An Inquiry into the Balance between Federal and State Energy Policy in the Southeast

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ABSTRACT

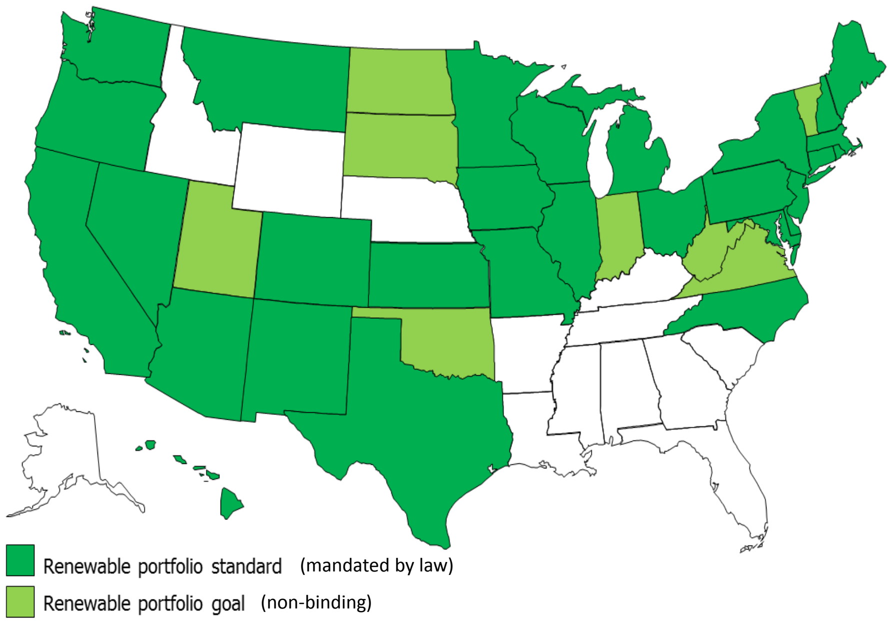
Many policies have been proposed to address America's growing energy needs, but a broad-based compromise is often constrained by regional differences. It is important to highlight the regional benefits of potential energy policies that drive renewable generation. North Carolina enacted a renewable portfolio standard in 2007 known as the Renewable Energy and Energy Efficiency Standard (REPS). This was significant because a mandatory renewable energy requirement was passed through a state legislature in the Southeast for the first time and in a region where power markets are heavily regulated. Our energy modeling endeavor forecasts the results of other Southeastern states adopting a similar renewable portfolio standard, along with various levels of federal action. Our results indicate that a coordinated renewable portfolio standard throughout the Southeast could reduce wholesale electricity prices by $6 per megawatt hour and mitigate carbon dioxide emissions by 18 million tons in North Carolina relative to other policy alternatives by 2025.

Our analysis utilizes two distinct energy models to evaluate the impact of federal and state energy policies. By incorporating the Department of Energy's National Energy Modeling System (NEMS) and the AURORAxmp models, we are able to perform a robust scenario analysis that tests political ideologies, congressional action, and federal agency regulation. The results allow us to identify potential outcomes of renewable portfolio standards within the reality of an uncertain energy future.

INTRODUCTION

In the absence of federal carbon mitigation legislation, many state governments have implemented renewable energy portfolio standards (RPS) in an attempt to reduce reliance on conventional fossil fuels. Since 1997, more than 29 states have developed plans to diversify their sources for power generation in the future.[1] However, relative to other regions in the US, the Southeast has been slow to adopt renewable standards. In fact, North Carolina is the only state in the region that has passed a renewable energy portfolio standard.[2]

Figure 1 - Map of States as of March 2012 with Renewable Portfolio Standards[3]



Federal policy, though uncertain, could affect state-level energy measures such as renewable portfolio standards. Three possible federal actions include a carbon regulatory market mechanism, greater regulation of hydraulic fracturing, and tighter energy efficiency standards. It is possible that the U.S. Congress will reconsider carbon cap-and-trade legislation or a carbon tax at some point in the foreseeable future. It is also possible that future presidential administrations will mandate federal agencies to introduce new natural gas “fracking” regulations and stricter energy efficiency standards.

These aforementioned policies were selected out of many possibilities for federal action (including nuclear subsidy programs, biofuel minimum generation requirements, greater investment in carbon-capture and storage technologies, etc). We selected federal policies based on other modeling studies (Carley 2011 and Brown 2010) and also those that represent potential actions of various policy makers across federal and state institutions. While not an exhaustive list, we felt that these policies best represented contemporary issues in energy policy that have a high likelihood of adoption. However, it is noteworthy that Congress has also considered a national-level RPS policy.[4] Nonetheless, a uniform federal RPS seems unrealistic because of the unequal renewable resource endowments among states.

Given this political uncertainty, we ask whether the Southeastern states should follow North Carolina's lead to enact a similar RPS or wait for the possibility of additional federal energy legislation. It is intriguing if state energy plans would complement or counteract the effect of future federal energy policy on fossil-fuel energy reductions and emissions abatement. A third possibility is that energy policy at the federal level would simply render state-level policies duplicative. We hypothesize that state and federal actions would interact in a positive manner to reduce emissions, and our analysis is motivated to uncover a better understanding of this interaction.

POLICY BACKGROUND

Role of state policy

US States have many options to address energy and climate issues. California recently passed a cap and trade bill to target greenhouse gas emissions (Assembly Bill 32: Global Warming Solutions Act). North Carolina adopted regulations in 2002 to reduce nitrogen oxide (NOx) and sulfur dioxide (SO2) emissions from fossil-fuel generating power plants (Clean Smokestacks Act). The Northeastern and Mid-Atlantic states (excluding Pennsylvania and New Jersey) have also developed a regional-based regulatory program to reduce greenhouse gas emissions (Regional Greenhouse Gas Initiative). Our state policy analysis will focus on renewable portfolio standards, but it is one of many possibilities to address state level issues.

State legislatures could impact electric power markets by implementing renewable energy portfolio standards, which may help to influence neighboring states to adopt similar standards. State governments have been innovative in crafting unique energy plans tailored to their specific renewable resource endowments.[5] This investigation focuses on the Southeastern states because they are the largest contiguous block of states that have yet to develop renewable standards.[6] A renewable portfolio standard is a policy mechanism that sets a requirement for electricity retailers to provide a minimum portion of electricity sales from defined renewable sources. Some states, like Texas, set a megawatt capacity target for their RPS.[7] North Carolina's version of the renewable portfolio standard also includes an option for energy efficiency measures, so it is appropriately called a "Renewable Energy and Energy Efficiency Standard." This legislation is referred to as Session Law 2007-393 (Senate Bill 3). The first provision of the REPS law, a 0.2% minimum solar requirement, was required in 2010. By 2021, 12.5% of electricity retail sales in the state must come from renewable generation and energy efficiency.[8]

Role of federal policy

Like the states, the federal government can utilize several policy options to address energy and climate issues. The US Congress passed a cap-and-trade greenhouse gas regulation bill for the first time in 2009 (H.R. 2454: American Clean Energy and Security Act of 2009). The bill passed through the House of Representatives but stalled in the Senate. The US Congress also considered a national renewable electricity standard (RES) in 2010 (Senate Bill 3813), and President Obama proposed a clean energy standard in his 2011 State of the Union Address. Aside from mandates, federal officials can offer subsidies, tax benefits, and guaranteed loans to drive renewable energy adoption. Approximately $9.3 billion in energy tax incentives, for instance, were distributed as part of the American Recovery and Reinvestment Act of 2009.[9] We selected certain elements of each of these policies for this analysis.

The Environmental Protection Agency (EPA) also plays a role in energy policy and is expected to finalize a number of regulations over the modeling time period (e.g. Cross-State Air Pollution Rule, Mercury Air Toxics Standard for Utilities, Coal Combustion Residuals Rule, and the Cooling Tower Rule). To focus our analysis and limit the number of uncertainties, the EPA regulations were not included in this analysis. These regulations have been specifically evaluated in a number of other modeling studies.[10]

The U.S. Congress could greatly impact electric power markets by requiring a tax on the carbon dioxide emitted from conventional fossil fuel power plants. Legislation similar to the Waxman-Markey Bill of 2009 (H.R. 2454) could eventually be passed, which would establish a cap-and-trade program akin to the European Union Emission Trading Scheme. A carbon tax is as an alternative to the cap and trade mechanism, which can be used as a form of revenue generation for the federal government. Following upon the work of Carley (2011), we explored three different national carbon prices: $0/ton, $25/ton, and $50/ton CO2 equivalent. These scenarios respectively represent a low, medium, and high case of congressional actions. As mentioned above, Congress could influence energy policy through many mechanisms besides a tax on carbon, but it is the main congressional action explored in this analysis.

The White House could also impact electric power markets by mandating federal agencies to introduce new regulations. Aside from the climate regulations mentioned above, the EPA is currently scrutinizing the environmental effects of natural gas hydraulic fracturing. If strict environmental rules are placed on shale gas drilling operations, then the price of natural gas could increase significantly and reduce future investment in gas-fired power plants. A rise in the price of natural gas would imply that conventional resources are declining, while demand is increasing. The scenarios included in this analysis reflect varying levels of recoverable natural gas. If restrictions are minimal or non-existent, it is assumed that the supply of natural gas will increase steadily over the modeling time period. On the other hand, stringent hydraulic fracturing regulations will reduce the amount of recoverable natural gas. The three scenarios reflect a high supply, moderate supply, and a low supply of natural gas recovered from the Marcellus Shale. As mentioned above, we are not examining other EPA regulations such as the Maximum Achievable Control Technology (MACT) toxic rule. This analysis is focused on natural gas supply and the effect shale gas extraction restrictions can have on electricity generation profiles.

Another federal agency could also develop policies that reduce overall energy demand. The Department of Energy (DOE) is currently examining the possibility of modifying current energy efficiency standards for buildings and appliances. Regulatory actions taken by the DOE will likely have significant ramifications in the energy markets. If strict energy efficiency standards are implemented, then it is likely that the total electricity consumed across the country will decrease ceteris paribus. Our three energy efficiency scenarios reflect varying levels of program implementation and a varying degree of allowable efficiency standards. The first scenario strips most building and appliance efficiency standards away and revokes most subsidies. The second scenario includes a modest implementation of energy efficiency standards and subsidies for buildings and appliances. A third scenario imposes strict energy efficiency requirements, while providing robust subsidies for residential appliances, commercial equipment, and industrial combined heat and power (CHP) systems. Appendix B provides further details on the policy design of each scenario.

The outcome of the 2012 presidential election is far from certain, so three different regulatory scenarios are explored: an interventionist, a moderate, and a Laissez-faire presidential administration. These scenarios capture both of the federal agency policy variables (natural gas regulations and energy efficiency standards) described above. These scenarios are somewhat analogous to possible future administrations of Barack Obama, Mitt Romney, and Ron Paul. However, the scenarios are not actually tied to specific policies that the candidates have announced; rather they are simply representations of three different political ideologies.

LITERATURE REVIEW

This section reviews recent energy modeling research on renewable portfolio standards. Andy Kydes, an analyst at the US Department of Energy's Energy Information Administration (EIA), was one of the first to model a national RPS using the National Energy Modeling System (NEMS).[11] Kydes (2007) explores the effect of a federal non-hydroelectric renewable portfolio standard growing from 2.5% in 2003 to 20% by 2020. NEMS cannot disaggregate down to the state level, so a renewable portfolio standard can only be modeled at the national level in the software program. The reference case from the Annual Energy Outlook (AEO) 2002 was used for all other assumptions in his model.[12]

Kydes forecasts that the penetration of renewable generation due to an RPS policy would reduce new construction of natural gas combined cycle power plants. His model predicts that a national 20% federal portfolio standard would be met through a combination of power generation from biomass, wind, and geothermal resources. Moreover, he predicts that CO2 emissions from power generation under the standard would be 16% lower than the reference case in 2020. Interestingly, he calculates that an imposition of a 20% RPS would increase retail electric prices by just 3% compared to the reference case. Instead, Kydes' model indicates that the national RPS would reduce the future price of natural gas, thus mitigating a rise in retail power prices. Overall, his research indicates that a 20% federal RPS could be implemented for the entire United States with minimal effects on the cost of electricity for residential consumers. One limitation in his research is that portfolio standards have traditionally been set at the state level, yet NEMS is unable to model individual state policies.

