Potential Impacts of Federal Regulation of Greenhouse Gas Emissions on Wyoming's Energy Derived Tax Revenue

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Abstract

The implementation of federal climate change legislation would alter the relative price advantages of fossil fuels produced in Wyoming and resultant tax revenue. This analysis develops a systems dynamics model to evaluate the effects of recent proposed GHG legislation on the revenue structure of State Government in Wyoming. A policy model demonstrates changes in the prices and quantities produced of coal, natural gas, oil, and wind energy, including electrical generation and multiplier effects, from federal action. With carbon dioxide equivalent (CO_2-e) prices ranging from \$0-\$70/ton, Wyoming tax revenue would increase, due to tremendous growth in demand and production of natural gas that substitutes for declines in coal revenue. Wind energy contributions to tax revenue would remain limited due to a low effective tax rate relative to fossil fuels.

Introduction

This analysis evaluates Wyoming's State Government Revenue stream if greenhouse gas (GHG) legislation is passed in Congress. Wyoming is among a small group of states whose economies are highly dependent upon supplying energy to the rest of the nation. GHG legislation can have a significant impact on the regional economy and on the provision of state and local government services. This study seeks to explore how such legislation may affect Wyoming residents.

The drive for "energy independence" coupled with a growing demand for reduced greenhouse gas (GHG) emissions has placed the significant energy resources of Wyoming at the forefront of domestic energy policy. Wyoming contains substantial reserves of fossil fuels, including oil, natural gas, and coal, as well as significant renewable energy resources, particularly wind energy. The state is the nation's leading coal producer, fifth in natural gas production, and seventh in oil production. Wyoming also ranks eighth in available wind energy resource and, as of the end of 2009, is ranked 13th in total wind energy production (DOE EIA 2009b).

The utilization of these resources, particularly fossil fuels, has brought prosperity to the state's residents. In 2002, the fossil fuels industry directly employed 36,978 people (Census Bureau 2009). In 2009, Wyoming state and local governments received $3.571 billion of direct tax revenue from the mining sector, which is comprised primarily of fossil fuel extraction industries (98.2% of total mining related revenue) (State of Wyoming DAI 2009). These are significant impacts in a state of just over 500,000 residents.

The economic benefits to Wyoming from fossil fuel extraction are not without environmental costs, as the combustion of fossil fuels has known detrimental environmental impacts, including global warming. Although Wyoming's individual contribution to global warming is small, the aggregate use of fossil fuels is a primary driver of climate change. The United Nations Intergovernmental Panel on Climate Change (UN IPCC) (2007a) determined that there is a high probability (90% certainty) that global warming is caused by anthropogenic sources, primarily the burning of fossil fuels and land use change. Global warming affects all regions of the Earth; potential impacts include melting polar icecaps and resultant elevated sea level, increased extreme weather events such as drought, floods, and hurricanes, and species decline due to changing habitats (IPCC 2007b). The impacts to the human environment and the endangerment of other species serve as the impetus to act to stabilize Earth's climate. This requires the reduction of GHG emissions and eventual large-scale carbon sequestration schemes (IPCC 2007c).

Responding to the negative environmental externalities of fossil fuel combustion, the federal government is engaged in rapidly evolving consideration of limiting the emissions of GHGs. In 2007, the U.S. Supreme Court ruled that the Environmental Protection Agency (EPA) had the statutory authority to regulate GHG emissions, as the court determined that emissions could lead to detrimental effects on health and welfare. The EPA has subsequently issued a finding that GHG emissions pose a danger to human well-being. The Executive branch also places regulating GHG emissions as a policy priority (Executive Office of the President 2009). The type and scale of federal regulation ultimately lies with Congress. Numerous bills have been considered by both houses, with the Waxman-Markey American Clean Energy and Security Act of 2009 (H.R. 2454) passing the House of Representatives. Previous bills considered by

Congress, such as the Lieberman-Warner Climate Security Act of 2008 (S.2191) and the McCain-Lieberman Climate Stewardship Act of 2003 (S.139), provided similar restrictions on the emission of GHGs. The interaction between federal climate policy, energy consumption, and the source of energy has been previously examined (e.g. Paltsev et. al 2007, EIA 2008, Ford 2008). Paltsev et. al. (2007) provides a detailed analysis of the seven cap-and-trade plans proposed in the U.S. Congress as of early 2007. The authors utilize a computable general equilibrium model of the world economy incorporating EPA data on GHG emissions. Estimated welfare losses range from 0.06 to 0.55% by 2020 with CO_2 prices varying $7-53/ton. By 2050 escalators in the proposed laws could increase carbon prices to $39-210/ton. Paltsev et. al also consider the impacts on the quantity of price and fuels. At ~$27/ton CO_2 equivalent, the authors estimate that the added cost to coal will be 207%, natural gas will be 28%, and oil will be 30% based upon base price averages from 2002-2006. The modeling framework includes includes own and cross-price general equilibrium effects, also changes with different levels of GHG emission regulation. Coal prices are constant through 2030, although the prices are lower than would be expected with no regulation; coal prices are forecasted to increase from 2030-2050 due to the rise of carbon capture and storage (CCS) technologies. Oil prices are forecasted to increase nearly 50%, although GHG regulation slows this growth. Natural gas prices are forecasted to more than double by 2030, with low levels of GHG regulation actually increasing the price of natural gas. Electricity prices are expected to increase over 50% in the face of GHG regulation, as consumers substitute lower carbon intensity electricity for fossil fuels. The overall quantity of energy is reduced at all levels of GHG regulation as compared to the reference case through 2030. Coal consumption decreases markedly, with natural gas filling the majority of the void. The quantity of oil is not as sensitive to less stringent GHG regulations. Renewable energy grows in all scenarios, although growth is the fastest with a greater price of GHG emissions.

