3-4 years</u>**

Cooling water and ash regulations

Cooling Water

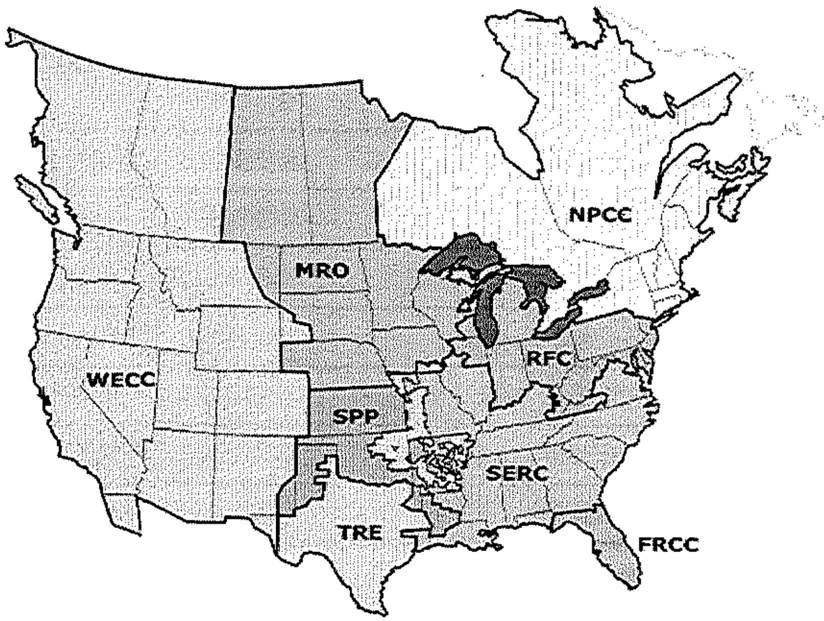
- EPA and states are beginning to apply the Clean Water Act (CWA) to force generators to replace **once-through cooling**, sometimes subject to cost/benefit tests
- EPA is expected to **issue rules in 2011/12** regarding cooling water intake structures and waste water discharges

Ash

- **Currently** exempt from EPA hazardous waste regulations
- EPA proposed **two options**:
  - Regulate as hazardous waste under Subtitle C of Resource Conservation and Recovery Act (RCRA).
  - Regulate similar to those for municipal and non-hazardous solid waste, hence less stringent than Option 1.

Existing coal fleet

The US coal fleet has a total of 316 GW capacity (~1/3rd of all capacity), and generates roughly half of all electrical output.
About 75% of the coal fleet is owned by regulated entities (IOUs, munis, federal power agencies, etc.).
Capacity factors of coal units in U.S. averaged 61% in 2009.



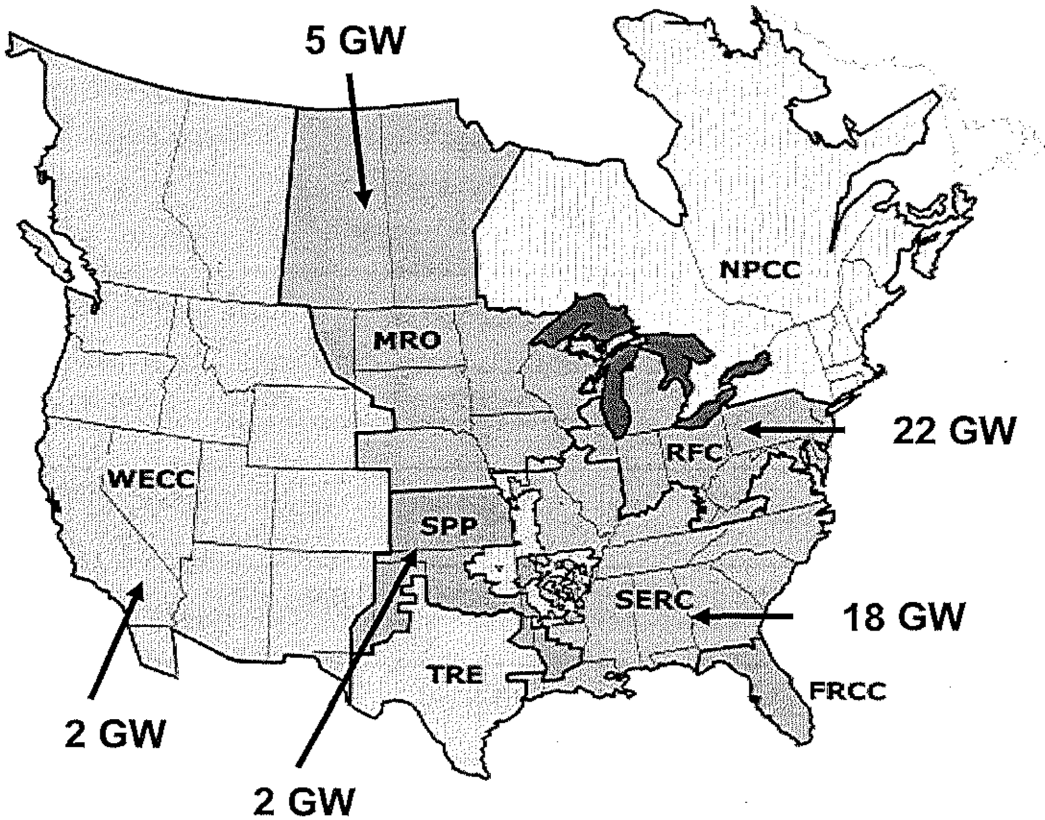
NERC Region	Coal Capacity (GW)	% Owned by Regulated Entities	2009 Capacity Factor
RFC	105	63%	61%
SERC	100	88%	62%
WECC	32	89%	78%
MRO	27	96%	70%
SPP	20	98%	72%
ERCOT	18	28%	77%
FRCC	10	92%	58%
NPCC	6	16%	58%
Total	316	77%	65%

Large portion of the current coal fleet lacks major environmental controls:

- 165 GW (52%) without scrubbers, majority of them in RFC and SERC regions
- 180 GW (57%) without SCRs, about half in RFC and SERC regions
- ~300 GW (96%) without ACI and baghouse, majority of them in RFC and SERC regions

Old and small coal units with no controls

About <u>50 GW</u> of existing <u>small</u> (< 500 MW) and <u>old</u> (> 40 years) coal units have <u>no environmental controls</u>*. Most of these units are in RFC and SERC regions.