Brown, Gumerman, Baek, et al (2010) used NEMS to model renewable energy resources in the southern United States.[13] A unique feature of their research is the division of renewables into two separate categories: (1) utility-scale resources and (2) customer-owned resources. The first category includes wind power, bio-power, landfill gas, hydropower, and utility-scale solar power. The second category includes combined heat and power, distributed bio-power, heat pump water heaters, solar water heaters, and distributed solar photovoltaic generation. Previous studies have not emphasized the important division between utility-scale resources and customer-owned resources.

Brown, Gumerman, Baek, et al used a modified version of the National Energy Modeling System known as SNUG-NEMS (Southeastern NEMS User Group version of NEMS) to complete their analysis. Their investigation builds six scenarios to test their hypothesis.[14] The first scenario is the reference base case from EIA. The second scenario is Expanded Renewables, which includes new estimates of hydropower and wind resource capacity and a new projection of the cost of solar energy. The third scenario is the Renewable Electricity Standard, which attempts to model a federal RPS of 25% by 2025 across all states. The fourth scenario is the Carbon-

Constrained Future that models a carbon price of $15/ton by 2012 that grows over time. The fifth scenario combines Expanded Renewables with the Renewable Standard, and the sixth scenario combines Expanded Renewables with the Carbon-Constrained Future.

The results of Brown, Gumerman, Baek, et al (2010) suggest that policies represented in the Expanded Renewables in a Carbon-Constrained Future scenario could increase utility-scale renewable generation up to 29% of total generation in the South by 2030. Furthermore, this increase in sustainable energy could significantly reduce CO2 emissions in the South without causing a spike in electricity rates. They forecast just a modest rate increase to $0.11/kWh by 2030 due to a large expansion of inexpensive wind power in the Southeast. Included in their analysis is the introduction of the $15/ton carbon price early in the year 2012.

In contrast to the previous studies, Carley (2011) employed the electricity dispatch optimization software AURORAxmp rather than NEMS in her modeling research on state renewable portfolio standards.[15] The advantage of using AURORAxmp, compared to NEMS, is that it is capable of modeling policies at the state level.[16] Carley's research focused on states in the Western Electric Coordinating Council (WECC). In particular, she modeled the effect of RPS policies implemented in Utah and Arizona in isolation, and then contrasted the results with a model where RPS policies are implemented across the entire WECC.

Carley also analyzed the effect of a federal price on carbon dioxide in conjunction with the state-level RPS. Her results indicate that state energy plans have only modest carbon mitigation effects in the long run if neighboring states do not also implement similar renewable portfolio standards. For example, a Utah-only renewable portfolio does not dampen power generated from coal inside the state of Utah. In fact, she finds that Utah generates more electricity from coal under a RPS than it would in the absence of such a policy.[17] In her model, states bordering Utah—which lack a renewable portfolio standard—take advantage of the opportunity to purchase inexpensive electricity generated from coal inside of Utah. She characterizes this phenomena as a "carbon leakage" when inexpensive electricity generated from coal is sold from a state with a RPS to a state without a RPS. According to her research, this problem could be solved through policy coordination where all states inside a region agree to adopt a similar RPS.

There are three critical gaps in the existing literature that motivates our research. First, previous studies have modeled exclusively at the national level using NEMS or exclusively at the regional level using AURORAxmp. To our knowledge, there are no published studies examining how the two models could be integrated together to explore the interaction between federal and state level policy. Also, past research has not had a geographic focus on the interaction of different state RPS policies in the Southeast. Lastly, past studies have not examined natural gas supply, energy efficiency, and climate legislation impacts in conjunction with heterogeneous state RPS policies.

ANALYTICAL APPROACH

We analyze 27 scenarios reflecting possible actions that could be taken by (1) the U.S. Congress, (2) the White House, and (3) the legislatures in Southeastern states to stimulate a more sustainable and clean power generation mix. These scenarios are representations of actions that could be taken by governmental entities from a broad range of possible policy actions. A trichotomy is used to model policy choices that could be made by each of the three political entities. States lying in the Southeastern Electric Reliability Council (SERC) and in the Florida Reliability Coordinating Council (FRCC) are modeled using the AURORAxmp program. One challenge is predicting the actual energy mix each state may choose to deploy in the future. We assume that the RPS passed by North Carolina in 2007 will serve as a precedent that neighboring states can replicate.[18] We also assume that there would be a "propinquity effect" where states neighboring North Carolina will be more likely to adopt a RPS than states distant from North Carolina. Therefore, we explore three different geographic scenarios, as seen in Figure 3: (1) RPS only in the Carolinas, (2) RPS extended to Carolinas' neighbors, and (3) RPS extended throughout entire Southeast region of the US.

This investigation builds upon past research to analyze the interaction of federal and state energy policies in the Southeast.[19] However, our analysis is somewhat unique in that it uses two models to conduct the forecasting and to evaluate the scenarios. We believe this modeling strategy allows us to most efficiently use the model that is most appropriate and best suited to each part of the analysis. Likewise, we feel this modeling strategy will be more effective because we can reduce any underlying assumptions or biases of either model. Past investigations have used just one of these tools to model federal and state energy policies. This investigation models federal energy policies with NEMS and state energy policies with AURORAxmp so that output from the former becomes input into the latter. The NEMS system developed by the U.S. Department of Energy is used in conjunction with the AURORAxmp program created by the EPIS Corporation. The former is the preeminent energy model used primarily to explore scenarios at the national level, while the latter is a prominent energy model used to explore scenarios at a regional level.

Three different governmental entities are modeled in this framework. The policy decision of each entity is assumed to be made independent of the other two. For example, the decision of Congress to pass a carbon tax is not dependent on other Southeastern states adopting an RPS. Likewise, the Southeast states' legislation is not dependent upon the presidential administration.

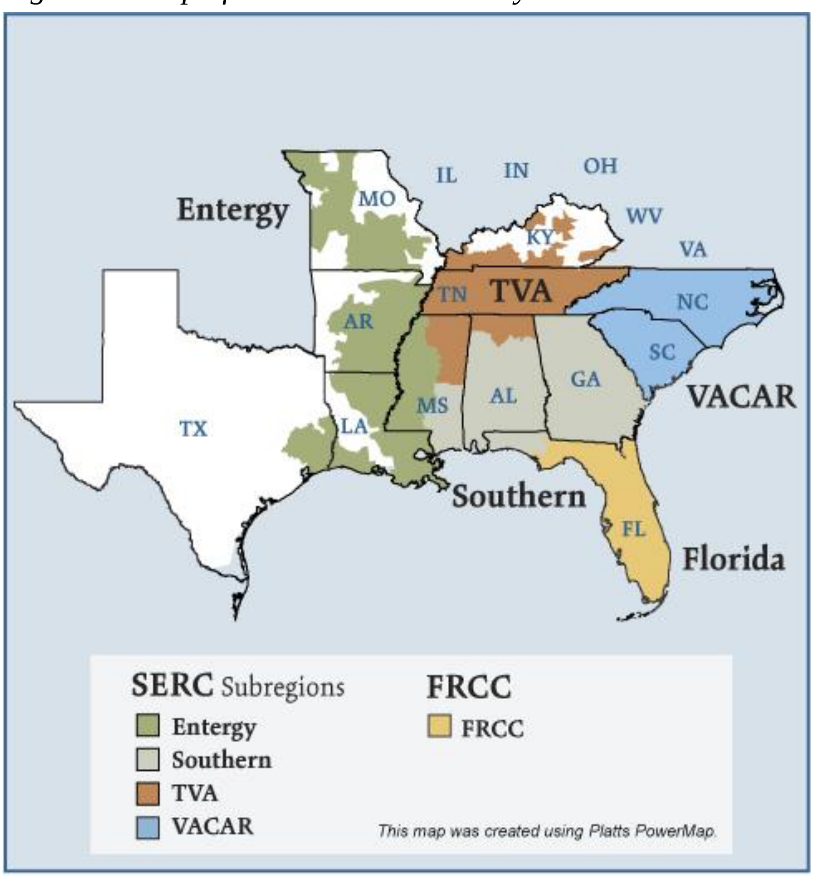
Figure 2 - Overview of our 27 Policy Scenarios

RPS only in the Carolinas		Congressional Decision on Carbon Tax		
		$0/ton	$25/ton	$50/ton
Presidential Administration	Interventionist	**1**	**2**	**3**
	Moderate	**4**		
	Laissez-faire	**7**		

RPS extended to Neighbors		Congressional Decision on Carbon Tax		
		$0/ton	$25/ton	$50/ton
Presidential Administration	Interventionist	**10**	**11**	**12**
	Moderate	**13**		
	Laissez-faire	**16**		

RPS throughout Southeast		Congressional Decision on Carbon Tax		
		$0/ton	$25/ton	$50/ton
Presidential Administration	Interventionist	**19**	**20**	**21**
	Moderate	**22**	**23**	**24**
	Laissez-faire	**25**	**26**	**27**

Figure 3 - Map of the Electric Reliability Councils in the Southeast[20]



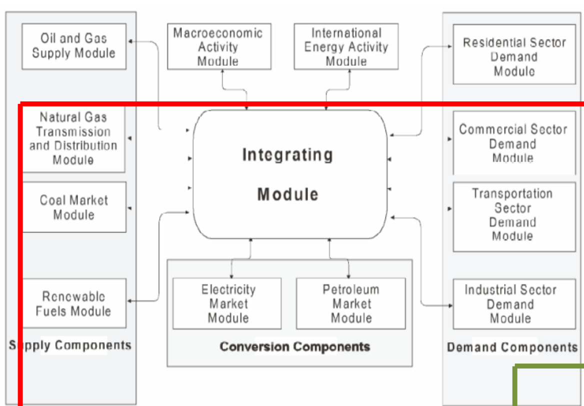
<u>(1) RPS only in the Carolinas</u>
North Carolina
South Carolina

<u>(2) RPS extended to neighbors</u>
North Carolina
South Carolina
Southern Virginia
Tennessee
Georgia
Alabama

<u>(3) RPS throughout Southeast</u>
North Carolina
South Carolina
Southern Virginia
Tennessee
Georgia
Alabama
Florida
Louisiana
Kentucky

Figure 4 - Major Inputs to Models and Major Outputs from Models

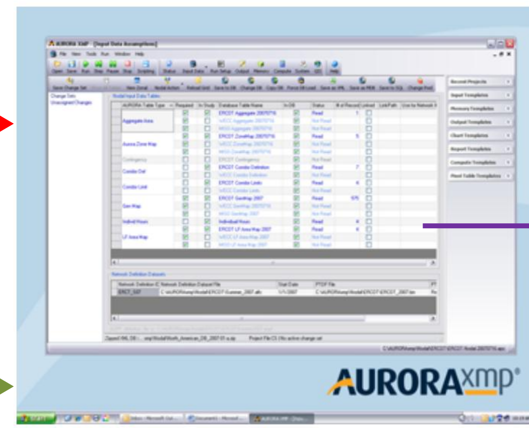
NEMS



Natural Gas Price Forecast

Electricity Demand Growth

AURORAxmp



Construction of New Generation and Electricity Price Forecast

EPA attempts to regulate natural gas fracking, which alters price of natural gas:

1)High natural gas supply due to laissez faire conditions

2)Medium natural gas supply due to moderate regulations

3)Low natural gas supply due to moratorium on fracking

DOE sets standards for energy efficiency, which alters demand growth:

1)Limited standards and no efficiency incentives

2)Moderate efficiency and standards

3)High efficiency and stringent standards

Renewable Energy Portfolio Standards proliferate throughout Southern states:

1)North Carolina is the only state with REPS

2)Surrounding states adopt REPS (VA, GA, & TN)

3)REPS is adopted by all states in the South

U.S. Congress pass climate legislation:

1)No carbon tax $0/metric ton CO2

2)Medium carbon tax $25/metric ton CO2

3)High carbon tax $50/metric ton CO2

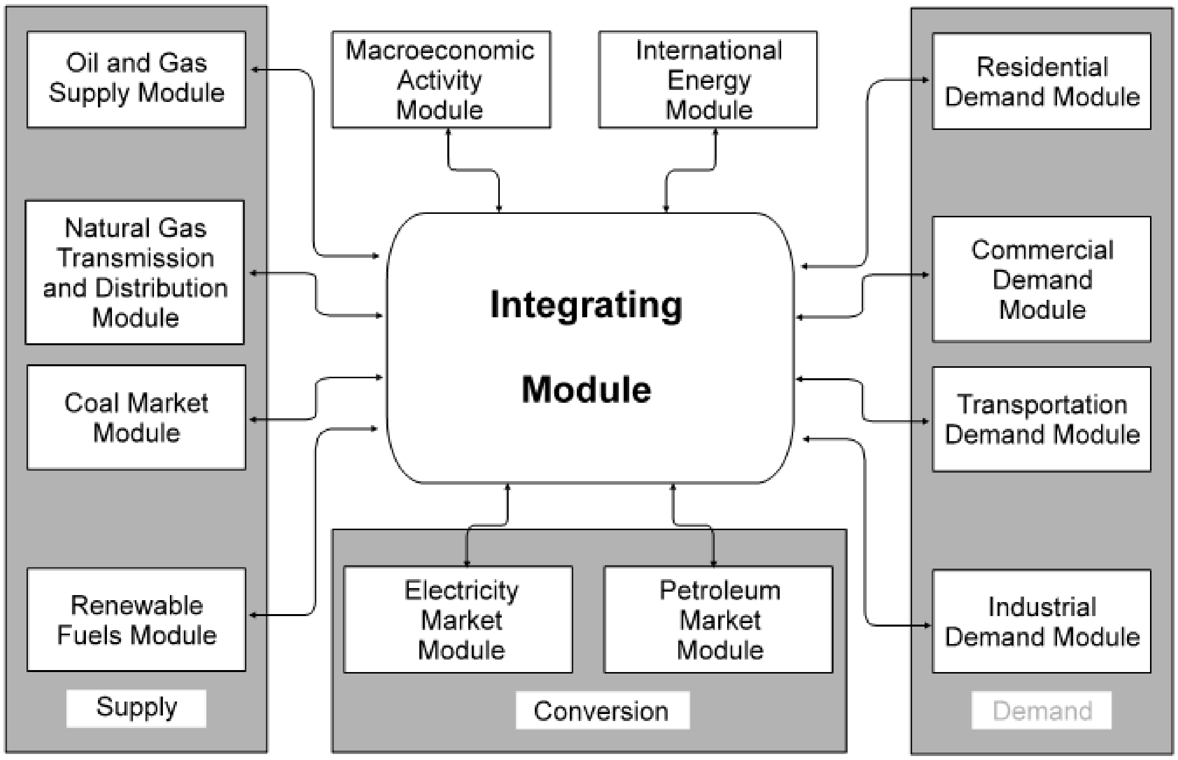
As illustrated, two separate energy modeling programs are used in sequential order to perform this analysis. First, the Nicholas Institute's version of the National Energy Modeling System (NI-NEMS) is used to model the potential energy efficiency policy scenarios and a range of natural gas supply scenarios. NI-NEMS is a customized version of the Department of Energy's NEMS model. The DOE's solver is proprietary, so another solver must be used. Otherwise, there is very little difference between the DOE's NEMS and the Nicholas Institute's NI-NEMS. To construct these scenarios, the NEMS model developed for this inquiry builds upon earlier research completed by Gumerman, Koomey, and Brown (2001) as part of the Interlaboratory Working Group.[21]

Second, AURORAxmp is used to evaluate the impact of the state renewable portfolio standards and the carbon tax scenarios. This approach is sequential because the energy consumption (quad BTUs) and natural gas price (Henry hub 2009$/mmBTU) output values from NI-NEMS are used as input values into AURORAxmp. This investigation only uses a single direction for the flow of information between the two models. Output from NEMS is used as inputs into AURORAxmp as seen in the diagram on the previous page. Unfortunately, it would be too complex to cycle data back and forth between the two models. The end points that we examine in the results include the forecasted electricity prices and greenhouse gas emissions.

NI-NEMS MODELING OVERVIEW

The National Energy Modeling System (NEMS) was designed by the Energy Information Administration.[22] It is a large optimization-based energy economic model of the United States. The model projects energy consumption, production, imports and exports, and prices. Further, it can project energy technology trends, carbon dioxide emissions, and energy market drivers. NEMS is structured to represent energy supply, conversion, and demand in a unified, but modular system. Figure 5 depicts the modules in NEMS. For this analysis, the Macroeconomic Activity module was not used.

Figure 5 – Modules in the National Energy Modeling System (NEMS)[23]



Each module represents distinct aspects of the energy and electricity markets in the US. Relevant modules to this analysis are described briefly below:[24]

- <u>Residential and Commercial Demand Modules</u>: This module tracks changes to buildings and equipment and appliance stock by type and region. New or replacement equipment for each energy service is chosen based on cost, performance characteristics, and economic behavior. Technology characteristics reflect future cost reductions, performance improvements, mandated efficiency standards, and building regulations.

- <u>Industrial Demand Module</u>: The sector is decomposed into nine manufacturing industries, agriculture, construction, and mining. The energy use is estimated by major process steps or end uses based on major technology bundles. Energy intensity for each bundle declines based on time, rate of capacity additions, and energy prices.

- <u>Electricity Market Module</u>: New plant additions are based on expected electricity demand, load profile, fuel prices, technology, and regulations. Dispatch decisions are based on least-cost generation. Fuel use is determined by fuel prices, plant efficiency, electricity demand, and trade opportunities, subject to environmental regulations. Electricity prices are based on average cost of service in regulated regions or marginal cost in competitive regions.

- Oil, Natural Gas, and Coal Supply Module: Oil and natural gas supply technology is characterized by time trend improvements in the drilling, operating, and lease equipment costs per well, which captures improvements such as 3-D seismology and horizontal drilling. The technology improvements offset such factors as higher costs for deeper depths and resource depletion. The oil and gas supply module operates for exploratory and developmental wells in six onshore, three offshore, and three Alaskan regions, including shallow and deep offshore, EOR, and unconventional gas-methane, shales, and tight sands.

A run of the entire NEMS system is known as an "integrated run."[25] These integrated runs are designed to achieve a convergent solution in energy markets on a fuel sector basis by region and year.[26] NEMS is designed to converge on a unique stable solution for all variables in the current solution years. All of the selected modules are solved in sequence and the change in the solution values must match the convergence criteria. The system will iterate until convergence tests are passed or the maximum number of iterations is reached. NEMS performs a cycle when it has passed through all the modules and all the solution years. If it passes the convergence criteria, the model will complete and finalize. If it has not sufficiently converged, it will cycle once again. The number of NEMS runs used in this analysis is set at a maximum of 7 cycles.

The natural gas policy scenarios were developed based on adjustments to the oil, natural gas, and coal supply module. The baseline case provided by the EIA's Annual Energy Outlook 2011 was used as the high supply level, Laissez-faire scenario. Since the publication of the AEO 2011, estimates from the US Geological Survey (USGS) have since reduced the EIA's baseline estimate of natural gas supply levels significantly.[27] The Moderate supply scenario reduced the amount of recoverable natural gas in the Marcellus region by 50%. The low supply Interventionist scenario reduced the amount of natural gas in the Marcellus region by another 50%. See Appendix A for more details on the NEMS modeling.

We chose to target the supply of Marcellus shale for our sensitivity analysis because it represents the natural gas supply region that is under the greatest public scrutiny due to the controversial horizontal extraction techniques that are prevalent in the area.[28] Of all recoverable natural gas resource locations in the US, we feel the Marcellus shale is likely facing the most uncertainty.

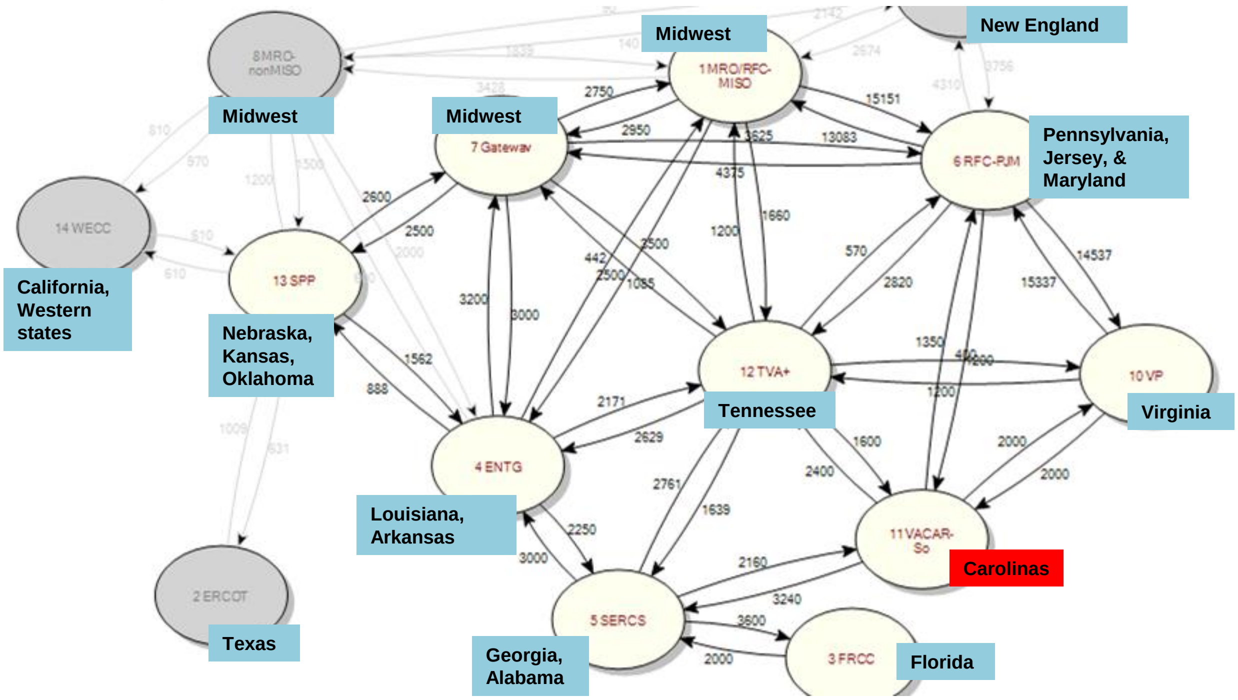
The energy efficiency scenarios were developed based on adjustments to the residential, commercial, and industrial modules. Most of the customization techniques are adopted from Brown et al. (2010). The subsidies and energy efficiency standards are applied by adjusting input files in NEMS. The Laissez-faire scenario is developed to measure a purely free market approach where all subsidies and standards are removed, so that the model will select the least-cost application without restriction. The Moderate scenario includes a number of subsidies and building restrictions, but at a lower level than the Interventionist scenario.

For the residential module, a Laissez-faire scenario is created by removing building codes and withdrawing all subsidies for energy efficient appliances. The Moderate scenario uses the baseline building code assumption from the 2011 EIA Annual Energy Outlook and provides 15% subsidies on energy efficient appliances. The Interventionist scenario adopts stringent building codes while also providing a subsidy for the most energy efficient homes. Additionally, a 30% subsidy is applied to all energy efficient appliances. For the commercial module, the Laissez-faire scenario does not provide a subsidy for energy efficient HVAC units while the other two scenarios provided 15% and 30% subsidies, respectively. For the industrial module, a subsidy for combined heat and power installation is included for the Moderate and Interventionist scenarios, while the Laissez-faire scenario does not include a subsidy. See Appendix A for additional details about the energy efficiency settings in NEMS.

AURORAxmp Modeling Overview

In contrast to NEMS, the AURORAxmp model uses agent-based optimization with a genetic algorithm to find the lowest cost of electricity subject to constraints of supply and demand. Agents represent a specific Regional Transmission Organization (RTO) or Independent System Operator (ISO). Each agent determines the best time to retire old power plants and build new power plants to meet growing demand.[29] In the model, agents generate power for their service territory on an hourly basis and can then trade electricity with each other to make a profit. The nodes represent a geographic conglomerate of investor-owned utilities. VACAR is an abbreviation of “Virginia and Carolinas” corresponding to the service territory of Duke Energy, Progress Energy, and Dominion utility companies. The node “VACAR South” is the agent representing the service territory of just Duke Energy and Progress Energy in North and South Carolina.