The Department of Energy analyzed the economic impacts of the proposed Lieberman-Warner Climate Security Act of 2007 (S.2191) (EIA 2008a). The cap-and-trade proposal would commence in 2012 with a cap 7% below 2006 levels and progress to 39% below 2006 levels in 2030. The Reference case represents energy growth with no GHG emissions regulation. The Core Case "represents an environment where key low-emissions technologies, including nuclear, fossil with carbon capture and sequestration (CCS), and various renewables, are developed and deployed in a timeframe consistent with the emissions reduction requirements without encountering any major obstacles, even with rapidly growing use on a very large scale, and the use of offsets, both domestic and international, is not significantly limited by cost or regulation" (p 8). Alternately, the Limited Alternative Case

> ***…represents an environment where the deployment of key technologies, including nuclear, fossil with CCS, and various renewables, is held to their Reference Case level through 2030, as are imports of liquefied natural gas (LNG). The inability to increase their use of these technologies causes covered entities to turn to other options in response to the Lieberman-Warner bill (p 9).***

Overall, the rate of growth of energy use is expected to decline under the Lieberman-Warner legislation. For example, under the Core Case use totals 113.4 quadrillion Btu versus 118.0 in the Reference Case. Coal is expected to decline in all cases different from the Reference. The escalating price of GHG emissions reduces coal further over time. The growth of nuclear power is important, as it impacts coal's dominance as a base load fuel. Liquid fuel consumption is universally reduced, although the impact is limited. Natural gas is not impacted as significantly as coal; the Limited Alternative Case depends heavily on natural gas. The growth of nuclear in the Core Case leads to declining demand for natural gas. Renewable energy benefits over the reference case in all GHG regulation cases.

The Energy Information Administration's (EIA) *Annual Energy Report* recognizes the impact that GHG regulation could have on the energy sector (2009a). The EIA forecasts strong growth in renewable energy, but also sees growth for the coal, oil, and natural gas industries through 2030. The manner in which fossil fuels are utilized is forecasted to change with carbon regulation, but overall consumption is predicted to increase. Demand for Powder River Basin Coal is expected to grow through 2030, as is demand for Western natural gas production. Overall, the EIA forecasts strong demand for Wyoming's energy production through 2030.

Ford (2008) explored the impacts of an explicit price for GHG emissions in the western electricity system. The author simulates the impact of the adoption of Senate Bill 139 (McCain-Lieberman Bill) with a base price of $22/ton of CO_2-e (CO_2 equivalent) in 2010 and escalating to $60/ton in 2025. Using a simulation model, Ford determined that the source of electricity in the Western Electricity Co-ordination Council (WECC), which includes Wyoming, would move away from coal towards renewables, primarily wind and biomass, and combined cycle gas turbines. If electricity demand is assumed to grow 2.5% annually and a natural gas price of $5.50 per million BTUs is assumed, traditional pulverized coal plants will not be economically viable by 2025. Wind will comprise 6% of the market, up from 0.6% in 2010. Integrated Gasified Combined Cycle (IGCC) plants will only comprise a small portion of the electricity supply market. Alternately, if demand growth slows and gas prices are assumed to be $7.50

/MMBTU, then coal plants will be constructed in eastern areas of the WECC, such as Wyoming and Montana, and large scale renewable energy development will still occur. The simulation methods used by Ford could be applied to estimating the impact on energy production in Wyoming.

Theoretical Framework

The existing literature contains little information regarding the ramifications of federal climate change legislation on energy-dependent states. The complex regulation-driven interaction between different fossil fuels and renewable energy, particularly wind energy, can have profound impacts on the fiscal well-being of energy producing states. Although this analysis considers only Wyoming, states with significant fossil fuel production and large renewable energy resource bases, such as Montana, Colorado, New Mexico, North Dakota, Kansas, Oklahoma, and Texas, would also benefit from similar consideration.

The theoretical framework used in this study is a an equilibrium displacement model at its core with an attached revenue model in a systems dynamics framework. EDMs are fairly common in agricultural and resource economics (e.g. Muth 1964, Gardner 1979, and Davis and Espinoza 1998). The EDM calculates responses to changes in price, considering both consumer (or factor) demand elasticities and supply elasticities. The core concept that drives this analysis is that as legislation changes the relative prices of fuels for generation of electricity cost minimizing behavior by firms will change the mix of fuels used to generate electricity. The structure of the core model follows Buse (1958), Piggot (1992), and more recently Zhao, et al (1997). Each fuel has a different tax incidence at the State and local level. The set of structural equations that drive changes in fuel use and ultimately tax revenues are summarized in equation 1.

$$\begin{aligned} D_f &= D(P_f, I, O_E) \\ S_f &= S(P_f, O_f, w_f) \\ Q_f &= D_f = S_f, \forall f = g, c, oi, w \end{aligned} \tag{1}$$

Fuel sources include coal (c), methane (g), oil (oi), and wind (w). “I” is income and “O” is output. Calculating the total differential of the system of derived demand for the three primary sources of energy are

$$\begin{aligned} D_f &= \sum_f \varepsilon_{f,pf} P_f + \varepsilon_I I \\ S_f &= \sum_f \varepsilon_{f,pf} P_f + \varepsilon_O O \\ Q_f &= D_f = S_f \end{aligned} \tag{2}$$

Change in consumption of fuel “*f* ” then is a function the elasticity of demand and supply for each fuel and the cross elasticities of demand for competing fuel sources which allows for fuel substitution as prices change. The overall structure of the system models coal, natural gas, oil, and wind energy industries and their respective tax-revenue generating activities, equation 3.

$$\begin{aligned} \Delta TR_f &= \Delta P_f * \varepsilon_{f,pf} * txr \\ \Delta TR_{roe} &= \Delta P_{roe} * txr \end{aligned} \tag{3}$$

Finally, to account for broad economy-wide effects fuel shifting we also incorporate an input output model. We use a 2006 IMPLAN model for the State of Wyoming. Changing input demand mixes for fuels mined in Wyoming translates to changes to different components of the regional economy down stream from the fuel sectors.