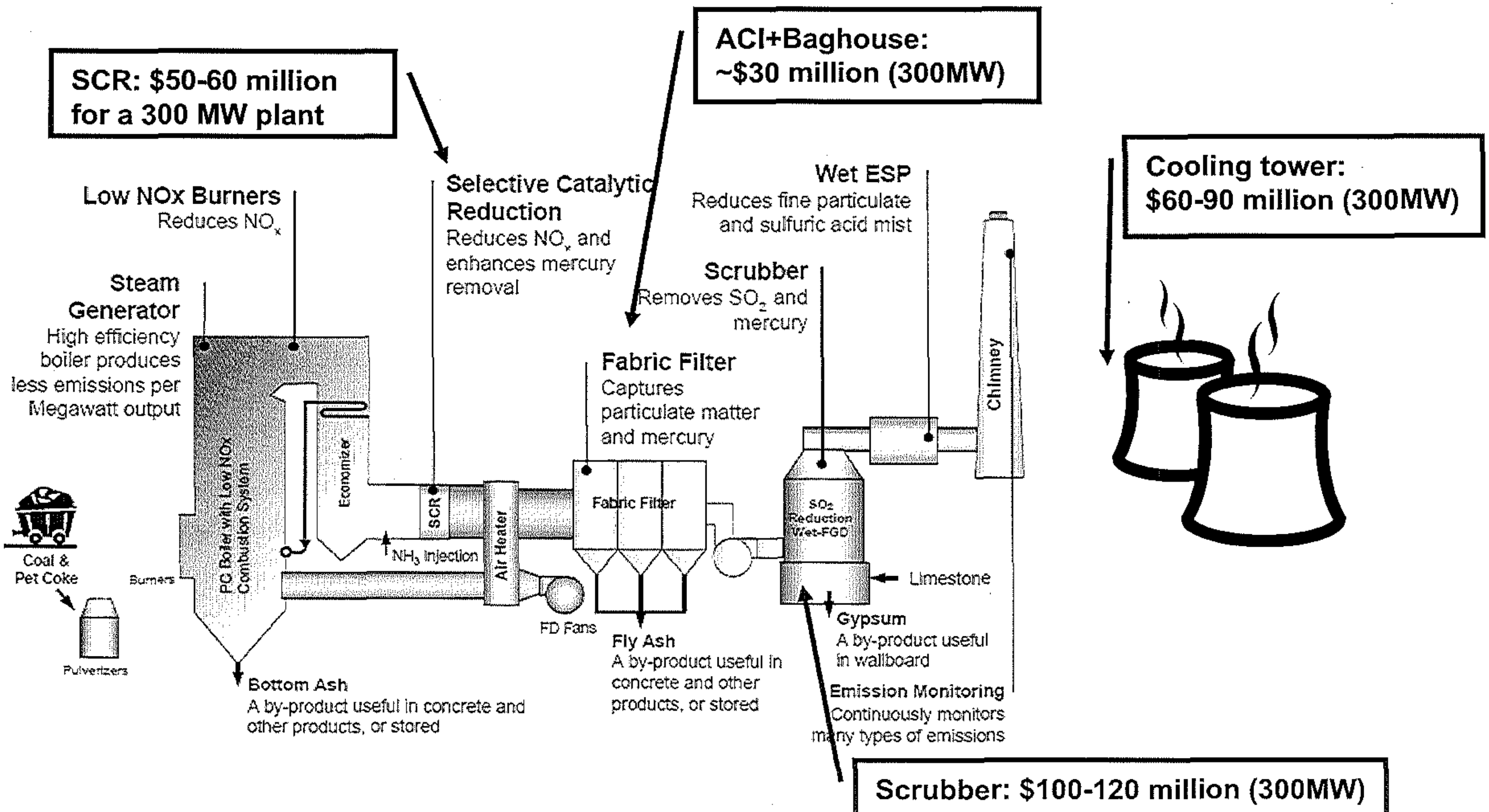


Region	% of Coal at Risk	% of 2018 Reserve Margin
RFC	20%	60%
SERC	18%	32%
MRO	20%	67%
SPP	8%	14%
WECC	5%	3%

*Environmental controls here refer to scrubber for SO_2 and SCR/SNCR for NOx.

EPA regulations – implications

Potential technology-based environmental restrictions in air (SO_2, NOx, Mercury), water and coal ash disposal in lieu of market-based approaches.



Costs of compliance

A new regulation that requires scrubbers would add $8-34/MWh (in O&M and carrying costs) to the existing costs of coal plants. If NOx controls (SCR) and/or mercury controls (ACI) are also required, this would bring the total increase in levelized costs to $12-46/MWh.

COST OF ENVIRONMENTAL CONTROL EQUIPMENT FOR COAL PLANTS

Controls			Scenario I	Scenario II	Scenario III
FGD			x	x	x
SCR				x	
ACI (No Existing Baghouse)					x
Total Cost			*Million 2009 $'s*		
600 MW unit at 70% CF			$153	$233	$199
600 MW unit at 30% CF			$149	$227	$194
300 MW unit at 70% CF			$118	$168	$149
300 MW unit at 30% CF			$116	$165	$147
Economic Life	*Size (MW)*	*Capacity Factor*	*Levelized Cost in 2009 $/MWh*		
10	600	30%	22.36	32.22	30.38
		70%	10.63	15.31	14.31
	300	30%	34.02	46.40	45.02
		70%	15.61	21.42	20.57
15	600	30%	18.49	26.23	25.43
		70%	8.97	12.75	12.19
	300	30%	27.99	37.69	37.48
		70%	13.03	17.69	17.34
20	600	30%	16.64	23.36	23.06
		70%	8.18	11.52	11.17
	300	30%	25.10	33.51	33.86
		70%	11.79	15.90	15.79

Current energy margins (excluding capacity revenues) already low for merchant coal plants due to low gas prices, low demand growth, and new renewables

- Current dispatch costs for an existing coal plant ~$20-35/MWh
- Low wholesale power prices in 2009
  - PJM West: ~$40/MWh
  - Midwest (Illinois/Michigan): ~$25-39/MWh
  - Southeast: ~$30/MWh

Some implications of coal plant retirements

- Electric reliability (grid and reserves) at risk

- Decrease in coal demand
  - Effect on rail transport (2/3rd of coal shipped by rail, approximately 20% of rail freight revenues from coal)

- Likely increase in gas demand
  - Possibly offset partially by increased renewable expansion
  - Effect on gas prices and volatility? – not examined in this study
  - Effect on pipeline basis prices? – not examined in this study

- Increase in electricity prices (energy and capacity) – not examined in this study

- Potential stranded costs for regulated utilities – not examined in this study

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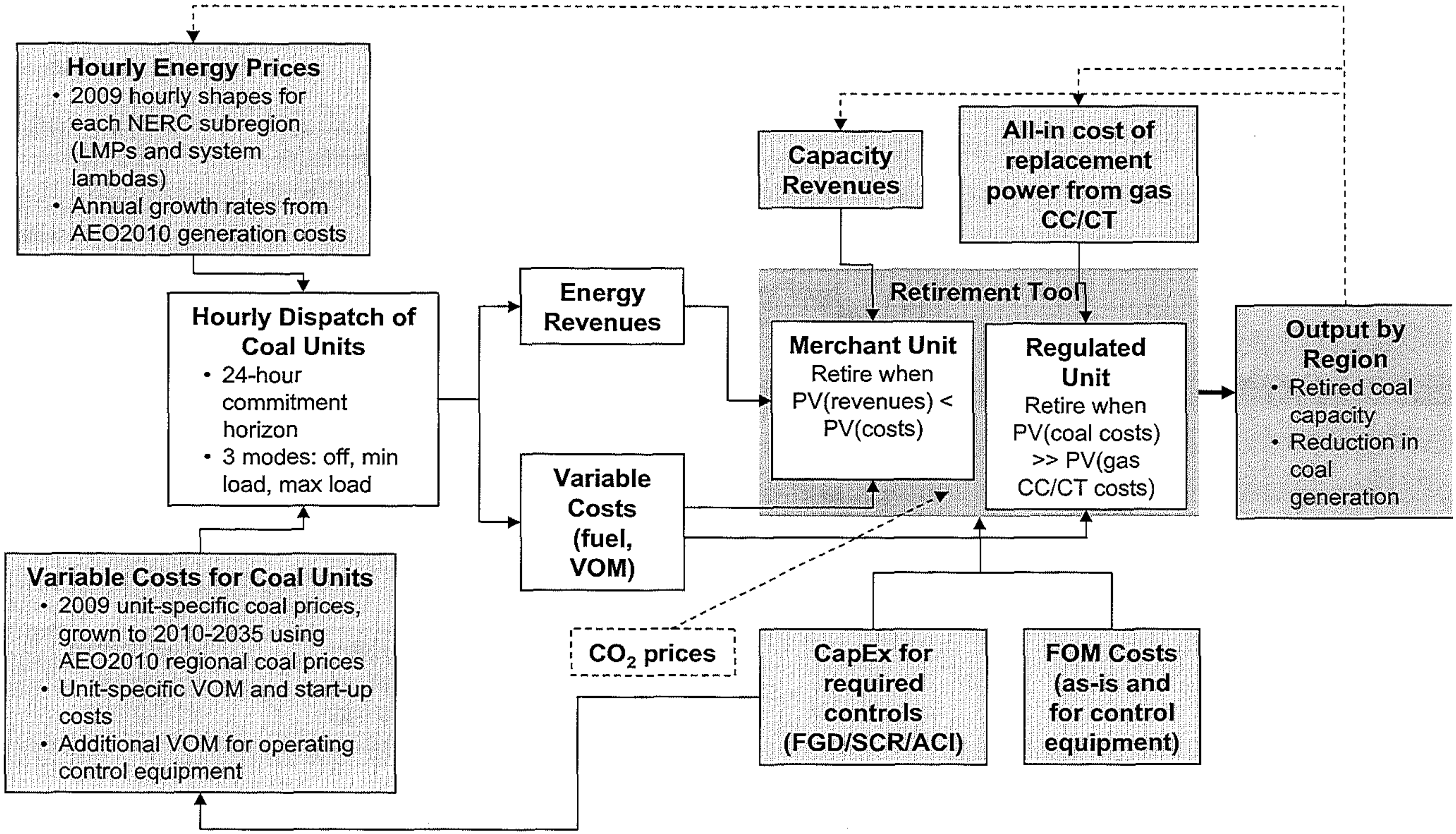
Brattle coal plant retirement screening tool – details



Note: Dashed lines and boxes represent factors and feedback effects that are planned to be incorporated into the model.