Figure 6 – System Diagram of Electric Power Markets for the Southeast in AURORAxmp[30]



Costs of new generation are crucial inputs to the model. Each agent competes with other agents to maximize profits while also meeting base load and peak load for their service territory. New generation capacity is represented as a leased asset, like a rental car, that costs a specific amount of $/megawatt/week. Investors demand a rate of return from funding new generation. In an unconstrained world, agents will invest mainly in inexpensive new generation (e.g. combustion turbines). However, the user can constrain agents from investing in too much conventional generation. A renewable portfolio standard can be modeled by constraining investment in conventional generation by mandating that a certain percentage of renewable generation comes online in a specific year. Figure 7 delineates the default capital and fixed O&M costs per fuel source in the AURORAxmp model. These costs are derived from EIA data on the overnight costs ($/MW) for each type of generation listed on Figure 8.[31]

Figure 7 – Capital and Fixed O&M Annual Requirements for the SERC VACAR South Region[32]

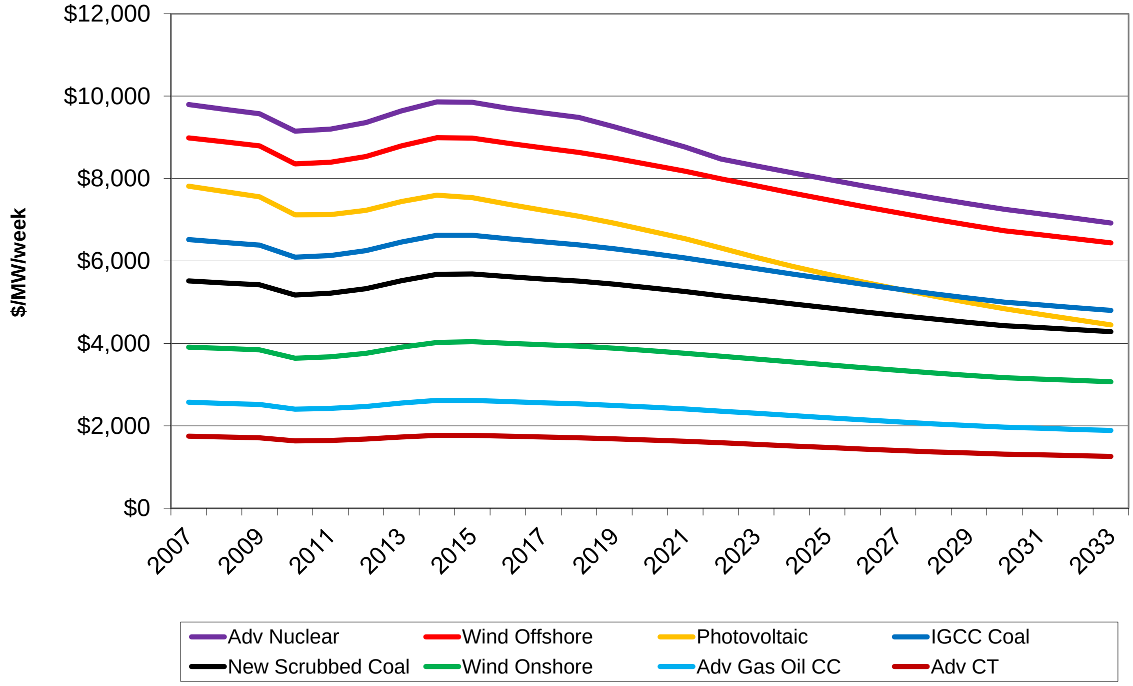


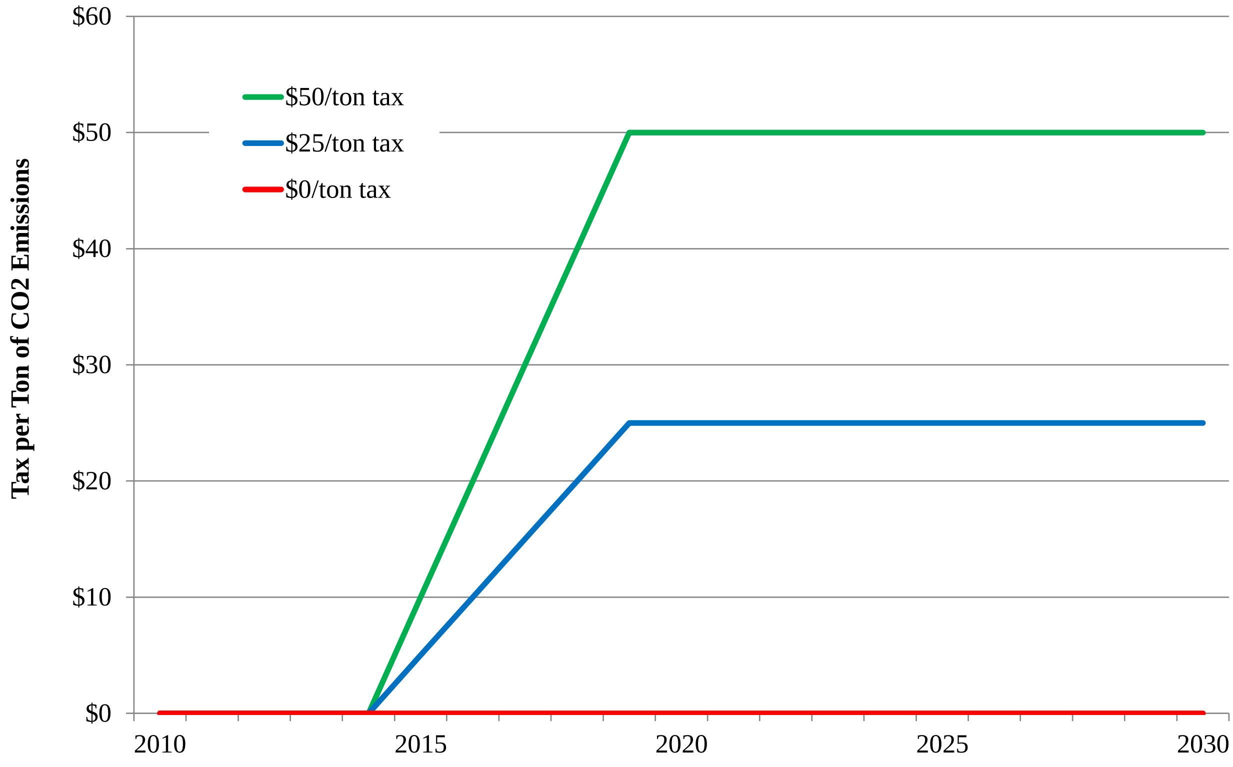
Figure 8 – EIA Installation "Overnight" Costs ($/MW) for each Generation Type[33]

Technology	Online Year[1]	Size (mW)	Leadtime (Years)	Base Overnight Cost in 2008 ($2007/kW)	Contingency Factors: Project Contingency Factor[2]	Contingency Factors: Technological Optimism Factor[3]	Total Overnight Cost in 2008[4] (2007 $/kW)	Variable O&M[5] ($2007 mills/kWh)	Fixed O&M[5] ($2007/kW)	Heatrate[6] in 2008 (Btu/kWhr)	Heatrate nth-of-a-kind (Btu/kWr)
Scrubbed Coal New[7]	2012	600	4	1,923	1.07	1.00	2,058	4.59	27.53	9,200	8,740
Integrated Coal-Gasification Combined Cycle (IGCC)[7]	2012	550	4	2,223	1.07	1.00	2,378	2.92	38.67	8,765	7,450
IGCC with Carbon Sequestration	2016	380	4	3,172	1.07	1.03	3,496	4.44	46.12	10,781	8,307
Conv Gas/Oil Comb Cycle	2011	250	3	917	1.05	1.00	962	2.07	12.48	7,196	6,800
Adv Gas/Oil Comb Cycle (CC)	2011	400	3	877	1.08	1.00	948	2.00	11.70	6,752	6,333
ADV CC with Carbon Sequestration	2016	400	3	1,683	1.08	1.04	1,890	2.94	19.90	8,613	7,493
Conv Combustion Turbine[8]	2010	160	2	638	1.05	1.00	670	3.57	12.11	10,810	10,450
Adv Combustion Turbine	2010	230	2	604	1.05	1.00	634	3.17	10.53	9,289	8,550
Fuel Cells	2011	10	3	4,640	1.05	1.10	5,360	47.92	5.65	7,930	6,960
Advanced Nuclear	2016	1350	6	2,873	1.10	1.05	3,318	0.49	90.02	10,434	10,434
Distributed Generation -Base	2011	2	3	1,305	1.05	1.00	1,370	7.12	16.03	9,050	8,900
Distributed Generation -Peak	2010	1	2	1,566	1.05	1.00	1,645	7.12	16.03	10,069	9,880
Biomass	2012	80	4	3,339	1.07	1.05	3,766	6.71	64.45	9,646	7,765
MSW - Landfill Gas	2010	30	3	2,377	1.07	1.00	2,543	0.01	114.25	13,648	13,648
Geothermal[7,9]	2010	50	4	1,630	1.05	1.00	1,711	0.00	164.64	34,633	30,301
Conventional Hydropower[9]	2012	500	4	2,038	1.10	1.00	2,242	2.43	13.63	9,919	9,919
Wind	2009	50	3	1,797	1.07	1.00	1,923	0.00	30.30	9,919	9,919
Wind Offshore	2012	100	4	3,416	1.10	1.03	3,851	0.00	89.48	9,919	9,919
Solar Thermal[7]	2012	100	3	4,693	1.07	1.00	5,021	0.00	56.78	9,919	9,919
Photovoltaic[7]	2011	5	2	5,750	1.05	1.00	6,038	0.00	11.68	9,919	9,919

There are many other important inputs to the model besides the costs of new generation. AURORAxmp has a default hourly load profile for each agent derived from Federal Energy Regulatory Commission (FERC) Form 714 data on historic load-shapes.[34] The model also has default annual demand escalation for each RTO agent derived from proprietary forecasts from the EPIS Corporation. However, the default annual demand escalation is a simple “back of the envelope” calculation. For example, electricity in the Carolinas is assumed to grow at a constant rate of 1.71% from 2012 to 2050. Instead of using these defaults, output from NEMS is used to adjust the annual demand escalation in AURORAxmp. The annual demand escalation for each agent is adjusted to create more realistic growth rates that could be expected under the three different presidential administrations. Appendix C contains further details on the methodology.

It is not possible to explicitly model cap-and-trade in AURORAxmp, but it is possible to implicitly model the effect of emission trading through the simulation of a federal carbon tax, which will lead to somewhat similar economic results. It is straightforward to add a tax on carbon dioxide to the AURORAxmp model. The year of 2015 was chosen as the starting year for the tax because it is distant from the present, but not too far out in the future. Also, 2015 is not an election year, so passing cap-and-trade legislation might be politically feasible. The tax is set to start at a low level and increase over time to reflect the gradual implementation of federal carbon mitigation. By default, the AURORAxmp model already has a carbon tax for states participating in the Regional Greenhouse Gas Initiative (RGGI). Currently, RGGI only pertains to New York, Massachusetts, Connecticut, and other states in the Northeast.[35] It is unlikely that North Carolina or any Southeastern states would join such an initiative in the foreseeable future. Also, AURORAxmp already includes assumptions to represent current air quality regulations for sulfur dioxide and nitrogen oxide emissions.

Figure 9 – Input of Congressional Carbon Tax Scenarios into AURORAxmp



It is more of a challenge to add a renewable energy portfolio standard (RPS) to the AURORAxmp model. A simple yet plausible portfolio has been created for this investigation. This hypothetical portfolio requires 5% of all electricity to be generated by renewables in 2015. The requirement increases to 10% by 2020 and then to 20% by 2025. According to the design, onshore wind makes up 80% of renewables, biomass makes up 15% of renewables, and solar makes up only 5% of all renewables. The AURORAxmp software includes hourly wind generation profiles by region. EPIS developed these hourly wind generation profiles based on historic wind speed data and power curves on wind turbines. The East Coast wind profile produces an annual capacity factor of 25%. The generic solar generation profile used in the model produces an annual capacity factor of 15%. Biomass is an amorphous category that includes wood products, landfill gas, swine waste, etc. For this investigation, power generated from biomass is set to have an 80% capacity factor.