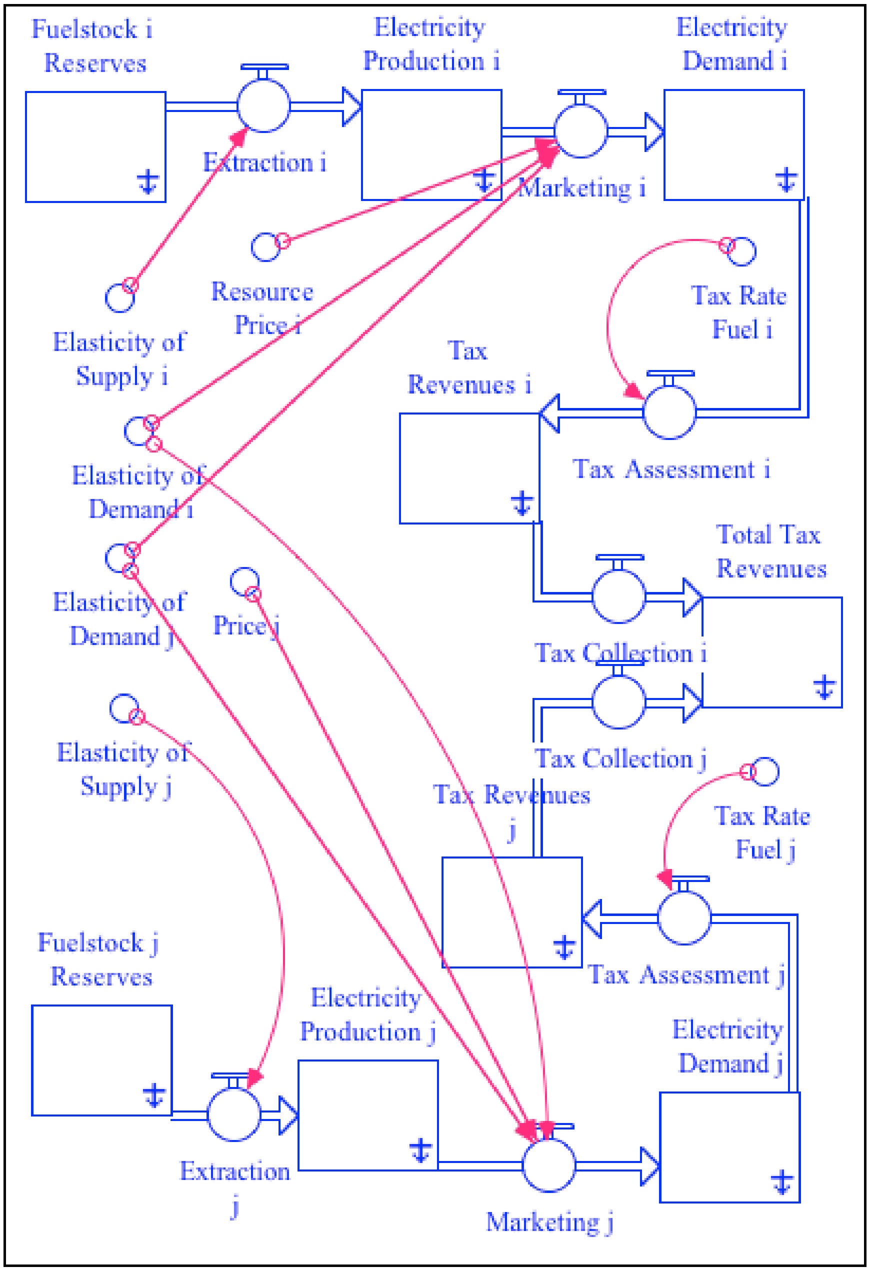
Simulation Model

The analysis uses STELLA to model predicted changes the State's tax revenue mix. Key assumptions in the model include the alteration of Department of Energy, Energy Information Administration (EIA) production and price forecasts, the summation of elasticity effects, the calculation of effective tax rates, and the inclusion of Wyoming specific indirect and induced economic multipliers. The policy model exposes the impacts of current policy decisions and the potential for an altered course in the future. Most fundamentally, this model is designed to consider the external shock of climate change legislation with the resulting price for CO_2 and other GHGs. The price per ton of CO_2 equivalent (CO_2-e) will modify the quantity and price of resources, which will also impact Wyoming state tax revenues.

Equilibrium Displacement Model and Elasticities

Embedded in STELLA is the EDM that governs price and quantity relationships of fuels used to produce electricity through the utilization of own-price elasticity of demand, cross-price elasticity of demand, and elasticity of supply. The EDM component in the STELLA model is configured in simplified form in Figure 1. This method tempers the change in quantity by firm's ability to respond (supply elasticity), as opposed to the more robust consumer (factor) demand response. The blocks are considered stocks and the "valves" reflect the flow relationships out of one stock and into another stock. The stock can be fuels or tax revenues and the "valves" convert flows out of each stock to the relevant unit in the receiving stock. Ultimately the system registers a change in State tax revenues.

Figure 1. EDMP Models with taxes in STELLA with two fuel stock sources



The own-price elasticity of demand, cross-price elasticity of demand, and elasticity of supply utilized in the policy model are based upon previous studies, although information regarding supply elasticities was difficult to locate. The elasticities utilized are presented in

Table 1. The elasticities are all intermediate to long-run elasticities, where capital stocks have adequate time to adjust to changing market conditions.

Table 1: Own-Price, Cross-Price Elasticities, and Supply Elasticities for Wyoming's Energy Resources

	Own-Price	**Supply**	**Cross-Price: Coal**	**Cross-Price: Natural Gas**	**Cross-Price: Oil**	**Cross-Price: Wind**
Coal	-0.395[1]	0.90[4]	-	0.174[1]	0.370[2]	.91[2]
Natural Gas	-1.012[1]	0.55[4]	0.26[2]	-	0.13[2]	0.65[2]
Oil	-0.253[1]	0.10[4]	0.10[2]	0.13[2]	-	0.04[2]
Wind	-0.263[3]	0.50[4]	0.13[2]	0.53[2]	0.01[2]	-

[1]Serletis & Shahmoradi (2006), [2]Waverman (1992), [3]Maddala (1997), [4]User defined based upon Krichene 2002, Wiser & Bollinger 2007, When & Mahieu 2003

The EDM incorporates price and quantity effects for each individual resource, including own-price and cross-price effects. These are partial effects, as it only accounts for a change in price and quantity resulting from a direct relationship between two energy resources or simply from own price effects. The total price effect is estimated through a summation of these partial effects. For example in the natural gas module, the cross-price impact of an increase in coal and oil prices from GHG emissions regulation, leads to an increase in the quantity of natural gas demanded. Wind energy is not directly impacted by GHG regulation, so no cross-price effect occurs for natural gas. This increase in quantity demanded is tempered by the own-price effects of increased natural gas prices resulting from its own carbon intensity and by inelastic supply elasticities. The model does not consider the second-order impacts resulting from interactions between energy commodities. For example, a dramatic increase in coal prices can be expected to increase demand for natural gas, which would raise the price of natural gas. This feedback resulting from the relationship between natural gas and coal is not considered in the own-price analysis. Therefore, the summation of partial impacts should only be considered an approximation of the total effect. The actual effect would likely be more moderate, due to the cross price effects impacting the own-price effects. To account for some of this over-estimation in quantity (either too large of an increase or decrease), the price effects calculated from the elasticities are reduced by 50% in the demand response variable. This also covers the possibility of more long run inflexibility due to the widespread use of forward contracts in supplying fuel to electric utilities. The actual nature of the forward contracts are

Production, Price, and Tax Revenue

The policy model relies upon the price and quantity forecasts of the Energy Information Administration's *Annual Energy Outlook 2009.* In previous years, Wyoming's energy resources have sold at prices below national levels; therefore the EIA national price forecast was scaled to reflect the local market conditions found in 2007. Wyoming received 37% of the national average for coal, 73% for natural gas, and 79% for oil. These price discounts were assumed to hold into the future, which excludes technological change or infrastructure development that alters these levels. Energy production was also assumed to maintain constant levels of national/regional production as found in 2007. In 2007, Wyoming produced 73% of Western coal, 9.6% of national dry gas, 2.9% of Lower 48 oil, and 1.7% of national wind energy. These proportions were assumed to hold through 2030, once again ignoring technological change or resource stock changes.