Key assumptions on markets

Wholesale power prices

- Hourly actual prices in 2009 projected to 2010-2035 using AEO2010 escalation rates for generation prices
- Annual average prices in the range of $25-35/MWh (2008 dollars), largely remain flat in the future
  - except for increasing prices in ERCOT, NYISO, and PJM

Capacity prices

- Only applied to regions with capacity markets
- In the range of $10-80/kW-year until 2020, then growing to $40-190/kW-year based on *Brattle* forecasts
- Brattle has developed region-specific capacity price outlooks based on reserves, planned additions and retirements, cost of new entry, and RTO market rules. Similar to other inputs in this study, only one scenario for capacity price outlook is examined.

Natural gas prices

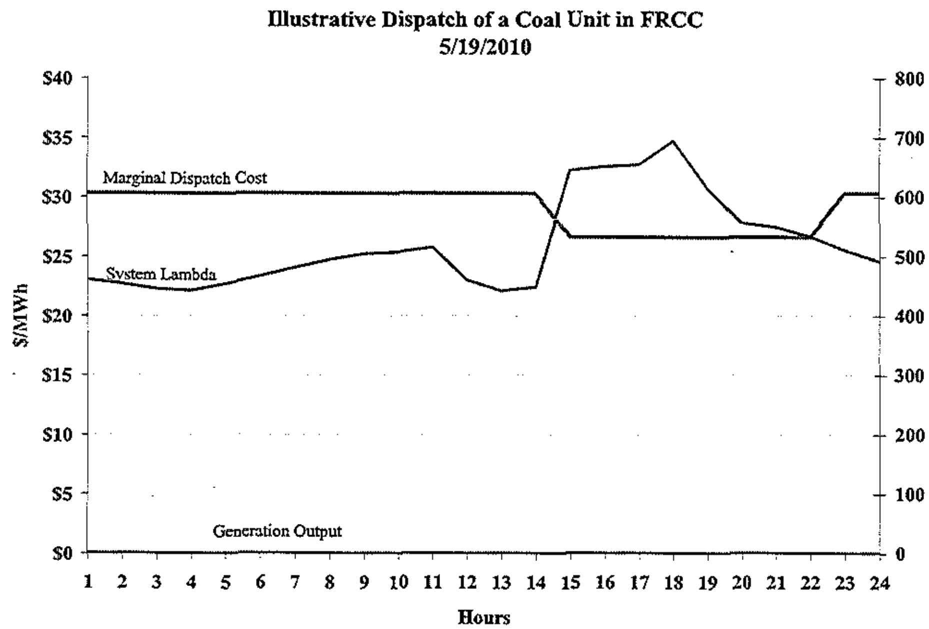
- Regional annual projections based on AEO2010
- Steep growth from $4-6/MMBtu range in 2010 to $5.5-8.5/MBtu in 2020 (all in real dollars)

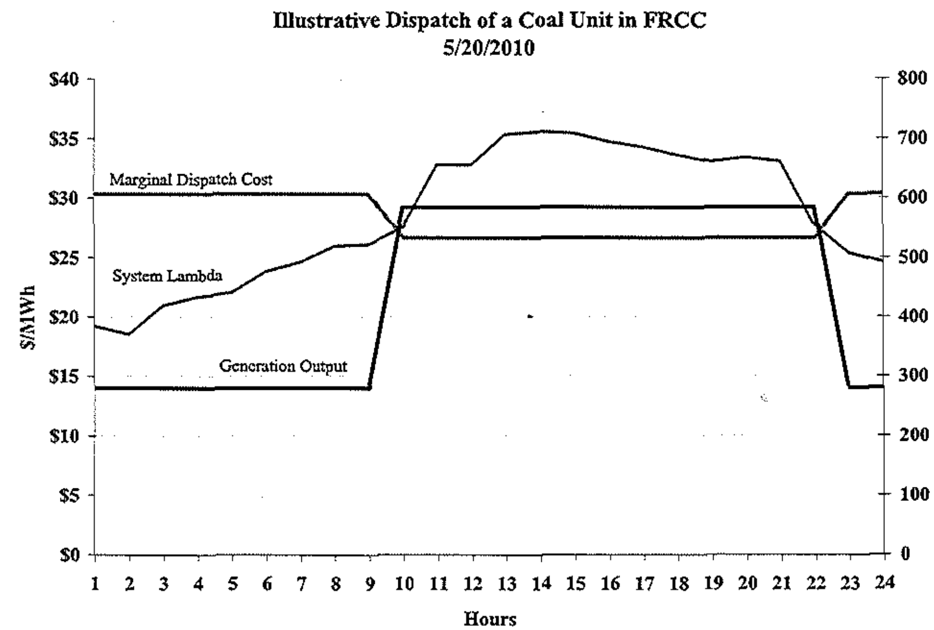
Coal prices

- Regional annual price projections based in AEO2010
- Most regions with flat real prices over time

More details in the Appendix

Illustration of coal hourly dispatch





No generation since operating margins during the day not sufficient to recover start-up costs.

Unit started up and generation output at min load (280 MW) or max load (584 MW) since operating margins during the day were enough to recover start-up costs.

Illustration of retirement decisions – a regulated unit

Cost of continued coal operations is compared to cost of replacement power from a gas CC/CT (amortized over 40 years of capital recovery at a utility ATWACC).

Even though the CapEx for installing a scrubber and an SCR on the unit is ~$220M in 2015, 15-year present value (at 7% discount rate) of continued coal operations with CapEx is roughly half of new gas CC/CT costs. Therefore, the unit does not retire in the model.