Figure 10 – Hypothetical Renewable Portfolio Standard that is modeled using AURORAxmp

RPS Requirements	2015	2020	2025
Onshore Wind Resources	4.00%	8.00%	16.00%
Solar Resources	0.25%	0.50%	1.00%
Biomass Resources	0.75%	1.50%	3.00%
Total Required Renewables	5.00%	10.00%	20.00%

There is an important caveat about modeling a renewable portfolio standard in AURORAxmp that affects that forecast of electric market prices. According to the architects of the software, the predicted electricity prices only reflect the market transactions chosen by the RTO agents:

> AURORAxmp assumes that new generators will be built (and existing generators retired) based on economics. The economic measure used is real levelized net present value (revenues less cost) on a $/MW basis. Investment cost is included in the cost portion of the formula. Also, the methodology assumes that potentially non-economic contracts will not influence the marketplace and that someone will capture the opportunity value of non-economic contracts. Therefore contracts are not modeled in the pricing component of AURORAxmp.[36]

The non-economic contracts refer to renewable energy investments that are forced online to satisfy the hypothetical RPS requirements. The "someone" who will capture the opportunity value of non-economic contracts refers to ratepayers that will pay a renewable energy rate rider to subsidize non-economic investments of wind, solar, and biomass facilities. Thus, AURORA's electricity price forecast only represents the "non-RPS" portion of power generation.

Carley (2011) elucidates that when one forces a resource online in a specific year (e.g. 1000 megawatts of wind capacity in 2015), then the "overnight" capital installation costs of the wind farm are not included in AURORA's simulation of the electricity price.[37] Carley solves this problem by calculating an additional cost to represent renewable resources forced online using a formula for the capital cost of recovery. Then, she adds this exogenous cost to the price outputted by the model to compute the final wholesale price of electricity for each RTO agent. The vulnerability with this approach is that it may be summing together two very different numbers to compute the final wholesale price of electricity. To resolve this problem, this investigation will examine the electricity price output from AURORA, but focus on the electricity price differentials among the 27 scenarios in the VACAR region.

ANALYSIS OF RESULTS

To review, the NEMS model is run three times to produce outputs that are used as inputs to generate the 27 scenarios in AURORAxmp. The three runs represent an (1) Interventionist, a (2) Moderate, and (3) a Laissez-faire presidential administration. The Interventionist presidential administration represents a high natural gas price (due to hydraulic fracturing regulations) coupled with high energy efficiency standards. The Laissez-faire presidential administration represents a low natural gas price (due to few regulations) coupled with no new energy efficiency standards. The Moderate presidential administration is an in-between case that represents a medium natural gas price coupled with a medium level of energy efficiency.

As expected, the Interventionist run depicts a reduction in energy consumption and an increasing natural gas price. The Moderate run remains between the other two extremes. Both the Moderate and the Interventionist runs return similar national electricity prices in Figure 11 because the reduction of natural gas supply likely has a significant impact on electricity prices, amongst other factors. Moreover, we find that reducing the baseline natural gas supply by 50% (Laissez-faire to Moderate) likely has a greater relative impact than reducing the supply by another 50% (Moderate to Interventionist). The Laissez-faire scenario has a significantly lower national electricity prices than the other two runs. Figure 12 displays a reduction in energy consumption under the Interventionist run. The Laissez-faire run has the highest consumption, 112 quad BTUs in 2030. In Figure 13, there is a stark contrast between the Interventionist and the Laissez-faire natural gas prices, though the Moderate scenario once again more closely mirrors the Interventionist scenario.

Figure 11 – NEMS Avg. National Electric Prices under Different Presidential Administrations

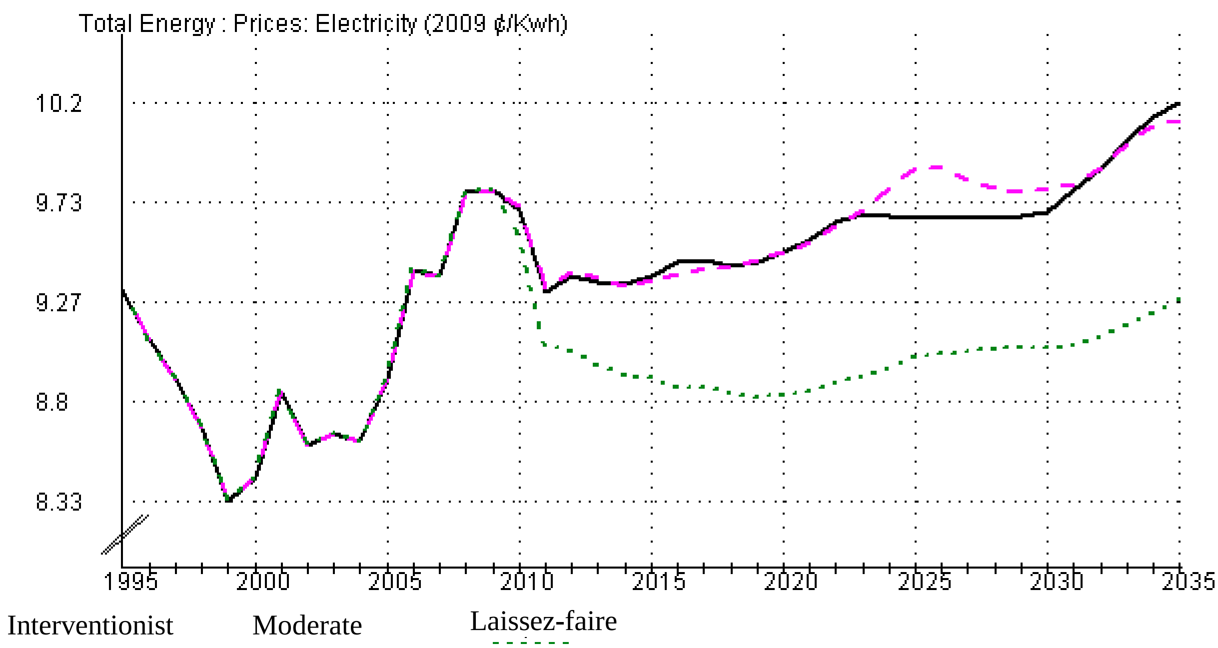


Figure 12 - NEMS Output of Total U.S. Energy Use under Different Presidential Administrations

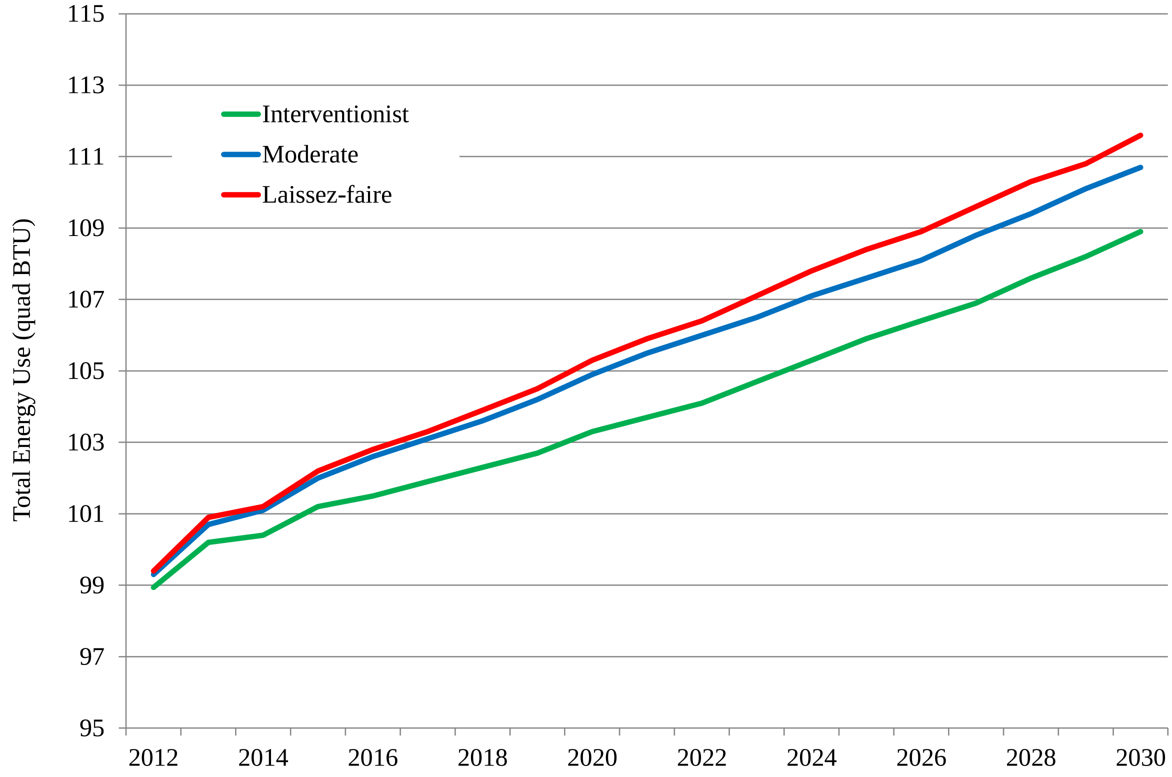


Figure 13 - NEMS Natural Gas Price Forecast under Different Presidential Administrations

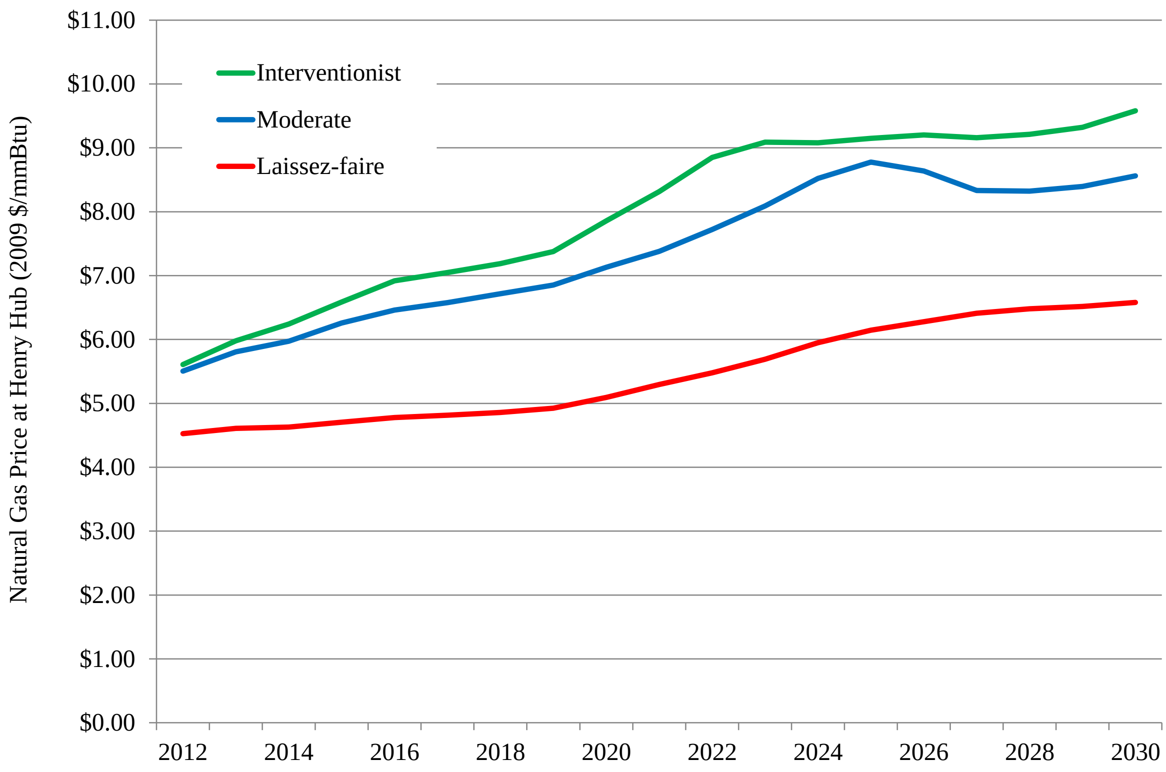


Figure 15 displays the average wholesale price of electricity inside the "Virginia and Carolinas" region in the year 2025 under all 27 scenarios. Thus, each cell in Figure 15 corresponds to a cell in Figure 14. The results demonstrate a complex interplay between the energy policies that could be implemented by Congress, the White House, and the legislatures in Southeastern states in the near future. The horizontal labels correspond to whether or not RPS policies are adopted by the Southeastern states. The vertical labels correspond to the regulatory actions of future presidential administrations. Under each administration is the list of possible carbon taxes that can be implemented by the U.S. Congress. The most important function of the table is to illustrate the relative price differentials over the continuum of policy choices holding everything else constant.

