Retail Electricity Price Savings from Compliance Flexibility in GHG Standards for Stationary Sources (forthcoming in *Energy Policy*)

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5th Annual Trans-Atlantic Infraday Conference
Washington, DC
November 11, 2011

Introduction

- EPA will soon regulate greenhouse gas (GHG) emissions at steam boilers under the Clean Air Act (CAA) using a performance standard
  - Flexible performance standard with fleet-wide averaging?
  - Or traditional, inflexible performance standard?

Preview of Results

- Flexible standard increases electricity prices by 1.3%
  Traditional standard increases electricity prices by 3.3%
- Traditional standard leads to more retirement of existing coal-fired plants
- Flexible standard leads to more investment in efficiency at existing coal-fired plants
- Total cost of a flexible standard is 1/3 the cost of a traditional standard

Overview

- Background
- Haiku electricity market model
- Scenarios
- Results and analysis
- Conclusions

Background

- *Massachusetts v. EPA*, 2007
  - Confirmed EPA authority to regulate GHG emissions under CAA
- EPA will regulate new and existing stationary sources with performance standards
  - First regulation will be for steam boilers and refineries
  - Final rule expected in 2012

Background

- Electricity sector GHG emissions
  - 33% of US GHG emissions
  - 40% of US CO_2 emissions
  - Expected to account for 2/3 to 3/4 of economy-wide emission reductions over the next deacde under a cost-effective GHG policy
- Coal-fired power plants
  - 82.5% of electricity sector CO_2 emissions
  - 33.3% of total US CO_2 emissions

Background

- EPA's advance notice of proposed rulemaking (2008)
  - Coal-fired plants can reduce CO_2 emissions by upgrading various systems to improve plant efficiency (reduce heat rate)
  - The coal-fired fleet-wide average heat rate could reasonably be reduced by up to 5%
  - Current average is 10,300 Btu/kWh, ranging from 9,000 to above 15,000 Btu/kWh