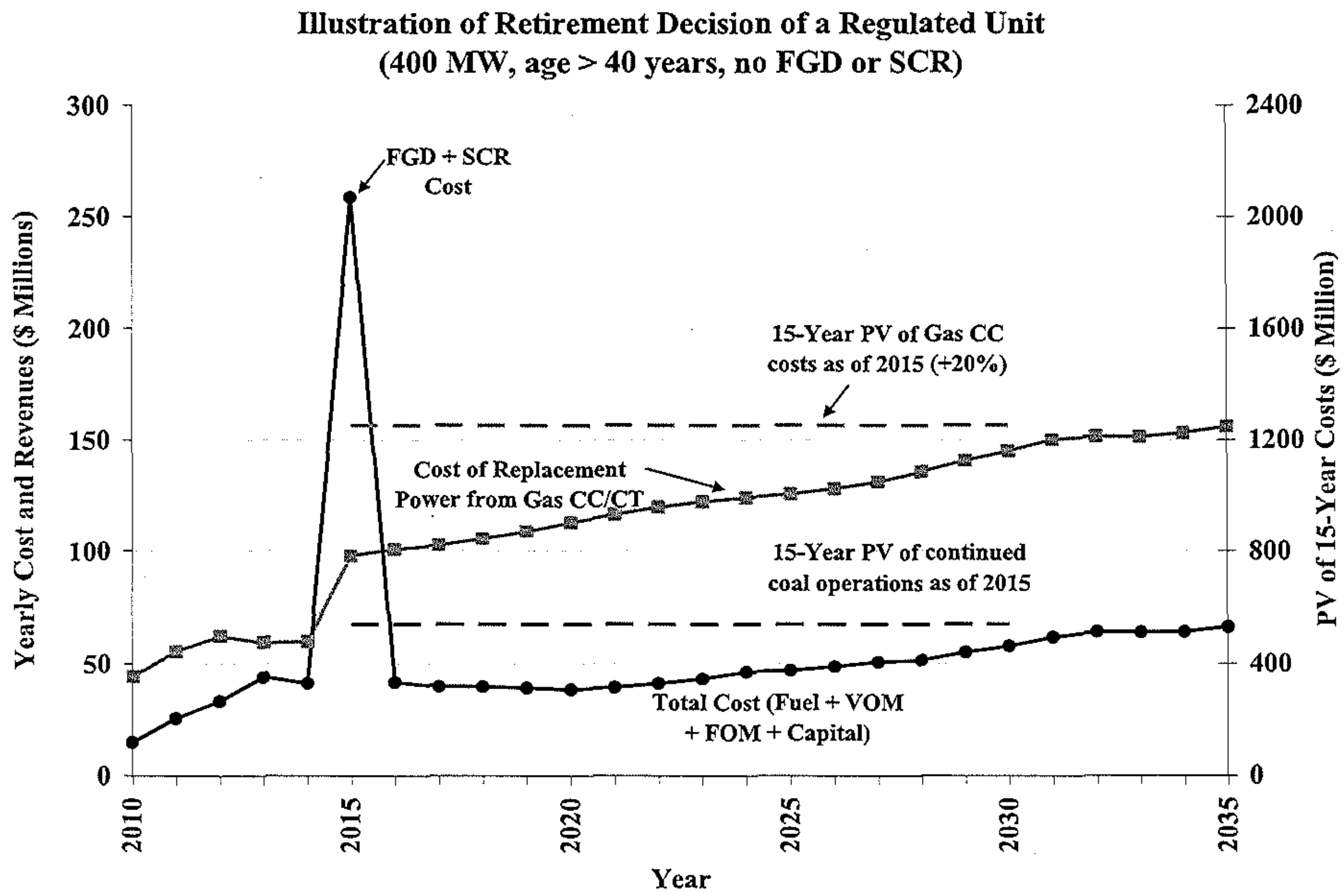
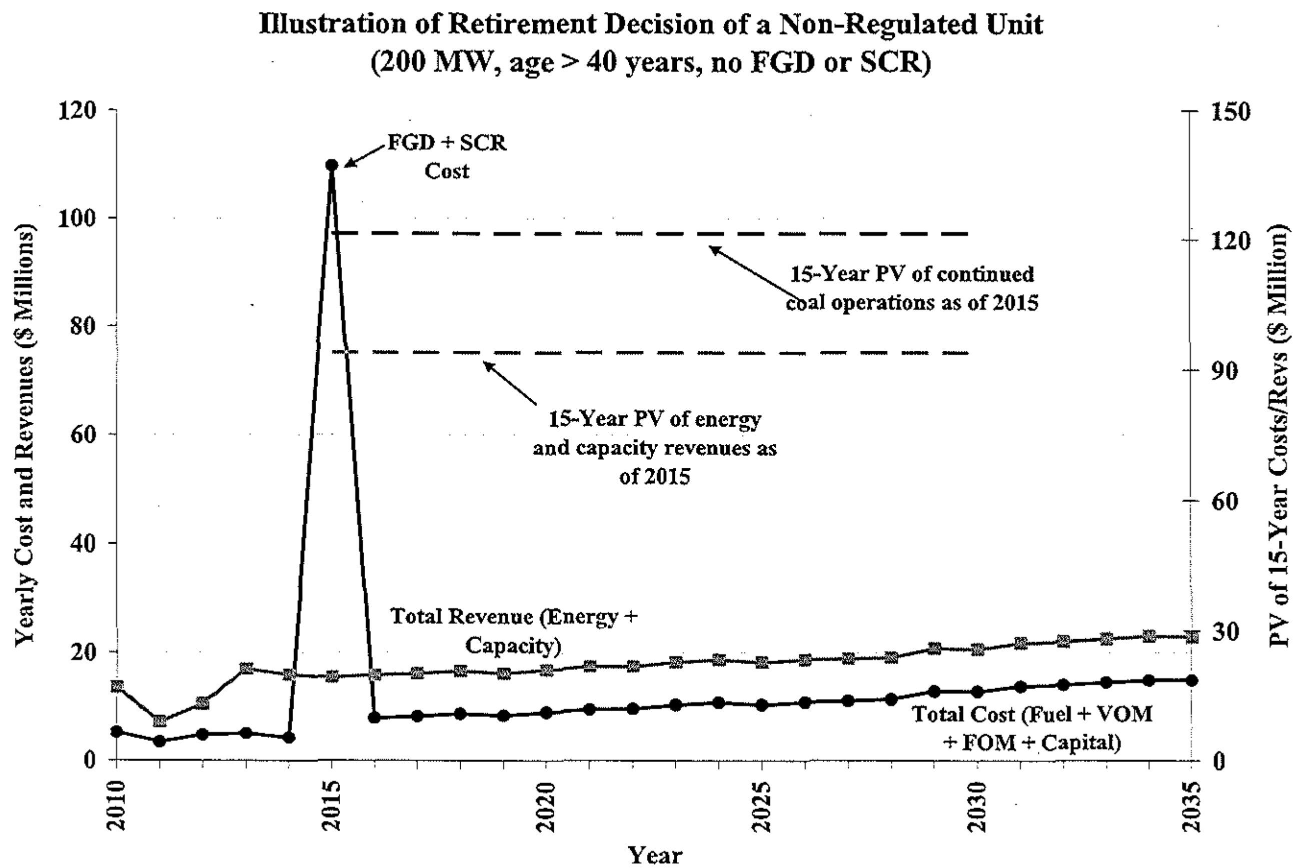


Illustration of retirement decisions – a merchant unit

Cost of continued coal operations is compared to revenues from energy and capacity markets.

The required $90 million CapEx in 2015 makes the 15-year PV (at 7% discount rate) of costs higher than revenues, hence the unit retires in 2015.



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Retirements under several criteria

Economic retirements mostly from merchant units, but more than half of coal capacity (~235 GW) could experience small (<10% of costs) or negative energy margins under an EPA mandate to install scrubbers and SCRs.

U.S. COAL PLANT CAPACITY VULNERABLE TO RETIREMENT BY 2020

Retirement Criterion		BASECASE GW	BASECASE % of coal capacity	BASECASE Output (TWh) in 2010	BASECASE % of coal generation	MANDATORY SCRUBBERS AND SCRs GW	MANDATORY SCRUBBERS AND SCRs % of coal capacity	MANDATORY SCRUBBERS AND SCRs Output (TWh) in 2010	MANDATORY SCRUBBERS AND SCRs % of coal generation
Age (> 40 yr old) and size (< 500 MW)	Merchant					13.6	18.4%	65.7	17.4%
	Regulated					35.9	14.8%	179.5	12.8%
	Total					**49.5**	**15.6%**	**245.2**	**13.8%**
Energy margins < 10% of costs	Merchant	17.7	23.8%	66.1	17.5%	49.2	66.4%	224.2	59.4%
	Regulated	120.6	49.8%	597.5	42.6%	187.5	77.4%	1026.0	73.2%
	Total	**138.3**	**43.7%**	**663.5**	**37.3%**	**236.7**	**74.8%**	**1250.1**	**70.3%**
Energy and capacity revenues for merchant units, replacement power for regulated units (+20% stranded cost adder)	Merchant	5.8	7.8%	12.2	3.2%	37.1	50.0%	156.0	41.3%
	Regulated	0.0	0.0%	0.0	0.0%	2.5	1.0%	1.6	0.1%
	Total	**5.8**	**1.8%**	**12.2**	**0.7%**	**39.6**	**12.5%**	**157.6**	**8.9%**

5.8 GW coal retirement: About the same as recent EIA and EPA projections absent new regulations

No CO_2 prices assumed, and no additional controls or operating constraints (e.g., cooling water, or ash handling).