Figure 14 – Review of the 27 Policy Scenarios

RPS only in the Carolinas		Congressional Decision on Carbon Tax		
		$0/ton	$25/ton	$50/ton
Presidential Administration	Interventionist	**1**	**2**	**3**
	Moderate	**4**		
	Laissez-faire	**7**		

RPS extended to Neighbors		Congressional Decision on Carbon Tax		
		$0/ton	$25/ton	$50/ton
Presidential Administration	Interventionist	**10**	**11**	**12**
	Moderate	**13**		
	Laissez-faire	**16**		

RPS throughout Southeast		Congressional Decision on Carbon Tax		
		$0/ton	$25/ton	$50/ton
Presidential Administration	Interventionist	**19**	**20**	**21**
	Moderate	**22**	**23**	**24**
	Laissez-faire	**25**	**26**	**27**

Figure 15 – AURORA's Wholesale Price ($/MWh) of Electricity in VACAR Region in 2025

	Renewable Portfolio Standard in the Southeast		
	Only in Carolinas	**Neighbors Also**	**All Southeast**
Laissez-Faire Pres. Admin.			
$0/ton CO2 tax	$71.89	$69.92	$68.82
$25/ton CO2 tax	$99.02	$97.89	$97.65
$50/ton CO2 tax	$132.46	$130.22	$129.25
Moderate Pres. Admin.			
$0/ton CO2 tax	$83.12	$78.06	$76.76
$25/ton CO2 tax	$112.73	$108.60	$107.64
$50/ton CO2 tax	$142.33	$141.51	$140.84
Interventionist Pres. Admin.			
$0/ton CO2 tax	$80.47	$75.73	$74.59
$25/ton CO2 tax	$111.94	$108.29	$107.36
$50/ton CO2 tax	$143.59	$141.81	$141.23

It is critical to acknowledge that the AURORAxmp model can only predict the wholesale price of electricity traded by utilities inside a geographic region rather than the actual price of electricity paid by residential customers. The North Carolina Utilities Commission regulates the price that utilities charge customers for electricity. For comparison, the current average retail electric rate in the state is $0.0843/kWh ($84.30/MWh).[38] However, an upward or downward shift in the wholesale price would exert pressure on the North Carolina Utilities Commission to revise the residential rates accordingly. In this sense, the future wholesale price can be considered a proxy for the future residential price of electricity.

The most striking feature of the table is the significant change in electricity prices resulting from a carbon tax. Passing a $25/ton carbon tax in 2015 would lead to roughly a $30/MWh increase in the wholesale electric price in 2025 according to the model. Moreover, passing a $50/ton carbon tax in 2015 would lead to roughly a $60/MWh increase. These results help elucidate why a carbon tax (and cap-and-trade) is so controversial.

Expanding an RPS to North Carolina's neighbors and then to all states in the Southeast will lead to a slightly lower wholesale electricity price inside the "Virginia and Carolinas" region. This result illustrates that it is actually in the interest of North Carolina ratepayers to expand the renewable portfolio standard to neighboring states. In theory, ratepayers in neighboring states would then pay a renewable energy rate rider to subsidize investments of wind, solar, and biomass facilities inside their states. Some of this subsidized renewable energy will likely be traded between regions, which would reduce the wholesale price of electricity inside VACAR. However, the wholesale electric price decrease due to a RPS expansion is modest.

Perhaps, the most intriguing results are the changes in wholesale electricity prices due to different political prerogatives. One might assume that the Laissez-Faire policies would produce the lowest electric prices, the Interventionist policies would produce the highest electric prices, and the Moderate policies would produce electric prices somewhere in-between. Contrary to expectations, the model indicates that a presidential administration characterized by Interventionist policies produces a lower wholesale electric price than one characterized by Moderate policies in all cases except under a $50/ton carbon tax. This is likely due to the fact that under the Interventionist scenario, the relative impact of reduced natural gas supply is smaller than the Moderate case, and it is coupled with aggressive energy efficiency regulations.

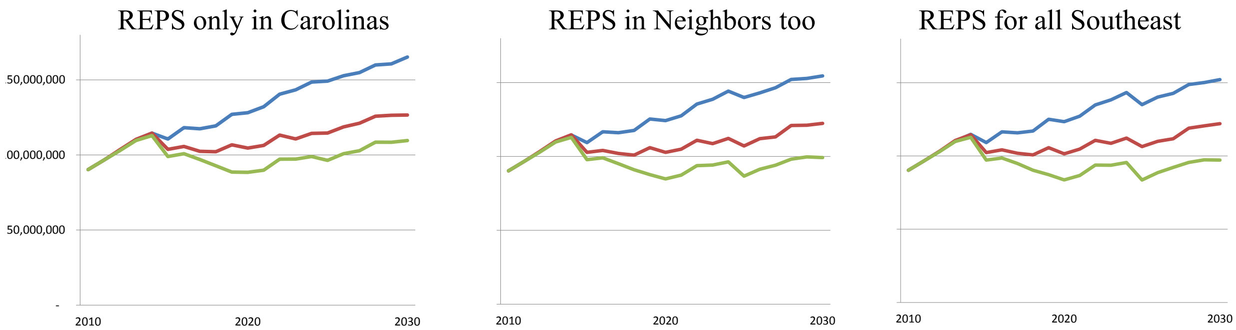
Figure 16 – Tons of CO2 Emissions in VACAR from Electricity Generation in 2025

	Renewable Portfolio Standard in the Southeast		
	Only in Carolinas	**Neighbors Also**	**All Southeast**
Laissez-Faire Pres. Admin.			
$0/ton CO2 tax	149,142,000	139,859,200	134,972,300
$25/ton CO2 tax	114,558,300	107,061,300	106,404,600
$50/ton CO2 tax	96,379,100	86,675,880	83,579,260
Moderate Pres. Admin.			
$0/ton CO2 tax	168,993,700	152,443,500	143,711,900
$25/ton CO2 tax	138,632,000	125,391,500	120,798,900
$50/ton CO2 tax	114,240,000	107,242,000	105,075,500
Interventionist Pres. Admin.			
$0/ton CO2 tax	147,640,000	136,130,400	128,813,000
$25/ton CO2 tax	135,543,100	115,643,300	111,366,400
$50/ton CO2 tax	107,514,100	99,193,530	97,243,760

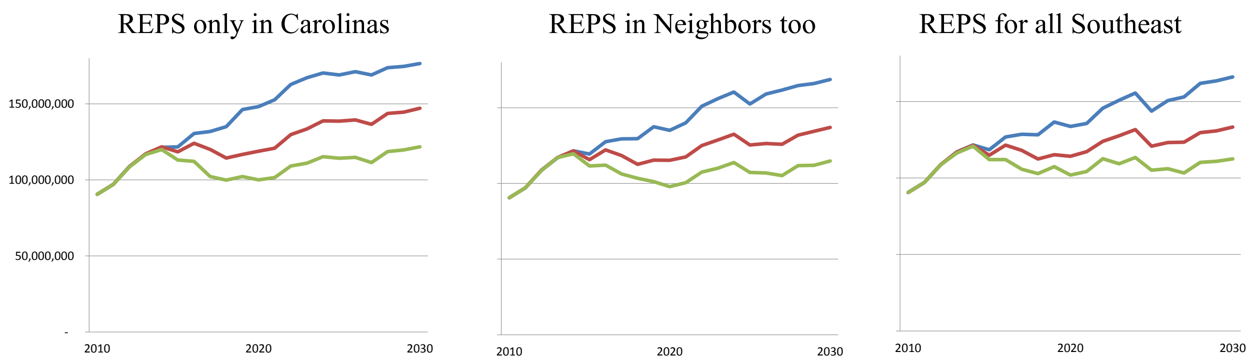
When excluding the effect of a carbon tax, the AURORAxmp output shows a decline in CO2 emissions between the Laissez-Faire policies and the Interventionist policies. Six million fewer tons of CO2 are emitted in the VACAR region as a result of more stringent regulatory policies in the scenario where the Renewable Portfolio Standard is extended to all states in the Southeast. This supports the conjecture that greater regulation focused on promoting cleaner power generation will result in lower emissions.

Figure 17 – Output of Tons of CO2 Emissions in VACAR from Power Generation

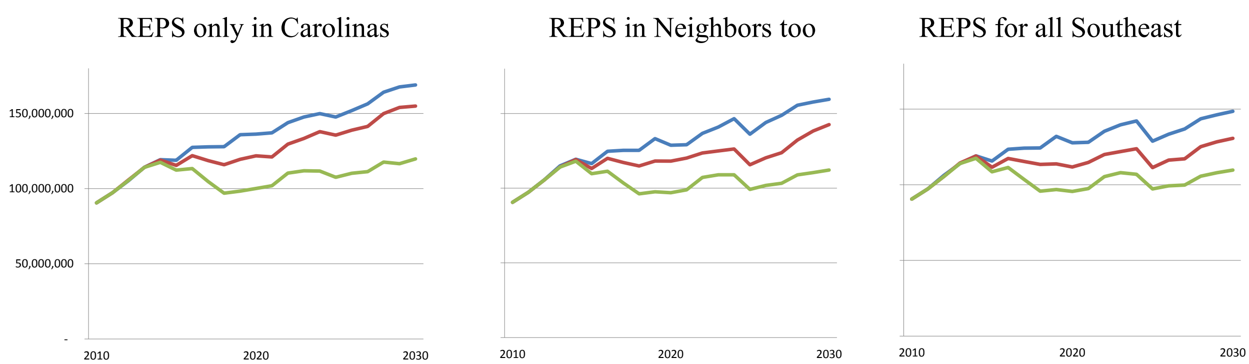
Laissez-Faire Presidential Administration



Moderate Presidential Administration



Interventionist Presidential Administration



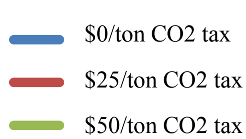


Figure 18 – Total Tons of NOx Emissions in VACAR from Power Generation in 2025

	Renewable Portfolio Standard in the Southeast		
	Only in Carolinas	**Neighbors Also**	**All Southeast**
Laissez-Faire Pres. Admin.			
\$0/ton CO2 tax	119,714	111,992	106,076
\$25/ton CO2 tax	71,171	65,947	65,254
\$50/ton CO2 tax	49,307	44,189	41,766
Moderate Pres. Admin.			
\$0/ton CO2 tax	133,761	118,553	112,620
\$25/ton CO2 tax	108,942	95,994	91,794
\$50/ton CO2 tax	71,049	69,381	68,095
Interventionist Pres. Admin.			
\$0/ton CO2 tax	122,793	107,861	103,939
\$25/ton CO2 tax	103,992	89,503	84,981
\$50/ton CO2 tax	72,855	65,880	64,428

Figure 19 – Total Tons of SO2 Emissions in VACAR from Power Generation in 2025

	Renewable Portfolio Standard in the Southeast		
	Only in Carolinas	**Neighbors Also**	**All Southeast**
Laissez-Faire Pres. Admin.			
\$0/ton CO2 tax	436,687	398,265	371,416
\$25/ton CO2 tax	159,862	141,985	140,490
\$50/ton CO2 tax	74,110	64,816	58,649
Moderate Pres. Admin.			
\$0/ton CO2 tax	487,002	418,559	390,390
\$25/ton CO2 tax	384,279	313,709	290,172
\$50/ton CO2 tax	168,285	166,248	164,989
Interventionist Pres. Admin.			
\$0/ton CO2 tax	445,096	367,992	352,233
\$25/ton CO2 tax	356,307	280,455	255,839
\$50/ton CO2 tax	179,903	154,212	145,547

It is apparent that the inclusion of the carbon tax leads to a substantial reduction in carbon dioxide emissions in the VACAR region across the board. Somewhat surprisingly, the largest reduction is in the Laissez-Faire scenario. We believe that the abundant supply of natural gas likely creates a much easier transition from coal to natural gas. The other two scenarios are more likely constrained by the lower levels of natural gas and corresponding higher energy prices. It is necessary to examine the respective generation profiles to understand the effects of these policies.