The price and production of Wyoming energy resources leads directly to tax revenue, but different energy resources are taxed at different rates. Using information based upon 2006 and 2007 production, price, and tax revenue, the effective tax rates were calculated (Table 2). For fossil fuels, the effective tax rate considers property tax, ad valorem property tax (tax on the value of production), severance tax, sales and use tax, state royalties, and federal royalties returned to Wyoming. Information for wind energy was difficult to located, therefore, only property taxes paid by all electrical generation are considered; wind energy is currently exempt from sales ad use tax in Wyoming. Electrical generation and general economic activity consider property taxes and sales and use tax.

Table 2: Effective Tax Rates (2007)

	Coal	Natural Gas	Oil	Wind	Electrical Generation – Fossil Fuel	General Economic Activity
Tax Rate (%)	20.07	19.45	18.82	1.25	3.50	7.13

STELLA Model Structure

The overall STELLA policy model is designed to simulate the flow of energy stocks through markets, as revealed by price and quantity changes, to eventual tax revenue. Wyoming is treated as a “small country,” being an energy producer and a price-taker. The entire U.S. market dictates the price that will be received for Wyoming’s energy resources. The cost structure also influences the type of energy resources produced by Wyoming.

We use the energy information agency’s price forecast applied to the core EDM models. This allows fuel stock quantities to adjust given the price and implicit carbon tax. The price change caused by valuing GHG emissions is used to directly influence the quantity of energy resources extracted (fossil fuels) or utilized (wind energy). As the focus of this policy model was tax revenues, price is a vital component of tax receipts; the higher the price at a given quantity, the greater the revenue. Therefore, price changes from existing EIA estimates wrought by GHG regulation are considered using an artificially isolated “demand response.” This parameter allows for some influence of price to be incorporated into revenues without creating a simultaneous system. The STELLA model is based upon two partial systems, quantity changes and price changes. For example a fossil fuel has a starting price of $10/MMBtu, a base production of 1000 MMBtu/year, and a sufficiently large reserve to be unconstrained over the time period. The imposition of GHG regulation leads to an increase in production to 1200 MMBtu/year (implying low carbon intensity relative to other fossil fuels). The increase in quantity is 20%, or a ratio of 0.2. The parameter for demand response is defined as 0.5, which reflects the supposition that the supply curve is generally inelastic. The isolated demand response, which eliminates the feedback of price to quantity, provides information on price change for revenue. The relationship would be expressed as:

$$\$10/\text{MMBtu}*(1+ (0.2*0.5) = \$11.00/\text{MMBtu}$$

The new price can be utilized to calculate revenues received by producers. The isolated demand response leads to total revenues of $13,200 versus $12,000 at the EIA price estimate.

Results

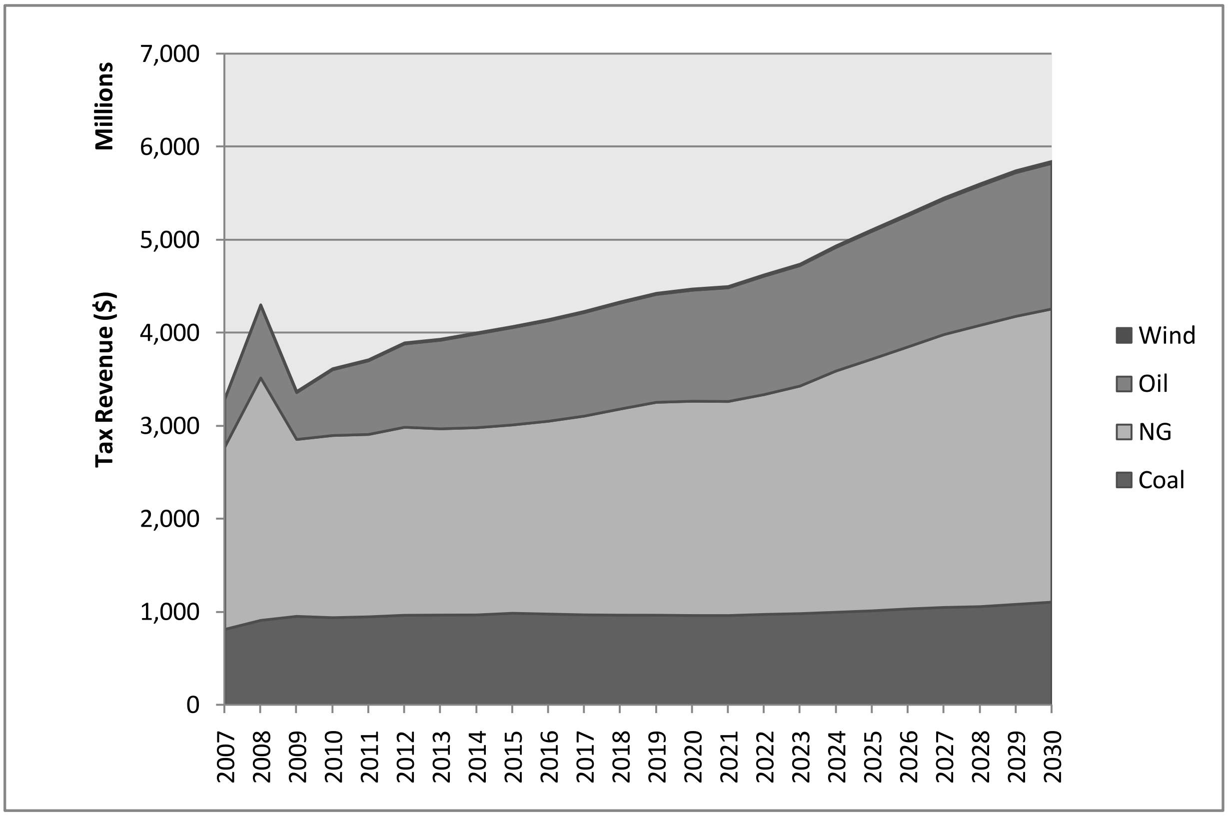
Four scenarios were considered: The reference scenario where no Federal action occurs, two scenarios with varying estimates of the carbon price per ton, and a scenario modeling the Lieberman-Warner (S.2191) bill. The Reference Scenario provides a control for comparing changes in tax revenues under the different exogenous shocks. The Reference Scenario considers production, prices, and tax revenue at $0/ton CO_2-e. A carbon tax is then applied to all fossil fuels based upon each fuels carbon intensity at a low and high level for sce The Core Scenario mimics the impacts of the Lieberman-Warner Climate Security Act of 2007 (S.2191).The scenarios are summarized in Table 2.