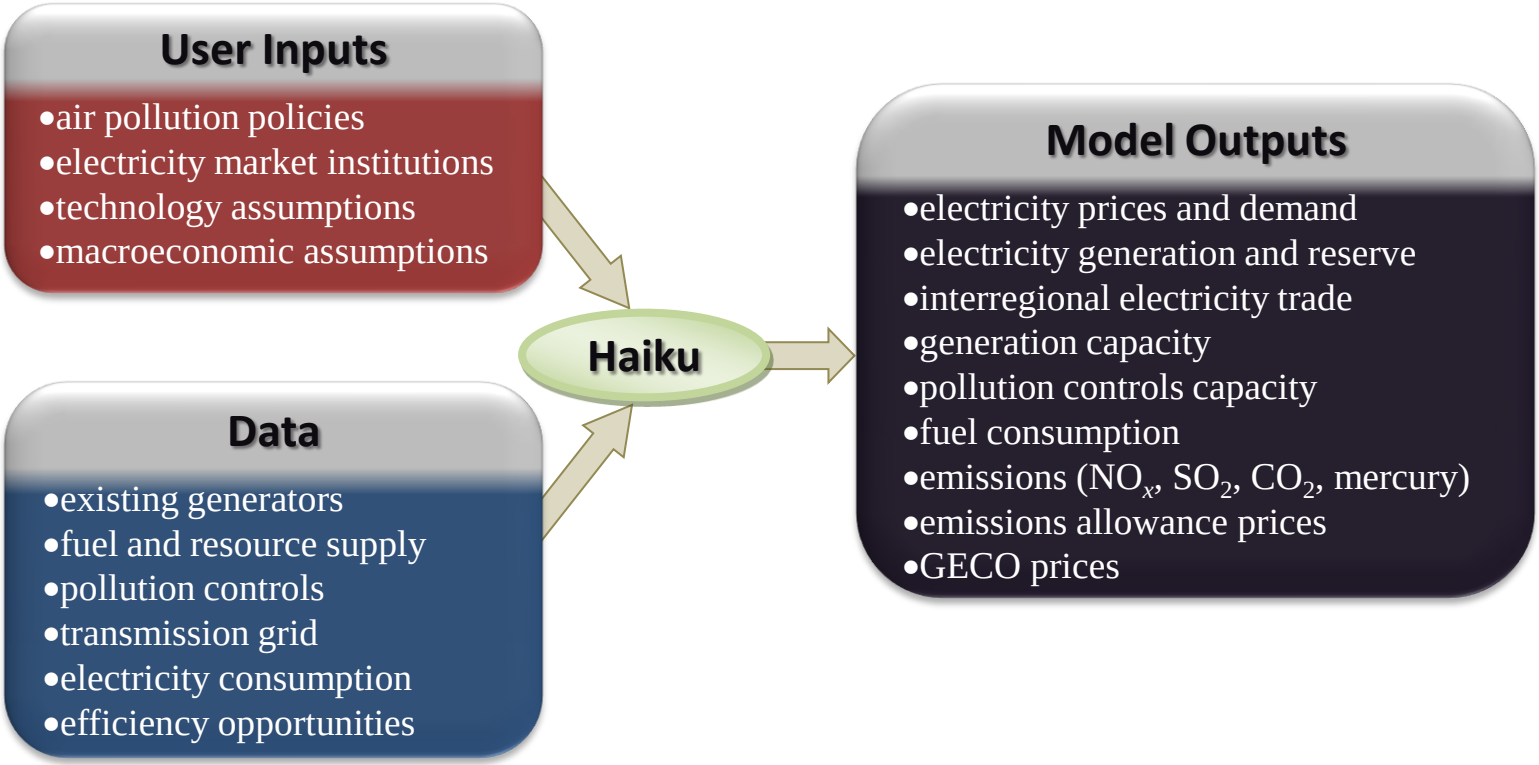
Background

- A number of previous studies have examined the ability of coal plants to improve operating efficiency
  - Sargent & Lundy, 2009
  - DiPietro and Krulla, 2010
  - NETL, 2010
  - Linn et al., 2011

Background

- Two regulatory approaches under CAA Section 111(d) (Richardson, Fraas, and Burtraw 2011)
  - Traditional, inflexible performance standards
  - Flexible performance standard with fleet-wide averaging