Sensitivities on regulatory shutdown criteria

Default retirement criteria for regulated units is whether the present value of:

- future coal plant operation, FOM and environmental CapEx costs

exceed

- the cost of replacement power from a gas CC/CT plus an assumed 20% stranded cost adder

Two sensitivities are performed on this assumed regulatory criteria for retirements:

1. With no 20% stranded cost adder: slightly higher (+2 GW) retired capacity
2. With 20% discount to gas CC/CT replacement cost: significantly higher (+8 GW) retirements
   - This sensitivity is a proxy for potential externality penalties imposed by regulators (e.g., future state/federal CO_2 legislation)

Coal retirements by age and size groups

About half of the economic retirements are from <u>younger</u> units (< 40 years in 2009) due to unfavorable regional power prices even though younger units have cost and efficiency advantages.

Not surprisingly, smaller units account for a large portion of the retirements.

Total Retired Coal Capacity by 2020 (GW)

		< 500 MW	>= 500 MW	Total
Basecase	Age <40 years	1.4	3.8	**5.2**
	Age >=40 years	0.6	-	**0.6**
	Total	**2.0**	**3.8**	**5.8**
Scrubber+SCR Mandate	Age <40 years	7.6	14.5	**22.1**
	Age >=40 years	17.4	-	**17.4**
	Total	**25.0**	**14.5**	**39.6**

Regional summary

Retired Capacity by 2020 (GW)

NERC Subregion	Basecase	Mandatory Scrubbers and SCRs
ERCOT	2.5	**9.4**
RFC-PJM	-	**7.5**
SERC-Gateway	0.2	**6.5**
RFC-MISO	0.1	**4.8**
Northwest	1.8	**2.2**
MRO	0.0	**1.7**
Top 6 Regions	**4.6**	**32.1**
Other Regions	1.3	7.4
Total US	**5.8**	**39.6**

Six NERC subregions account for about 80% of the likely retirements under the EPA mandate scenario.

Retired Capacity by 2020 (GW)

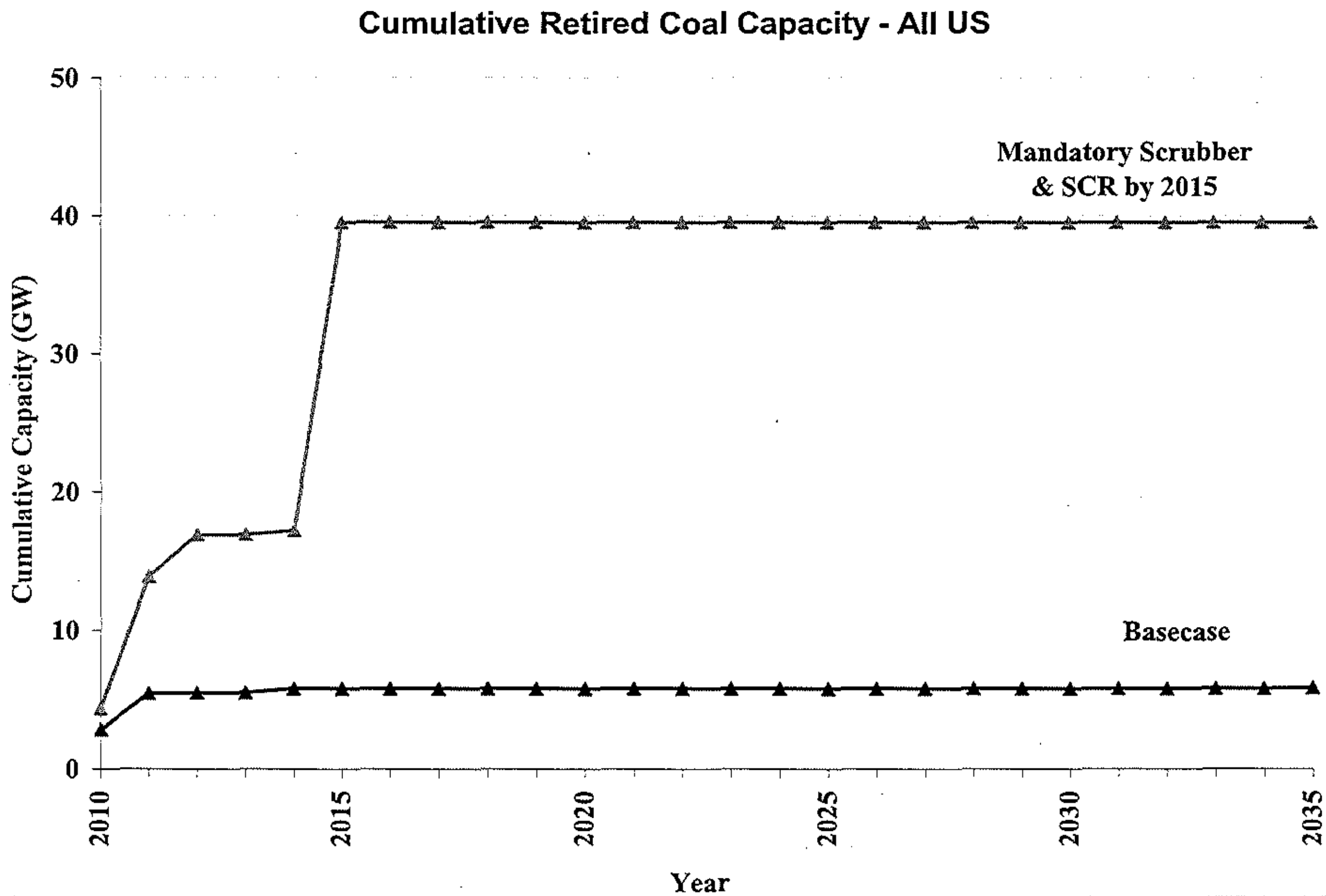
ISO/RTO Region	Basecase	Mandatory Scrubbers and SCRs
Midwest ISO	0.3	**12.3**
ERCOT ISO	2.5	**9.4**
PJM ISO	-	**8.3**
New York ISO	-	**1.2**
New England ISO	0.1	**0.8**
SPP	0.3	**0.6**
California ISO	-	**0.5**
Total ISO/RTO	**3.2**	**33.2**
Other Regions	2.6	**6.4**
Total US	**5.8**	**39.6**

Most of the retirements are in ISO/RTO regions (33 GW under the EPA mandate), with Midwest ISO being the largest one (12 GW).

Economic retirements with mandatory scrubber and SCRs

If all coal units are required to install scrubbers and SCRs by 2015, 39 GW of coal capacity would find it economic to retire by 2015.

Under base case assumptions (no equipment mandates), only 6 GW would retire.



Regional detail and reduced coal generation

Most retirements are in ERCOT, RFC-PJM and SERC-Gateway (IL, MO) regions.

EPA mandate would result in 275 TWh (16%) decrease in U.S. coal generation in 2020.