Table 2. Scenario Descriptions.

	Scenario Description	CO_2-e assumptions
1	Reference Scenario no Federal action occurs	\$0/ton CO_2-e
2	Core Scenario basted upon the Lieberman-Warner Bill	2012 - \$10/ton CO_2-e. 2012 to 2020 - price increases incrementally to \$30/ton. 2021 to 2030, prices increase to \$61/ton.
3	General reference scenario Low Carbon Tax	\$35/ton CO_2-e
4	General reference scenario High Carbon Tax	\$70/ton CO_2-e

In the Reference Scenario both production and real prices increase through 2030, tax revenue is also predicted to increase to nearly \$6 billion annually. In this scenario both natural gas and oil revenues experience the greatest expansion (Figure 2).   Coal revenues increase more gradually, and wind energy revenues remain very small (barely detectable at the scale of Figure 2).

Figure 2. Tax Revenue in the Reference Scenario



It is important to note that any changes to Wyoming's tax revenue must be compared against this growth scenario. With no federal action regarding climate change, Wyoming's real energy derived tax revenues are expected to increase 78% from 2007-2030. Total tax revenue from energy over the time period is over $107 billion. Natural gas provides 53% of total revenue over the time period. Alternately, wind provides a mere 0.31% of revenue.

Following the steep decline through 2010 with the current recession, tax revenues are expected to grow steadily. This growth concurs with forecasts of the Wyoming Consensus Revenue Estimating Group (CREG). If EIA forecasts of price and production are accepted as accurate, the only source of error is the proportion of national/regional production provided by Wyoming. As previously discussed, the proportion of production is held constant at 2007 levels;

this may not accurately reflect future production in Wyoming. For example, with heightened interest in Wyoming's wind resource, limited current development, and new interstate transmission infrastructure, wind energy in Wyoming may experience more rapid growth than the country as a whole. Therefore, wind energy may be underreported in the model. Similarly, oil production is forecasted to grow nationally, especially from 2015-2030; this is primarily the result of the development of deepwater Gulf of Mexico resources. Wyoming's oil industry has generally been in decline since the 1970's, although enhanced oil recovery has recently led to a slight increase. Therefore, oil production and revenues could be overstated.

Core Scenario

The core scenario is based upon the Lieberman – Warner proposal in Congress, which is the leading proposed legislation. An explicit price for GHG emissions commences in 2012 at \$10/ton CO_2-e. From 2012 to 2020, the price increases incrementally at a constant rate to \$30/ton. From 2021 to 2030, prices increase evenly to \$61/ton. This scenario receives the most analysis, due to the likelihood of GHG emissions regulation taking a form similar to this legislation. Information on price, production, and total tax revenue is subject to sensitivity analysis for elasticity, demand response, and price.

The level of production, price, and total tax revenue are presented in Figures 3, 4, and 5. As expected, the imposition of a price for GHG emissions leads to a decline in high carbon intensity coal. The increased price overwhelms the relative inelasticity of coal and the EIA estimated increase in production. Due to coal providing such a large share of total energy production (78% of energy in 2007), overall energy production also declines markedly. Natural gas production, the second largest source of energy, increases, but the elevated level of production does not offset losses in coal. Oil is not drastically impacted due to its very low price elasticity and the general EIA trend for increased production. Wind remains a very small portion of primary energy production in Wyoming.