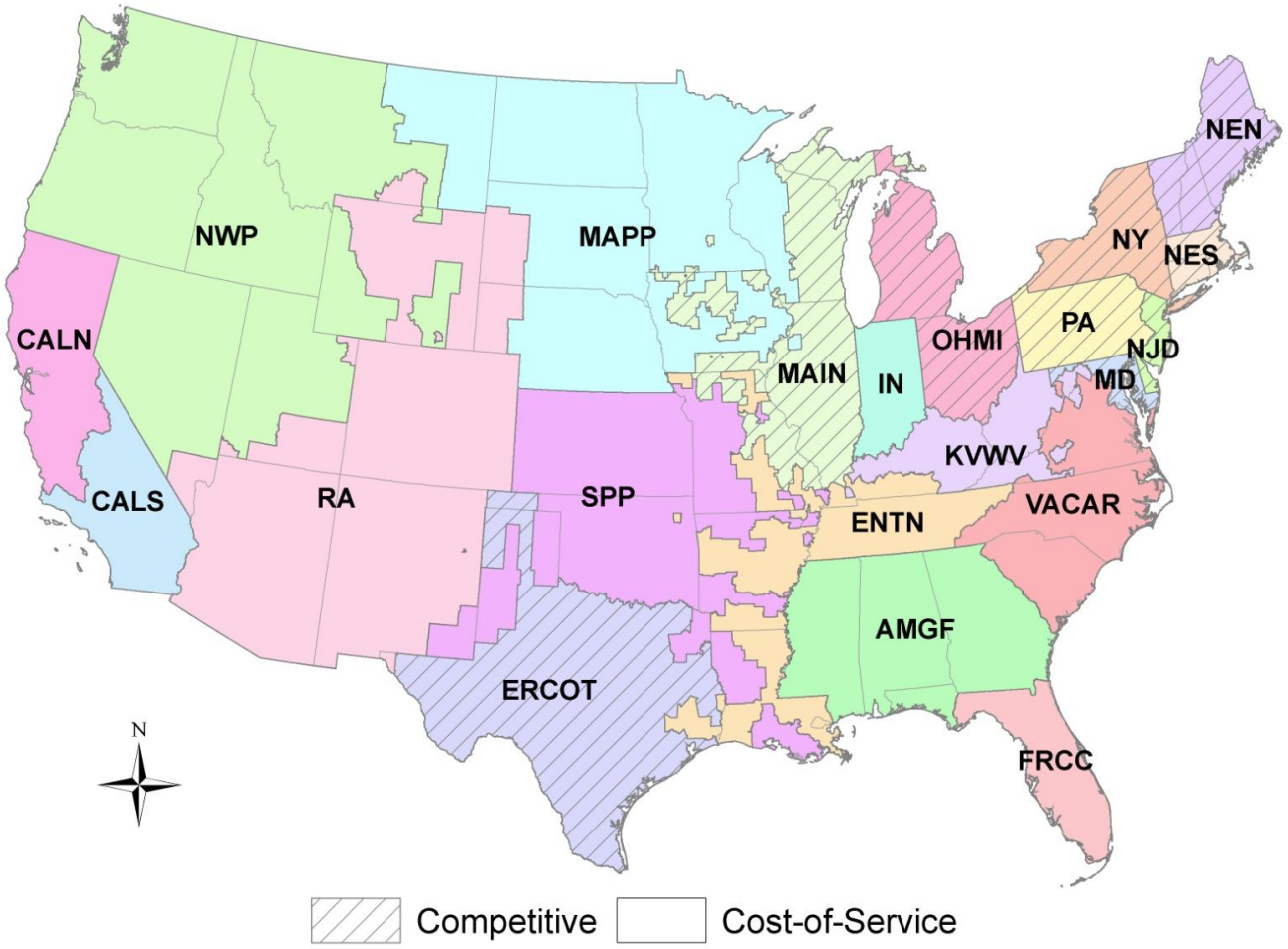
Haiku Electricity Market Model



Time, Regions, and Model Plants

- Time
  - Simulation years out to 2035
  - 1 yr = 3 seasons * 4 times of day = 12 time blocks
- 21 Haiku Market Regions = 21 nodes on electricity grid
  - Energy balance in each region
  - Regions connected by transmission grid
  - Regulatory structure: cost-of-service or competitive
- Model Plants
  - Represent groups of electricity generators sharing technological similarities
  - Pre-existing generators, planned & endogenous construction

Haiku Regions



Haiku Coal Plant Efficiency

- Operating efficiency improvement
  - Schedule of opportunities (Sargent & Lundy 2009)
  - Estimate a linear supply curve for efficiency
  - Approximately 700 Btu/kWh improvement available at a cost ranging from 0 to about $35/MW per Btu/kWh improvement
  - Width of supply curve grows at 1% annually
  - Opportunities available at a plant are inversely related to the plant's operating efficiency

Scenarios

- Two scenarios
  - Calibrated to achieve the same CO_2 emissions from the electricity sector, 5.4% below BL in 2020
  - Flexible performance standard
  - Traditional performance standard

Flexible Performance Standard

- By 2020, achieve 5% reduction in average coal-fired heat rate from observed 2010 rate
- Generators receive and surrender GECOs (generation efficiency credit offset) for every unit of generation
- Benchmark GECO rate is 9,657 Btu/kWh in 2020
- Generators surrender GECOs at actual heat rate
- GECO price is denominated in $/Btu
- Heat rate approach is roughly equivalent to using emission rates

Traditional Performance Standard

- Maximum heat rate of 10,300 Btu/kWh in 2020
- Coal-fired plants not meeting this standard must invest in efficiency improvements or retire

Electricity Prices

Year 2020 Values in 2008 dollars	Flexible Standard	Traditional Standard
Change in **Elec. Price** ($/MWh)	1.16	2.84
	1.3%	*3.3%*

- Price effect is much smaller for flexible standard than for traditional standard

Regional Electricity Prices

Year 2020 Values in 2008 $/MWh	Flexible Standard	Traditional Standard
RGGI	-0.40	4.75
Rockies & West	2.69	3.22
Big 10 & Appalachia	-0.25	4.10
Southeast	-0.38	-0.41
Plains	5.03	4.53
Wholesale Competition	0.12	4.61
Cost of Service	1.79	1.75
National	1.16	2.84

- Price difference between flexible and traditional standards occurs mostly in competitive regions

Generation Mix

Year 2020	Flexible Standard	Traditional Standard
Change in **Total Generation** (BkWh)	-40	-74
	-0.9%	*-1.7%*
Coal	-114	-209
	-5.9%	*-10.9%*
Gas	79	132
	7.8%	*13.1%*