NERC Subregion	Basecase: Cumulative Retired Capacity (GW) 2010	Basecase: Cumulative Retired Capacity (GW) 2020	Basecase: Weighted Average Capacity Factor (%) 2010	Basecase: Weighted Average Capacity Factor (%) 2020	Basecase: Generation Output (TWh) 2010	Basecase: Generation Output (TWh) 2020	Mandatory Scrubber & SCR by 2015: Cumulative Retired Capacity (GW) 2010	Mandatory Scrubber & SCR by 2015: Cumulative Retired Capacity (GW) 2020	Mandatory Scrubber & SCR by 2015: Weighted Average Capacity Factor (%) 2010	Mandatory Scrubber & SCR by 2015: Weighted Average Capacity Factor (%) 2020	Mandatory Scrubber & SCR by 2015: Generation Output (TWh) 2010	Mandatory Scrubber & SCR by 2015: Generation Output (TWh) 2020
ERCOT	-	2.5	52%	44%	79.3	58.7	-	**9.4**	52%	39%	79.3	28.0
RFC-PJM	-	-	69%	72%	385.7	402.9	-	**7.5**	69%	74%	385.7	366.1
SERC-Gateway	0.2	0.2	72%	72%	93.2	92.9	0.3	**6.5**	73%	64%	92.6	46.6
RFC-MISO	0.1	0.1	60%	51%	217.5	185.6	1.3	**4.8**	61%	48%	213.1	152.3
Northwest	1.8	1.8	85%	85%	77.6	77.6	1.8	**2.2**	85%	80%	77.6	70.3
MRO	0.0	0.0	65%	51%	152.6	119.9	0.1	**1.7**	66%	44%	152.5	97.1
NYISO	-	-	46%	45%	11.3	10.9	-	**1.2**	46%	50%	11.3	6.7
Entergy	-	-	75%	75%	52.3	52.3	-	**1.2**	75%	69%	52.3	41.2
TVA	0.0	0.0	68%	68%	148.0	148.6	0.0	**0.9**	68%	60%	148.0	126.4
ISO-NE	-	0.1	37%	36%	9.0	8.3	-	**0.8**	37%	32%	9.0	5.6
FRCC	0.7	0.7	32%	61%	25.1	47.0	0.7	**0.8**	32%	57%	25.1	43.6
Southern	0.0	0.0	71%	72%	160.0	161.1	0.0	**0.6**	71%	66%	160.0	144.4
VACAR	0.0	0.0	62%	62%	144.2	145.6	0.0	**0.5**	62%	59%	144.2	134.7
California	-	-	78%	78%	15.4	15.4	-	**0.5**	78%	78%	15.4	12.3
SPP South	-	0.3	50%	40%	50.7	39.8	-	**0.4**	50%	30%	50.7	29.8
SPP North	-	0.0	60%	51%	44.3	37.7	-	**0.2**	60%	45%	44.3	32.3
Arizona	-	-	71%	69%	67.1	64.8	-	**0.2**	71%	67%	67.1	61.7
Rocky Mountain	0.0	0.0	72%	68%	40.4	38.3	0.0	**0.1**	72%	61%	40.4	33.7
Total US	**2.9**	**5.8**	65%	63%	**1,774**	**1,708**	**4.4**	**39.6**	65%	59%	**1,769**	**1,433**

Potential impact on gas generation

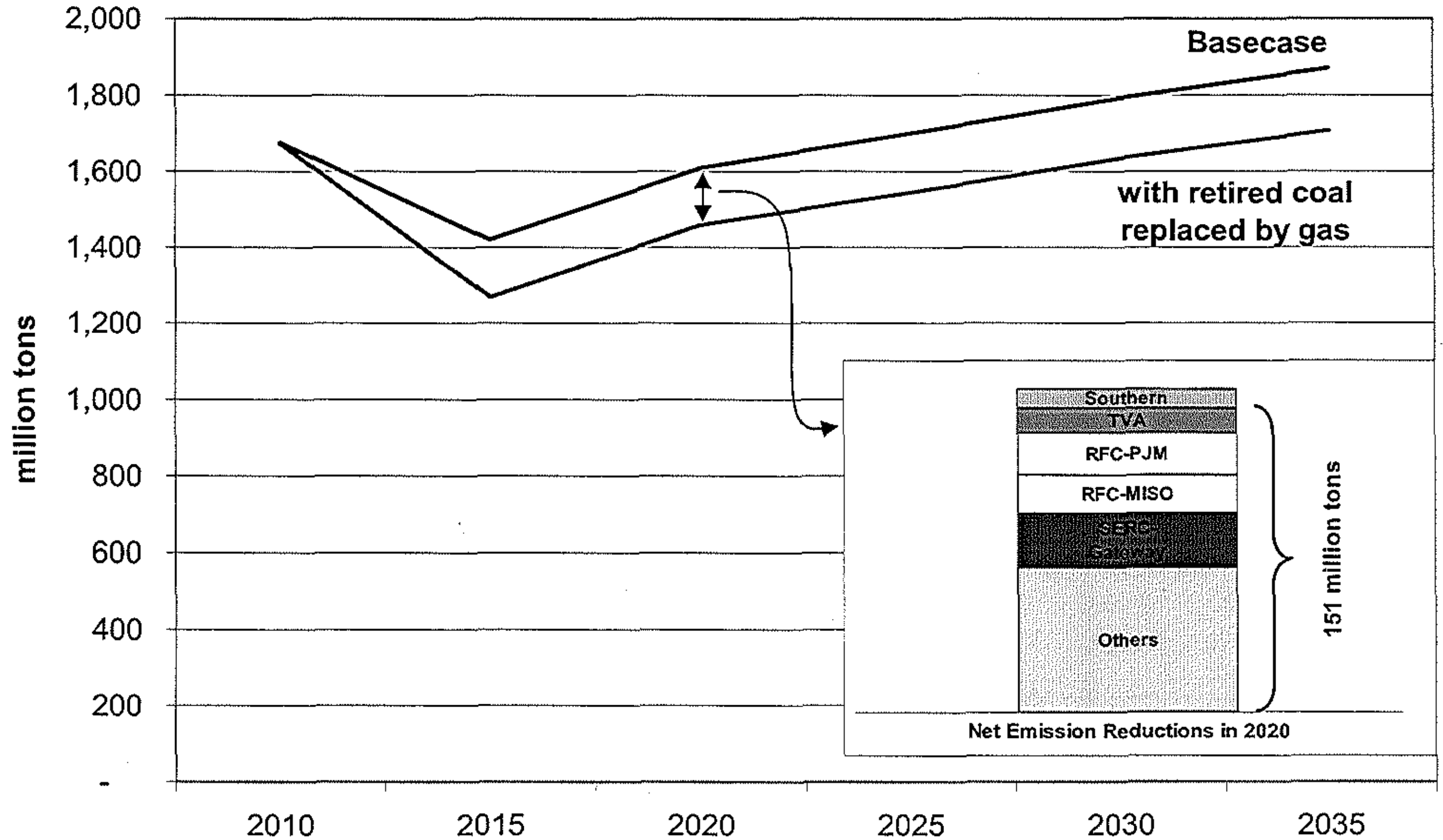
Coal retirements could increase gas generation by up to 5.8 Bcf/d in 2020 (assuming all of the decrease in coal generation is replaced with 8000 btu/kWh gas generation).

	Difference in Annual Coal Generation Output (TWh)		Increase in Natural Gas Use Relative to BaseCase (BCF/day)	
NERC Subregion	**2010**	**2020**	**2010**	**2020**
SERC-Gateway	(0.6)	(46.3)	0.0	**1.0**
RFC-PJM	-	(36.9)	-	**0.8**
RFC-MISO	(4.4)	(33.3)	0.1	**0.7**
ERCOT	-	(30.7)	-	**0.7**
MRO	(0.1)	(22.7)	0.0	**0.5**
TVA	-	(22.2)	-	**0.5**
Southern	-	(16.7)	-	**0.4**
Entergy	-	(11.1)	-	**0.2**
SPP South	-	(10.0)	-	**0.2**
VACAR	-	(10.9)	-	**0.2**
Northwest	-	(7.3)	-	**0.2**
SPP North	-	(5.4)	-	**0.1**
NYISO	-	(4.2)	-	**0.1**
Rocky Mountain	-	(4.6)	-	**0.1**
California	-	(3.1)	-	**0.1**
Arizona	-	(3.0)	-	**0.1**
ISO-NE	-	(2.8)	-	**0.1**
FRCC	-	(3.5)	-	**0.1**
Total US	**(5.1)**	**(275.0)**	**0.1**	5.8

Impact on CO_2 emissions

Reduction in coal generation due to EPA mandates could reduce CO_2 emissions from the coal fleet by 10% in 2020 if the lost generation is replaced by gas CCs.