Figure 3. Energy Production in the Core Scenario

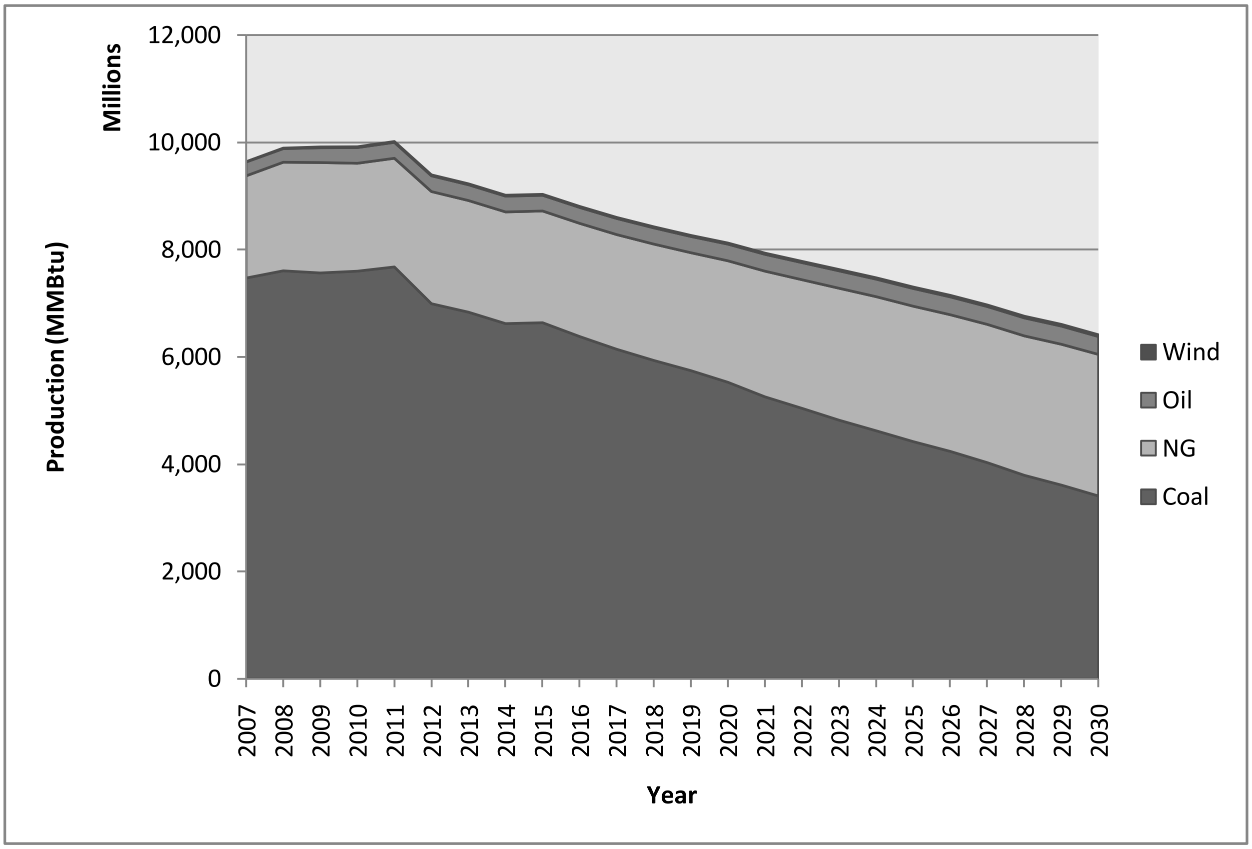
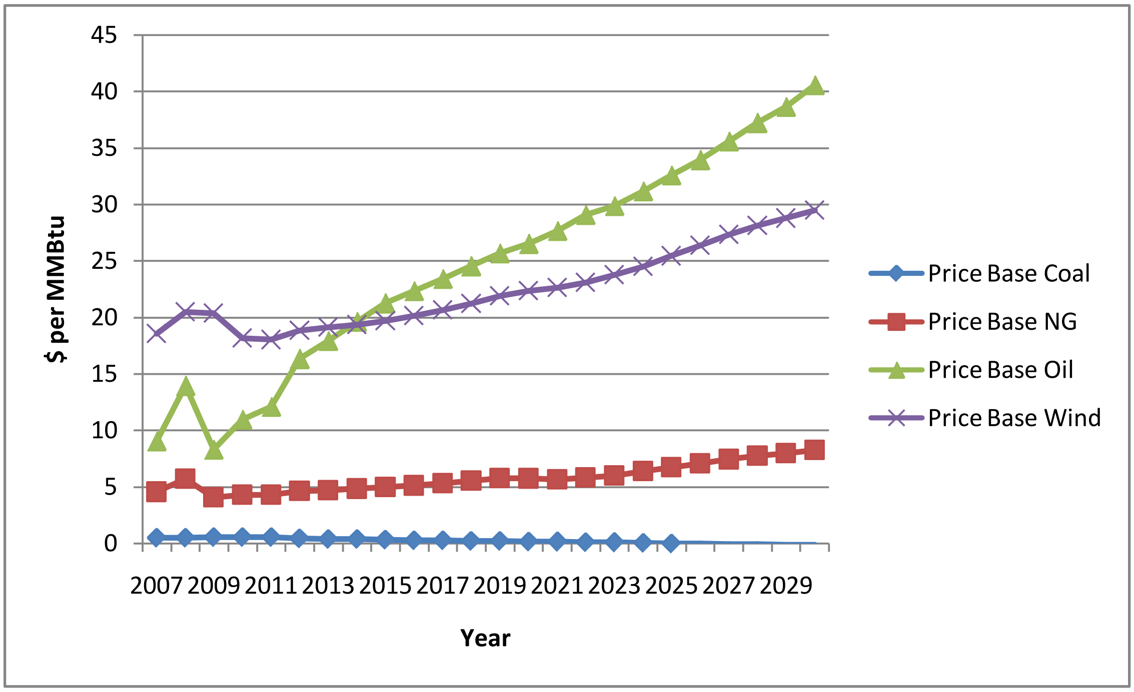
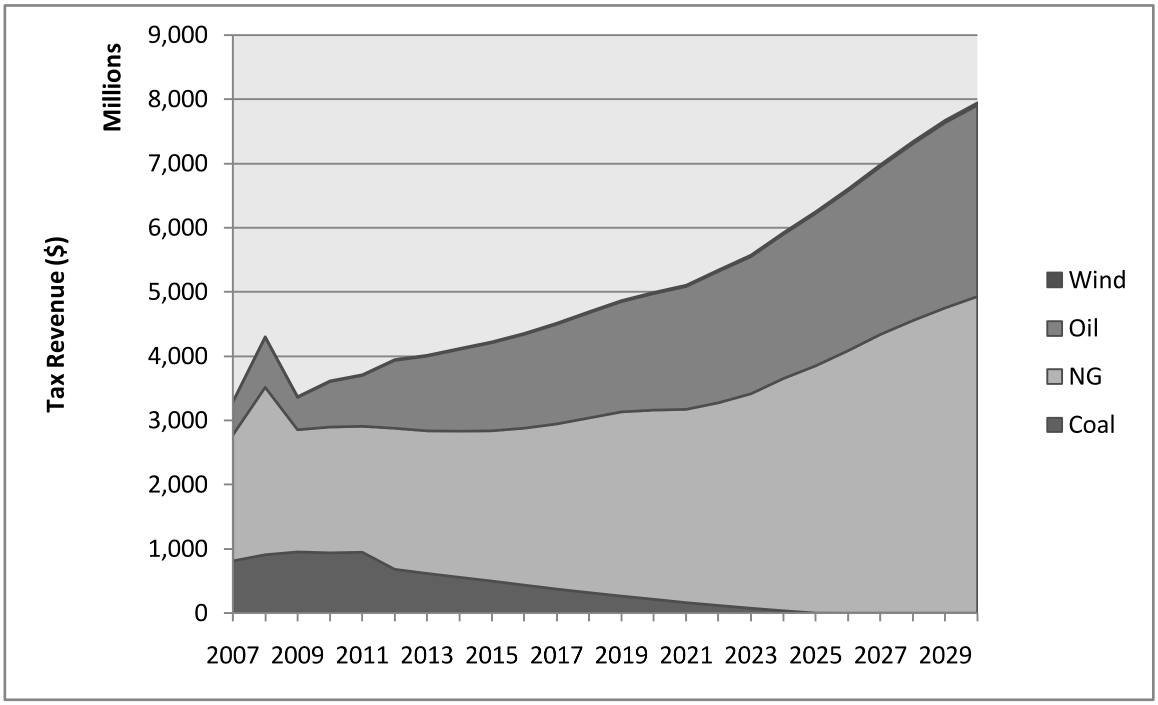