The generation profiles confirm some of our initial observations, while also producing other interesting results. The relative supply of natural gas appears to significantly impact natural gas and coal generation. The amount of renewable generation is not affected by the variables of each scenario, as renewables meet but never exceed the required level of annual generation. In 2035, combined wind and solar generation is equal to 5,677,072 megawatt hours across all scenarios. Interestingly, the imposition of renewable standards across the Southeast consistently reduces fossil fuel generation across all scenarios. Since our analysis does not include forthcoming EPA regulations on power plant generation (CSAPR or MACT) or a carbon risk factor on fossil fuel generation, this likely leads our model to overvalue coal generation and associated fossil fuel investments.

The results of natural gas generation correspond with the availability of natural gas and the cost of carbon emissions. The Laissez-faire scenario has the largest amount of recoverable shale gas supply, while the Moderate and Interventionist scenarios impose greater regulations on shale gas recovery that result in lower supply. Figure 20a below illustrates the results of natural gas generation (including both single combustion turbines and combined cycle turbines) without a carbon tax, while Figure 20b shows the results of including a $50 per ton carbon tax. Under Figure 20a, natural gas generation fluctuates between 4,200 and 7,600 thousand megawatt hours. The expanded RPS scenario (“SoutheastAll”) reduces generation levels relative to the Carolinas only scenario. The disparity between the scenarios increases with the imposition of a $50 per ton carbon tax. Figure 20b shows natural gas generation under Laissez-faire policies approaching 23,500 thousand megawatt hours. The high cost of carbon emissions and abundant supply of natural gas stimulates significant generation in natural gas.

Figure 20a – natural gas generation, no carbon tax

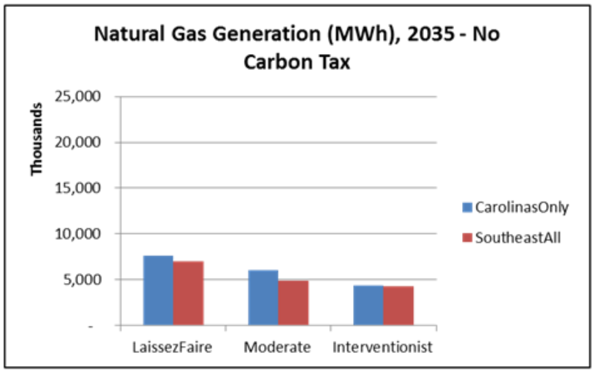
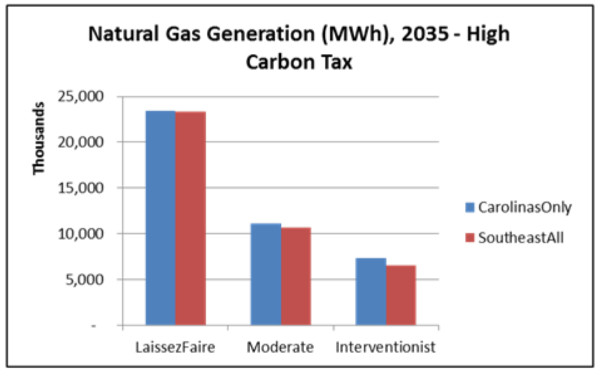


Figure 20b – natural gas generation, $50/ton carbon tax



Compared to natural generation results, coal generation is inversely affected by the varying levels of natural gas supply and carbon emissions policies. The expanded renewable portfolio standards continue to reduce fossil fuel generation overall, relative to the Carolinas only policy. Surprisingly, the more stringent regulatory scenarios, Moderate and Interventionist, result in higher levels of coal generation. As mentioned above, this is likely the result of the policies we chose to analyze. Since neither forthcoming power plant emissions regulations or financial risk factors of coal investments are included, the model likely responds to low gas supply and high prices by utilizing more coal production.

Figure 21a below illustrates the results of coal generation without a carbon tax, while Figure 21b summarizes the results of including a $50 per ton tax on carbon. Figure 21a shows the impact of an expanded renewable standard, which results in similar production levels for both the Interventionist and Laissez-faire scenarios (138,000 thousand megawatt hours to 134,000 thousand megawatt hours). Figure 21b shows the impact of a $50 per ton carbon tax, as coal generation significantly decreases by 35% or greater across all scenarios. While the results of our model disproportionately favor coal generation, the impact of natural gas supply levels and renewable standards is evident.

Figure 21a – coal generation, no carbon tax

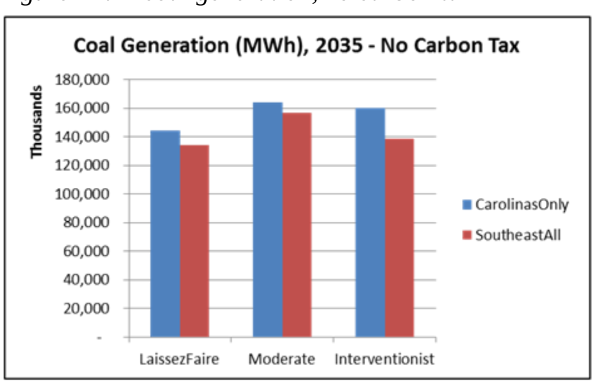
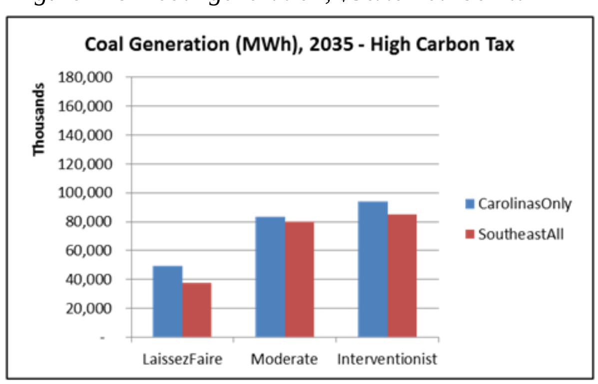


Figure 21b – coal generation, $50/ton carbon tax



Overall, the results show the powerful effect on emissions of an all-Southeast RPS with an interventionist approach. If a carbon tax never materializes, this approach leads to the lowest emissions levels. The 128 million tons under this scenario are lower than the 135 million tons that are emitted when a medium carbon tax occurs and the RPS does not extend beyond Carolinas' border. These two values are highlighted in yellow in Figure 16 above. This result demonstrates the utility of promulgating an all-Southeast RPS when the prospect of a carbon tax is increasingly uncertain. While the political ideologies (Laissez-faire, Moderate, and Interventionist) included in the model show somewhat surprising impacts on fossil fuel generation, the expanded RPS policy significantly reduces coal generation compared to the Carolinas only scenario in all cases, even without a carbon tax.

This outcome coincides with past research demonstrating that state energy plans have only modest carbon mitigation effects in the long run if neighboring states do not also implement similar renewable portfolio standards.[39] The decarbonization potential is much greater when neighboring states also adopt a RPS to prevent a "carbon leakage" where inexpensive electricity generated from coal is sold from a state with an RPS to a state without a RPS. This is also observed when assessing the generation profile under each scenario, as there is a consistent reduction in fossil fuel generation when renewable standards encompass more states. Finally, although the Interventionist scenario results in somewhat higher electricity prices, there is clearly a positive relationship with more stringent policies and reduced emissions levels.

CONCLUSION

The results of this inquiry illustrate potential benefits of greater adoption of renewable portfolio standards in the Southeast amidst uncertainty in energy and climate policy. We acknowledge that this is a modeling exercise that requires numerous assumptions. In particular, we did not look at technology costs, other federal regulations, or other demand projections. The implications of these limits are that they introduce a bias in our results. The EPA, for example, is currently formulating CSAPR and MACT air toxics rules, regulations that will significantly impact the electric power industry. Our modeling endeavor does not incorporate these regulations into our scenarios.

Our approach used two models to evaluate national and regional policies. To our knowledge, NEMS and AURORAxmp have never been combined to conduct an energy modeling assessment. We believe this approach offers greater flexibility to evaluate policies and uncertainties. We hope future work can build from our endeavor to produce more precise impact studies and policy evaluations. However, the use of two models limits the interaction between the scenarios and uncertainties. A carbon tax modeled in AURORAxmp is unable to influence the natural gas supply price that is modeled in NI-NEMS. The two models were chosen to narrow outputs and focus results on the Southeast and particularly North Carolina. It is acknowledged that certain interaction effects are limited by the desire to achieve more precise state-level results. Additionally, AURORAxmp is designed to represent NERC regions and sub-regions, and it is not designed with state boundaries in mind. While customization makes state-by-state analysis feasible, it is by no means an exact science.

The policies chosen for this modeling inquiry represent one of countless possibilities that could occur over the modeling time period. As the last 20 years in the electric industry have shown, it is difficult to predict what exactly will influence the future. Nonetheless, the results depicted in this analysis should lead to further discussion of renewable generation and the value of state renewable portfolio standards in the Southeast.

POLICY RECOMMENDATION

Renewable portfolio standards have been a driver for renewable energy adoption. Rader and Norgaard (1996) believe that "market imperfections will hinder the commercial advance of renewables in competitive markets" and that a renewable portfolio standard is the "most efficient means of correcting market imperfections and for moving toward sustainability."[40]

RPS policies have expanded to states across the United States. However, there are two regions where these policies are noticeably lacking. The Great Plains is one region where many states have opted to capture the benefits of local wind resources by encouraging state transmission authorities to export renewable power.[41] The Southeast is the other region, but it is without a similar viable alternative to an RPS.

North Carolina's REPS overcame significant barriers to create a renewable energy industry in North Carolina. The REPS can serve as a template for other Southeastern states that have similar renewable resources and political obstacles. This paper's results indicate that pursuing a strategy to expand renewable standards in the South will even create benefits for North Carolina through lower carbon emissions and reduced electricity rates.

This paper analyzes some of the uncertainties in energy policy that the US and its southern region will encounter over the next 20 years. Political ideologies will affect the direction and magnitude of certain energy and environmental policies. While the U.S. Congress might act on measures to reduce carbon emissions, renewable standards can be used to eliminate some of the uncertainty and set renewable goals for states to achieve. The upshot of our research is that North Carolina's REPS could be more powerful if other states in the Southeast develop a renewable portfolio standard of their own. Thus, we recommend that the North Carolina Sustainable Energy Association (NCSEA) increase its outreach to the neighboring states of South Carolina, Georgia, and Tennessee to advocate for a similar standard.

APPENDIX A: CUSTOMIZATION OF NEMS MODEL FOR NATURAL GAS POLICY SCENARIOS

Three natural gas supply scenarios were modeled in NEMS to capture uncertainty about unconventional shale natural gas supplies and potential regulations restricting shale gas drilling. The scenarios are based on EIA's Low Shale (EUR) side case.[i] These scenarios are described below:

- Laissez-faire: default natural gas supply assumptions from the EIA's Reference case for the AEO 2011.[42] This results in a low natural gas price.
- Moderate: the recoverable Marcellus shale gas resource adjusted to 50% lower than the Reference case resulting in a lower gas supply than EIA's Reference case.[43] This results in a high natural gas price.
- Interventionist: the recoverable Marcellus shale gas resource is reduced an additional 50%, resulting in a significantly lower natural gas supply relative to the Baseline scenario. This results in an extra high natural gas price.

[i] Parameters customized in NI-NEMS: (1) *OGTECHADJ = 0,50, or 75 (2) OGTECH = 18*

APPENDIX B: CUSTOMIZATION OF NEMS MODEL FOR ENERGY EFFICIENCY SCENARIOS

Below are potential policies to incentivize energy efficiency across various sectors. Most of the data is adapted from the research of Brown et al. (2010) on energy efficiency in the South.[44] Policies across the residential, commercial, and industrial sectors are evaluated.