CO2 Emissions from US Coal Fleet (million tons)



Impact on regional reserve margins

Economic retirements would have significant reductions below target in ERCOT and RFC.

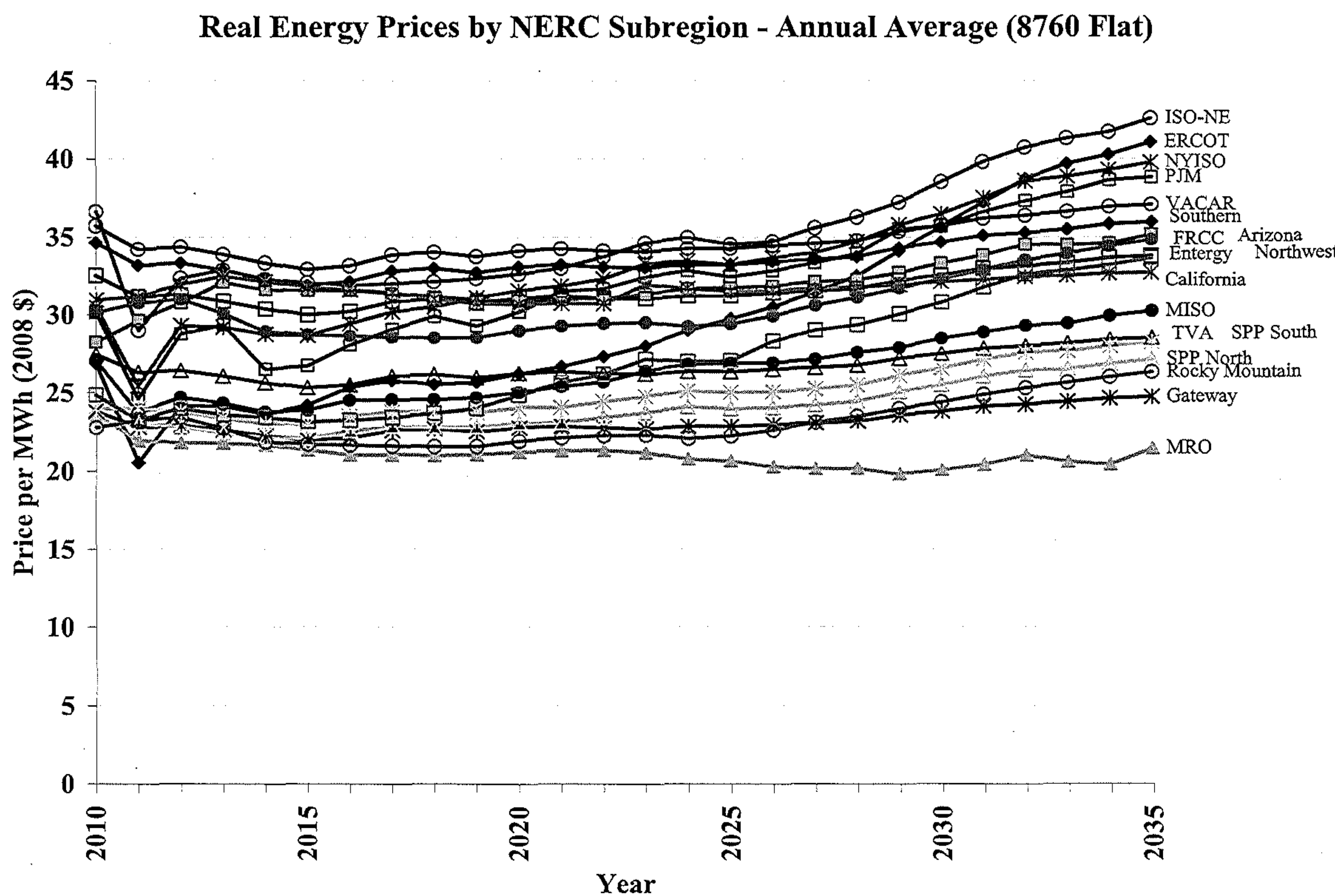
	Net 2018 Internal Demand (GW)	Adjusted Potential 2018 Capacity Resources (GW)	Adjusted Potential 2018 Reserve Margin	Cumulative Retirements by 2020 (GW)		Adjusted Potential 2018 Reserve Margin after retirements		NERC Reference 2018 Reserve Margin Level
				Basecase	Regulation	Basecase	Regulation	
ERCOT	75	85	13%	2	9	**10%**	**1%**	13%
RFC	193	230	19%	0	12	19%	**13%**	15%
MRO	48	54	14%	0	0	**14%**	**14%**	15%
NPCC	66	79	20%	0	2	19%	16%	15%
SERC	229	277	21%	0	10	21%	17%	15%
SPP	49	60	24%	0	1	23%	23%	14%
FRCC	50	63	27%	1	1	26%	25%	15%
WECC	157	211	34%	2	3	33%	32%	18%

Possible enhancements and applications

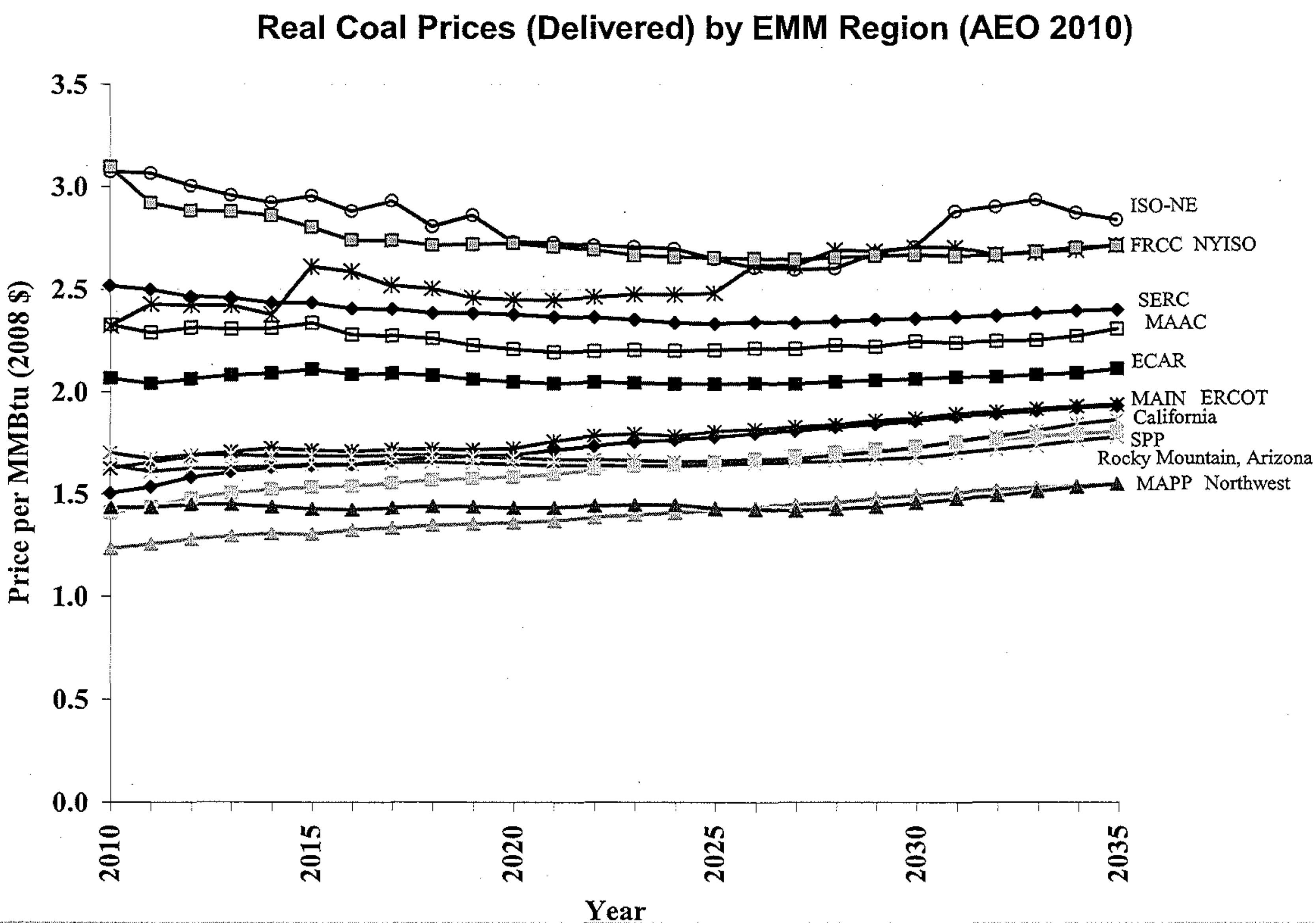
- Close scrutiny of single regions
  - Dispatch each coal plant against its own price curve
- Feedback of plant shutdowns on power prices
- Sensitivity to gas and power prices (uncertainty and feedback)
- Effect of potential CO_2 prices on retirement and operating margins
- Implications for coal shipments on major railroads