Figure 4. Price of Energy Resources in the Core Scenario



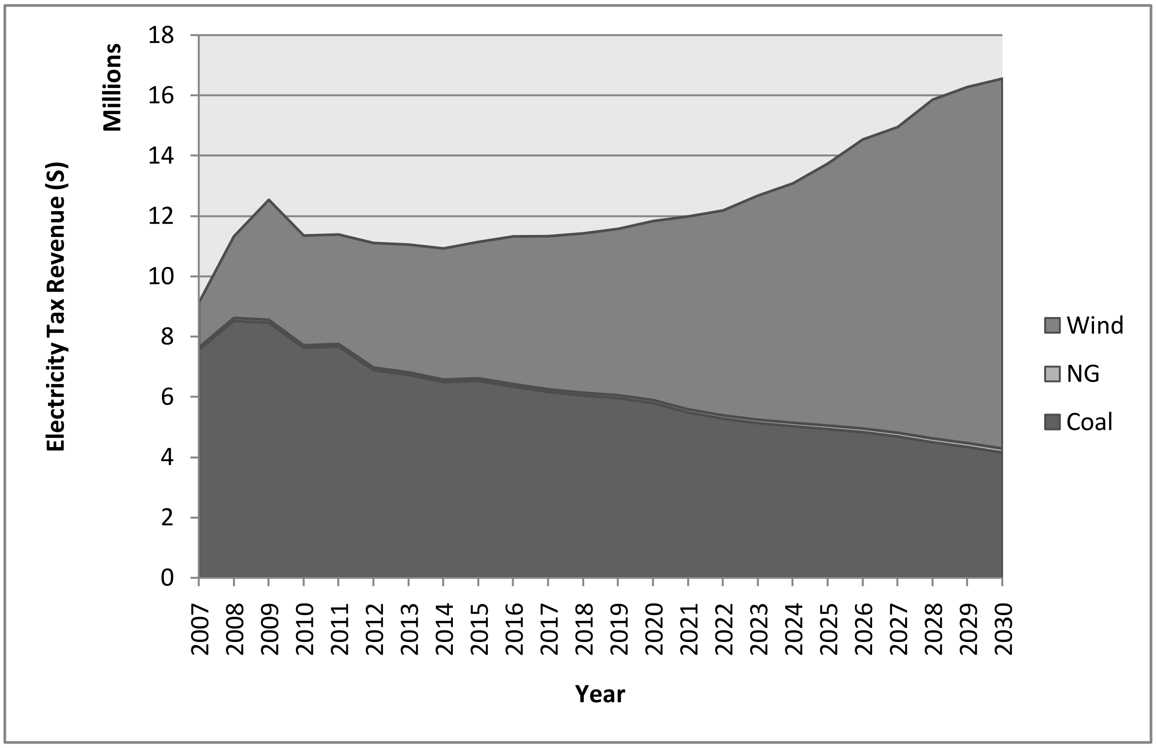
Prices are altered through the demand response measure. Coal prices slowly decline until reaching zero in 2026. The model then predicts a negative price for coal, which is reflected as zero in calculations for tax revenue. (Tax revenue cannot be negative.) Natural gas price increases through 2030, reflecting EIA forecasted price increases and an increase in quantity demanded for the relatively low carbon intensity energy source (demand response). Oil prices increase drastically reflecting higher demand for the moderate carbon intensity fuel. The reference case also predicted a significant (95% increase from 2007 to 2030) increase in oil prices. The price of wind energy also responds positively, as demand for wind increases with the large decline in coal production.

Figure 5. Tax Revenue in the Core Scenario



The impacts on tax revenue are particularly interesting. Overall tax revenue increases dramatically in the Core Scenario. Tax revenues from 2007-2030 are 14.07% higher in the Core Scenario than in the Reference Scenario. The increase comes despite the significant decline in coal revenues. The increase in total revenue is largely driven by growth in natural gas and oil revenues due to both increased production and prices. Wind energy tax revenue also grows drastically (418%) over the duration of the simulation, but the amount contributed is still very minor compared with fossil fuels.

Figure 6. Tax Revenues from Electricity Generation in Core Scenario



Electricity generation also contributes tax revenue (Figure 6), although it is much smaller than production revenue (0.002% of total revenue). The decline of coal electricity revenue mirrors the decline in total coal revenue. Wind electricity grows to become the largest portion of electricity tax revenue. Natural gas remains a minor component of electricity generation (the barely detectable sliver sandwiched between coal and wind).

Sensitivity Analysis

As stated above elasticities (own-price demand, cross-price demand, and supply), demand response, and prices are imposed from other studies so we evaluate the sensitivity of the results to changes in key parameters . Price and elasticities are allowed to vary by 50%. Demand response is allowed to vary by 100%.

Significant variation exists in published estimates of demand and supply elasticities. Although each individual elasticity measure can be easily altered in the policy model, for ease of reporting all elasticities are varied simultaneously. At 150% of base parameters, own price elasticities are more inelastic, as the values are negative, and cross-price and supply elasticities grow more elastic. The inverse occurs at 50% of base values. A summary of critical impacts is presented in Table 3.

Table 3: Key Findings of Elasticity Sensitivity Analysis

	50% Elasticities	**100% Elasticities**	**150% Elasticities**
Total Tax Revenue (billion $)	133	141	149
Coal Production (Billion MMBtu)	167	130	97

The increase in own-price inelasticity in the 150% scenario increases overall revenue, primarily from coal production (coal production ceases by 2028) being more rapidly replaced with more valuable natural gas and oil production. The increased elasticity of supply leads to coal being more responsive to changes in price, while the increased inelasticity of own-price demand makes changes in price from GHG regulation stronger on coal production. The elasticity sensitivity analysis supports the important conclusion that the loss of coal actually increases revenue through increasing the price and production of other, more valuable energy sources (e.g., natural gas and oil).

The demand response, which seeks to include some price effects in the model, possesses a strong influence over the model. The demand response parameter is set at 0.5 of the price effects predicted by the EDM model. Sensitivity analysis considers no (0.0) demand response and the full demand response predicted by the EDM model (1.0). The impacts on tax revenue are presented in Table 4.

Table 4: Key Findings of Demand Response Sensitivity Analysis

	0% Demand Response	**Core**	**100% Demand Response**
Total Tax Revenue (Billion)	$113	$141	$172
Coal Revenue (% of total)	14%	7%	4%

The demand response clearly has a profound impact on coal prices. With the full price impact considered, revenue from coal production ceases by 2017. Natural gas and oil tax revenues increases as they fill the void of coal. This leads to increased total revenue regardless of the demand response.