Residential

Building codes:[ii]

- Expiration dates of building codes are altered (in order from least to most stringent): International Energy Conservation Code (IECC 2000), Energy Star, Forty percent efficiency, and PATH
    - Laissez-faire: No building codes
        - No IECC from 2011 to 2050, all other efficiency codes end 2012
    - Moderate: Modest level of building code implementation
        - Default settings
    - Interventionist: More strict implementation of building codes
        - No IECC end 2012, IECC 2000 end 2012, Energy Star end 2016, FORTY and PATH through 2050, 30% installation subsidy for more efficiency homes (FORTY and PATH)

Appliance standards:[iii]

- Subsidies for energy efficient equipment and appliances are established for the most efficient options of the following appliances: electric heat pumps, natural gas furnaces, natural gas radiators, kerosene furnaces, LPG furnaces, distillate furnaces, distillate radiators, geothermal heat pumps, room AC, central AC, natural gas water heaters, electric water heaters, distillate water heaters, and LPG water heaters.
    - Laissez-faire: No subsidies
        - Default settings
    - Moderate: 15% incentives on most efficient equipment and appliances
        - Reduce EE equip by 15%
    - Interventionist: 30% incentives on most efficient equipment and appliances
        - Reduce EE equip by 30%

[ii] NI-NEMS customized input file: *rtektyc.txt*
[iii] NI-NEMS customized input file: *rtekty.txt*

Commercial
HVAC incentives: *(ktek.xml)*

- Subsidies for energy efficient technologies are established for the newest and most efficient HVAC units. These are the following: gas furnaces (7,8,9), gas boilers (6,7,8), reciprocating chillers (5-8), centrifugal chillers (7,8,9), rooftop AC (6,7,8), wall-window room AC (5-9), residential central AC (8-11), CAV ventilators, and VAV ventilators.
  - Laissez-faire: No subsidies
    - Default settings
  - Moderate: 15% incentives on most efficient technology
    - Reduce by 15% (ventilation systems by 4.5%)
  - Interventionist: 30% incentives on most efficient technology
    - Reduce by 30% (ventilation systems by 9%)

Industrial
Combined Heat and Power (CHP) tax credit:[iv]

- A subsidy for CHP installation is evaluated. A Combined Heat and Power system in an industrial facility would use the excess heat from combustion for air flow, heating, and power. This policy would strongly affect industrial energy consumption.
  - Laissez-faire: No tax credit
    - Default settings
  - Moderate: 10% incentives on CHP install
    - Reduce capital cost by 10%
  - Interventionist: 20% incentives on CHP install
    - Reduce capital cost by 20%

[iv] NI-NEMS customized input file: *indcogen.xml*

APPENDIX C: DEMAND ESCALATION AND INCREMENTAL WIND CAPACITY

Demand Escalation for Florida								
ID	Use	2010	2011	2012	2013	2014	2015	2016
DmdEsc_FRCC	Demand Esc Area2	1.35	2.69	2.69	2.69	2.69	2.69	2.69
Interventionist		1.36	-0.61	2.48	2.43	1.35	2.41	1.36
Moderate		1.35	2.69	2.69	2.69	2.69	2.69	2.69
Laissez-faire		1.31	6.12	2.55	2.88	2.01	2.99	2.68

Demand Escalation for Virginia								
ID	Use	2010	2011	2012	2013	2014	2015	2016
DmdEsc_VP	Demand Esc Area89	3.16	2.00	2.00	2.00	2.00	2.00	2.00
Interventionist		3.18	-0.45	1.84	1.81	1.00	1.79	1.01
Moderate		3.16	2.00	2.00	2.00	2.00	2.00	2.00
Laissez-faire		3.06	4.55	1.90	2.14	1.50	2.22	2.00

Demand Escalation for Tennessee								
ID	Use	2010	2011	2012	2013	2014	2015	2016
DmdEsc_SERCCen	Demand Esc Area14	0.51	1.01	1.01	1.01	1.01	1.01	1.01
Interventionist		0.51	-0.23	0.93	0.91	0.51	0.90	0.51
Moderate		0.51	1.01	1.01	1.01	1.01	1.01	1.01
Laissez-faire		0.49	2.30	0.96	1.08	0.76	1.12	1.01

Demand Escalation for Louisianna								
ID	Use	2010	2011	2012	2013	2014	2015	2016
DmdEsc_ENTG	Demand Esc Area15	0.9	1.8	1.8	1.8	1.8	1.8	1.8
Interventionist		0.91	-0.41	1.66	1.63	0.90	1.61	0.91
Moderate		0.90	1.80	1.80	1.80	1.80	1.80	1.80
Laissez-faire		0.87	4.10	1.71	1.93	1.35	2.00	1.80

Demand Escalation for Georgia/Mississippi								
ID	Use	2010	2011	2012	2013	2014	2015	2016
DmdEsc_SERCSo	Demand Esc Area12	1.03	2.06	2.06	2.06	2.06	2.06	2.06
Interventionist		1.04	-0.47	1.90	1.86	1.04	1.84	1.04
Moderate		1.03	2.06	2.06	2.06	2.06	2.06	2.06
Laissez-faire		1.00	4.69	1.96	2.20	1.54	2.29	2.06

Demand Escalation for Kentucky1								
ID	Use	2010	2011	2012	2013	2014	2015	2016
DmdEsc_KY-Coop	Demand Esc Area42	0.51	1.01	1.01	1.01	1.01	1.01	1.01
Interventionist		0.51	-0.23	0.93	0.91	0.51	0.90	0.51
Moderate		0.51	1.01	1.01	1.01	1.01	1.01	1.01
Laissez-faire		0.49	2.30	0.96	1.08	0.76	1.12	1.01

Demand Escalation for Kentucky2								
ID	Use	2010	2011	2012	2013	2014	2015	2016
DmdEsc_LGEE	Demand Esc Area103	0.51	1.01	1.01	1.01	1.01	1.01	1.01
Interventionist		0.51	-0.23	0.93	0.91	0.51	0.90	0.51
Moderate		0.51	1.01	1.01	1.01	1.01	1.01	1.01
Laissez-faire		0.49	2.30	0.96	1.08	0.76	1.12	1.01

Demand Escalation for Carolinas								
ID	Use	2010	2011	2012	2013	2014	2015	2016
DmdEsc_VACARSo	Demand Esc Area13	0.86	1.71	1.71	1.71	1.71	1.71	1.71
Interventionist		0.87	-0.39	1.57	1.54	0.86	1.53	0.86
Moderate		0.86	1.71	1.71	1.71	1.71	1.71	1.71
Laissez-faire		0.83	3.89	1.62	1.83	1.28	1.90	1.71

Derivation of Incremental Wind Capacity REPS Requirements that are Inputted into AURORA

Annual Demand MWh		2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
Florida	FRCC	262,890,259	269,962,007	277,223,985	284,681,311	292,339,238	300,203,163	308,278,628	316,571,324	325,087,092	333,831,935	342,812,014
Virginia	PJM_Dominion_VP	109,771,080	111,966,502	114,205,832	116,489,949	118,819,748	121,196,143	123,620,066	126,092,467	128,614,316	131,186,603	133,810,335
Tennessee	SERC_Central_TVA	190,908,824	192,837,003	194,784,657	196,751,982	198,739,177	200,746,442	202,773,981	204,821,999	206,890,701	208,980,297	211,090,998
Louisiana	SERC_Entergy_Delta	141,277,377	143,820,370	146,409,137	149,044,501	151,727,302	154,458,393	157,238,645	160,068,940	162,950,181	165,883,284	168,869,183
Georgia/Missis	SERC_Southern_SE	274,451,940	280,105,650	285,875,827	291,764,869	297,775,225	303,909,395	310,169,928	316,559,429	323,080,553	329,736,012	336,528,574
Kentucky1	SERC_TVA_KY_Coop	30,305,471	30,611,557	30,920,733	31,233,033	31,548,487	31,867,126	32,188,984	32,514,093	32,842,485	33,174,194	33,509,254
Kentucky2	SERC_TVA_LGEEnergy	35,454,059	35,812,145	36,173,848	36,539,204	36,908,250	37,281,023	37,657,562	38,037,903	38,422,086	38,810,149	39,202,131
Carolinas	SERC_VACARSouth	237,047,490	241,101,002	245,223,829	249,417,156	253,682,190	258,020,155	262,432,300	266,919,892	271,484,222	276,126,603	280,848,367

REPS in MWh		4.00%	4.00%	4.00%	4.00%	4.00%	8.00%	8.00%	8.00%	8.00%	8.00%	16.00%
Florida	FRCC	10,515,610	10,798,480	11,088,959	11,387,252	11,693,570	24,016,253	24,662,290	25,325,706	26,006,967	26,706,555	54,849,922
Virginia	PJM_Dominion_VP	4,390,843	4,478,660	4,568,233	4,659,598	4,752,790	9,695,691	9,889,605	10,087,397	10,289,145	10,494,928	21,409,654
Tennessee	SERC_Central_TVA	7,636,353	7,713,480	7,791,386	7,870,079	7,949,567	16,059,715	16,221,919	16,385,760	16,551,256	16,718,424	33,774,560
Louisiana	SERC_Entergy_Delta	5,651,095	5,752,815	5,856,365	5,961,780	6,069,092	12,356,671	12,579,092	12,805,515	13,036,014	13,270,663	27,019,069
Georgia/Missis	SERC_Southern_SE	10,978,078	11,204,226	11,435,033	11,670,595	11,911,009	24,312,752	24,813,594	25,324,754	25,846,444	26,378,881	53,844,572
Kentucky1	SERC_TVA_KY_Coop	1,212,219	1,224,462	1,236,829	1,249,321	1,261,939	2,549,370	2,575,119	2,601,127	2,627,399	2,653,936	5,361,481
Kentucky2	SERC_TVA_LGEEnergy	1,418,162	1,432,486	1,446,954	1,461,568	1,476,330	2,982,482	3,012,605	3,043,032	3,073,767	3,104,812	6,272,341
Carolinas	SERC_VACARSouth	9,481,900	9,644,040	9,808,953	9,976,686	10,147,288	20,641,612	20,994,584	21,353,591	21,718,738	22,090,128	44,935,739

Wind Capacity in MW under cap factor		25%	25%	25%	25%	25%	25%	25%	25%	25%	25%	25%
Florida	FRCC	4,802	4,931	5,063	5,200	5,340	10,966	11,261	11,564	11,875	12,195	25,046
Virginia	PJM_Dominion_VP	2,005	2,045	2,086	2,128	2,170	4,427	4,516	4,606	4,698	4,792	9,776
Tennessee	SERC_Central_TVA	3,487	3,522	3,558	3,594	3,630	7,333	7,407	7,482	7,558	7,634	15,422
Louisiana	SERC_Entergy_Delta	2,580	2,627	2,674	2,722	2,771	5,642	5,744	5,847	5,953	6,060	12,337
Georgia/Missis	SERC_Southern_SE	5,013	5,116	5,221	5,329	5,439	11,102	11,330	11,564	11,802	12,045	24,587
Kentucky1	SERC_TVA_KY_Coop	554	559	565	570	576	1,164	1,176	1,188	1,200	1,212	2,448
Kentucky2	SERC_TVA_LGEEnergy	648	654	661	667	674	1,362	1,376	1,390	1,404	1,418	2,864
Carolinas	SERC_VACARSouth	4,329.63	4,404	4,479	4,556	4,633	9,425	9,587	9,750	9,917	10,087	20,519

Incremental Wind Capacity in MW												
Florida	FRCC	4,802					6,165					14,079
Virginia	PJM_Dominion_VP	2,005					2,422					5,349
Tennessee	SERC_Central_TVA	3,487					3,846					8,089
Louisiana	SERC_Entergy_Delta	2,580					3,062					6,695
Georgia/Missis	SERC_Southern_SE	5,013					6,089					13,485
Kentucky1	SERC_TVA_KY_Coop	554					611					1,284
Kentucky2	SERC_TVA_LGEEnergy	648					714					1,502
Carolinas	SERC_VACARSouth	4,330					5,096					11,093

ENDNOTES

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