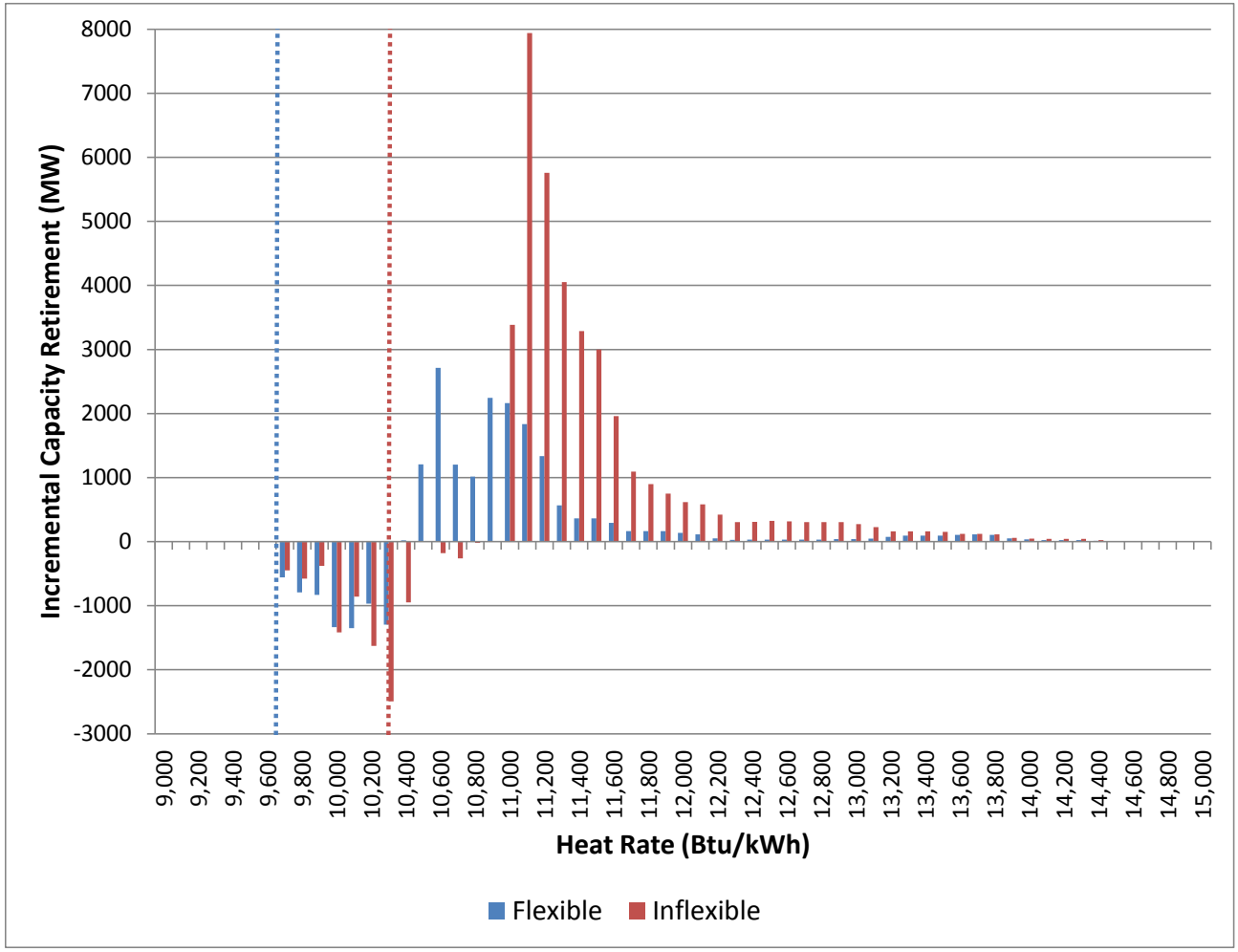
- Reduction in generation mirrors changes in electricity prices
- Most fuel switching occurs under traditional standard, second most in flexible standard

Capacity

Year 2020	Flexible Standard	Traditional Standard
Change in **Total Capacity** (GW)	-0.6	-3.2
	-0.1%	*-0.3%*
Coal	-5.5	-32.6
	-2.0%	*-11.9%*
Gas	6.2	29.7
	1.5%	*7.0%*

- Greatest coal retirement by far occurs under traditional standard

Capacity Retirements



- Coal retirements vary by heat rate
  - Most capacity is better off under the flexible standard
  - Some capacity benefits from the traditional standard

Efficiency Investments

Year 2020 Values in 2008 dollars	Flexible Standard	Traditional Standard
Avg. Coal Plant Heat Rate (Btu/kWh)	9,657	9,914
Avg. Effic. Improvement (Btu/kWh)	525	268
	5.2%	*2.6%*
Efficiency Investments (M$)	2,933	349

- Flexible standard leads to most efficient coal fleet and largest investment in efficiency improvements

Marginal Generation Costs

Year 2020 Values in 2008 dollars	Flexible Standard	Traditional Standard
GECO Price ($/MMBtu)	26.4	
Cost of Coal ($/MMBtu)	1.95	2.02
Cost of Gas ($/MMBtu)	5.42	5.45

- GECO price provides the greatest incentive for efficiency investments
  - 13 times greater than the cost of coal in the flexible standard scenario

Cost Effectiveness

Year 2020 Values in 2008 dollars	Flexible Standard	Traditional Standard
Change in **Total Cost** (B$/year)	1.4	4.9
Consumer Cost	1.9	7.0
Producer Cost	-0.4	-2.3
Cost to Government	-0.2	0.2
***Change* in Cost / MWh** ($/MWh)	1.9	5.8
	2.8%	*8.4%*

- Cost of flexible standard is about 1/3 the cost of the traditional standard

Conclusions

- Flexible standard increases electricity prices by 1.3%
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- Traditional standard leads to more retirement of existing coal-fired plants
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Conclusions

- EPA regulation
  - Final rule expected in 2012
  - Legal analysis indicates the agency has the authority to implement a flexible performance standard
  - Economic advantages of a flexible standard would be substantial relative to a traditional performance standard

Future Work

- Additional flexibility under flexible performance standard
  - Cofiring with biomass or natural gas, etc.
- Subcategorization of plants
  - Variable benchmark rates based on observed heat rate, boiler characteristics, etc.