APPENDIX

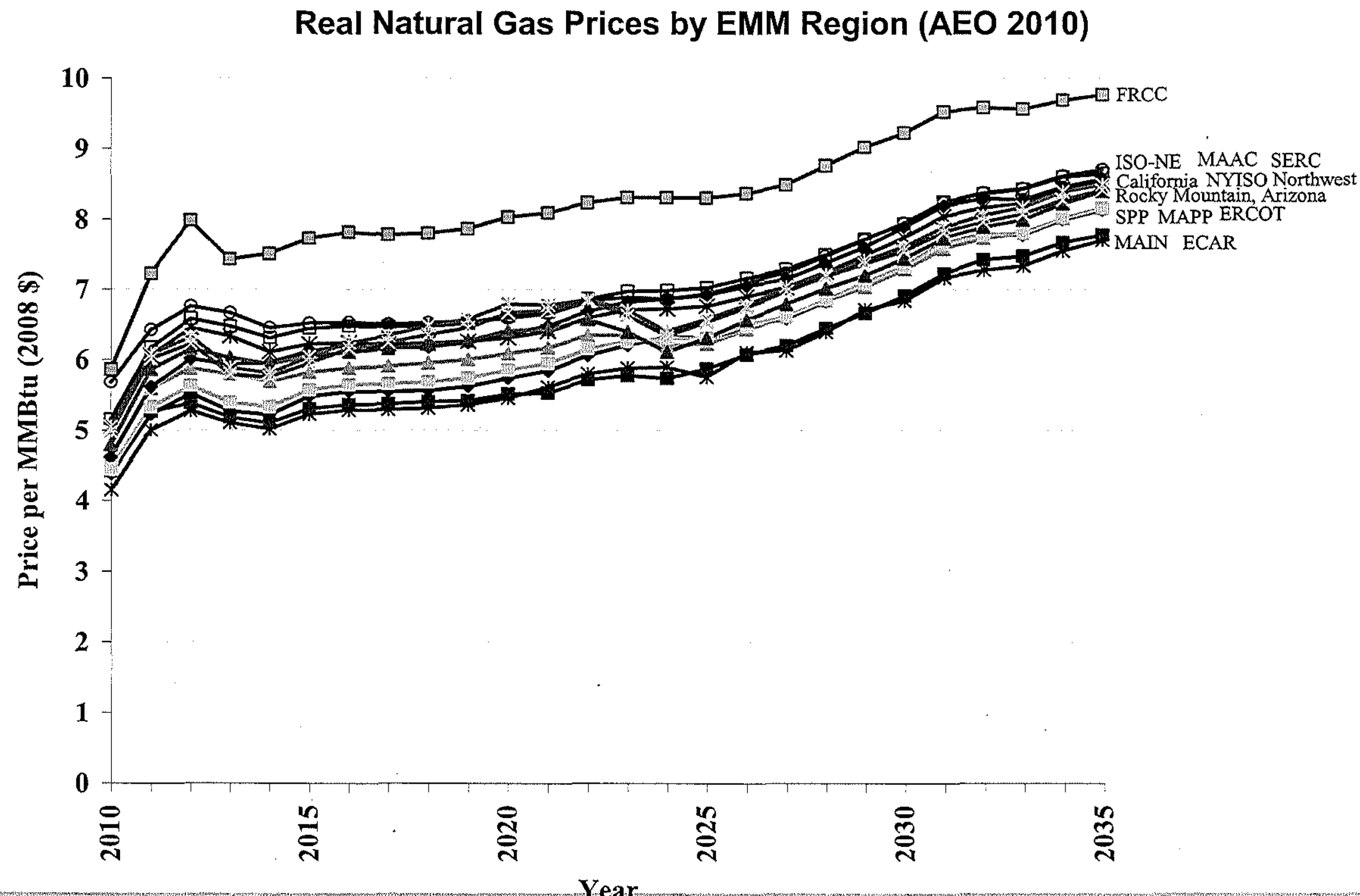
Key assumptions – wholesale power prices



Key assumptions – coal prices



Key assumptions – natural gas prices



Key assumptions – cost of replacement power for regulated coal units by region

REPLACEMENT COST SUMMARY (NEW CC AND CT)

NERC Region	NERC Sub Region	Average NG Price (2010-2020) ($/MMBtu)	Average Fuel Costs ($/MWh)		Overnight Cost ($/kW-year)		FOM ($/kW-year)		VOM ($/MWh)		Levelized All-in Cost ($/MWh)			
			CT @ 9.5 MMBtu/MWh	CC @ 6.8 MMBtu/MWh	CT	CC	CT	CC	CT	CC	CT 10% CF	CC 30% CF	CT 20% CF	CC 80% CF
ERCOT	ERCOT	5.48	52	37	66	109	10	18	3	2	142	87	99	57
FRCC	FRCC	7.70	73	52	66	109	10	18	3	2	163	102	120	72
MRO US	MRO	5.87	56	40	66	109	10	18	3	2	146	90	102	60
NPCC	NY	6.26	59	43	66	109	10	18	3	2	149	92	106	62
NPCC	ISO NE	6.60	63	45	66	109	10	18	3	2	153	95	109	65
RFC	MISO	5.36	51	36	66	109	10	18	3	2	141	86	97	56
RFC	PJM	6.47	61	44	66	109	10	18	3	2	151	94	108	64
SERC	Gateway	6.07	58	41	66	109	10	18	3	2	148	91	104	61
SERC	TVA	6.07	58	41	66	109	10	18	3	2	148	91	104	61
SERC	VACAR	6.07	58	41	66	109	10	18	3	2	148	91	104	61
SERC	Southern	6.07	58	41	66	109	10	18	3	2	148	91	104	61
SERC	Entergy	6.07	58	41	66	109	10	18	3	2	148	91	104	61
SPP	SPP South	5.59	53	38	66	109	10	18	3	2	143	88	100	58
SPP	SPP North	5.59	53	38	66	109	10	18	3	2	143	88	100	58
WECC	CA	6.27	60	43	66	109	10	18	3	2	150	93	106	62
WECC	NWPP	6.12	58	42	66	109	10	18	3	2	148	91	105	61
WECC	AZNMSNV	6.18	59	42	66	109	10	18	3	2	149	92	105	62
WECC	RMPA	6.18	59	42	66	109	10	18	3	2	149	92	105	62

Additional Reading

"Managing Natural Gas Price Volatility: Principles and Practices Across the Industry," by Steven H. Levine and Frank C. Graves, *The Brattle Group, Inc., prepared for the American Clean Skies Foundation*, forthcoming in Spring 2011.

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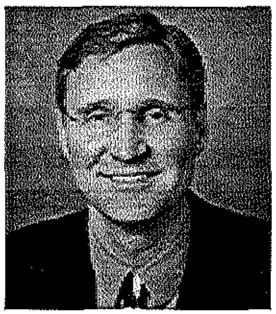

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