Finally, prices also exert a strong influence over the model results. Assuming constant elasticities of demand and supply, a decrease in price yields a more robust influence of elasticities, as the carbon price premium is a greater percentage of prices. The results are summarized in Table 5.

Table 5: Key findings of Price Sensitivity Analysis

	50% Prices	**ore**	**150 % Prices**
Total Tax Revenue (Billion)	$97	141	$191
Coal Revenue (Billion)	$3	9	$18

Once again, policy driven changes in coal production drive changes to other energy resources. With low prices, coal revenue drops dramatically and coal production ceases by 2023. Less coal is used because other energy sources are also less expensive, but the proportional impact from incorporating the cost of GHG emissions is greater. Changes in price expose the importance of the constant elasticity assumption.

The results presented for the Core Scenario provide insights into the potential impact of regulating GHG emissions on Wyoming's energy derived tax revenue. The most important implications are:

1. Coal price is heavily impacted by an explicit price for GHG emissions,
2. Coal quantity also declines with the loss of cost competitiveness,
3. Natural gas and oil derived tax revenues grow substantially with the decline of coal as electric power production shifts to lower carbon intensity fuels,
4. Wind energy remains a minor component of tax revenue, and
5. As GHG regulation strengthens, Wyoming revenue may actually increase.

The coal industry is dramatically impacted by federal climate change legislation. Effective price declines steadily from 2012 until approaching zero by 2026 (Figure 4). A price of zero occurs at approximately \$50/ton CO_2-e. At this price, no more production taxes are collected, although production still occurs. The continuation of production implies that Wyoming coal would still have some value, but the value of production tax revenues would be minimal. The decline in price also impacts quantity; Table 3 (demand response at 100%) reveals that with a full price effect displayed through the demand response variable, production ceases in 2023. As Wyoming produces approximately 40% of the America's coal, this is a significant loss of energy production, as revealed by the decline in overall energy production shown in Figure 5-3. The loss of production is driven by the impacts of own-price elasticity of demand; as price increases quantity declines.

The loss of revenue from coal is more than offset by an increase in natural gas and oil revenues. The cross-price effects of an increase in the cost of coal makes natural gas more competitive, despite the increase in cost due to its own carbon intensity. Natural gas output from 2007-2030 increased 19.6% versus the Reference Scenario, price increased 18.3%, and total tax revenues collected from natural gas increased 45.6%. The final year of the model, 2030, reveals and even greater growth, as production in the core scenario is 41% greater than in the reference scenario. Tax revenue from natural gas is elevated by 95%.

Oil, with its high degree of own-price inelasticity, is not as adversely impacted by an increase in cost due to its carbon intensity. Oil production increases in the Core Scenario versus the Reference, due to some ability to substitute for natural gas and coal, but the increase in production is much smaller than natural gas (9%), but tax revenue increases by 150% driven by a much higher price for oil (130% increase).

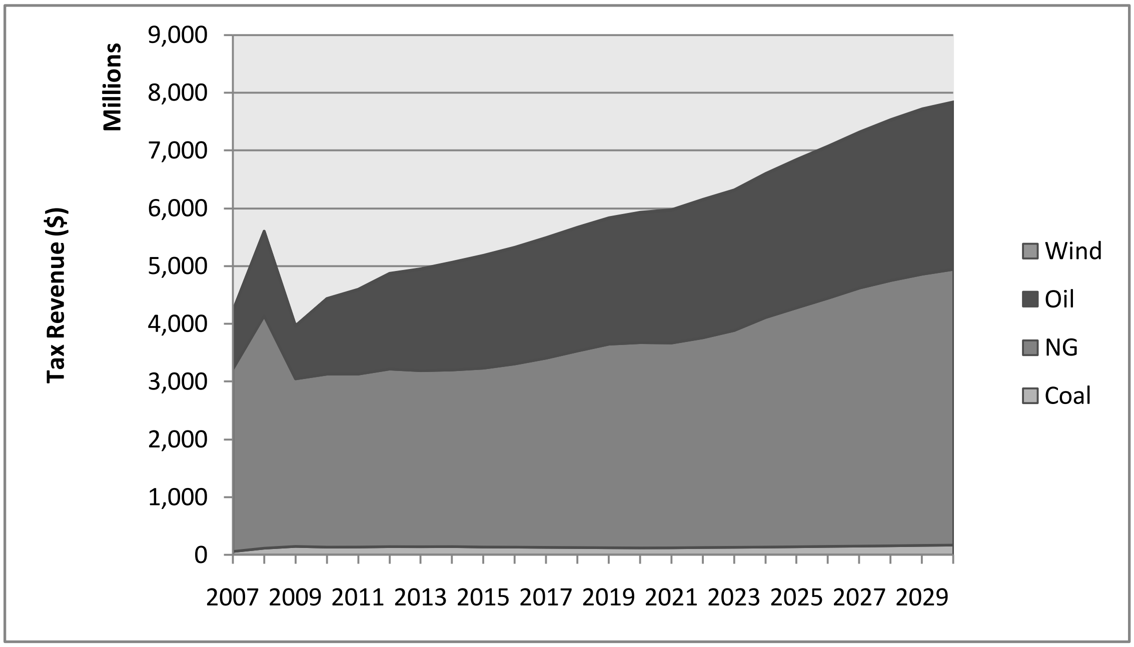
Wind energy remains a minor player in the Wyoming energy markets despite CO_2-e reaching $61/ton. Wind energy does grow more rapidly in the Core Scenario than in the Reference Scenario (38% more production and 91% more tax revenue) and grows very quickly overall (460% increase in production). Still, wind energy starts as an extremely small proportion of Wyoming's energy mix. Combined with its low effective tax rate, wind energy remains a limited source of revenue for the State of Wyoming.

Overall, the most significant finding is that as the price for GHG emissions increases, so do Wyoming's tax revenue. This occurs despite dramatic impacts on coal production and tax revenue. Natural gas and oil tax revenues grow faster than the loss of coal tax revenues. Although local economic impacts from a diminished coal industry could be significant, overall the state could benefit from federal action regarding climate change.

Reference Scenario + \$35/ton CO_2-e

To better understand the impacts of an explicit price for GHG emissions, the Reference Scenario +\$35/ton CO_2-e provides a rudimentary exogenous shock. An explicit price for CO_2-e is assumed to be applied retroactively to the existing energy production system in Wyoming. The price of GHG emissions in this scenario are similar to the upper range of prices found in the EU ETS. This scenario assumes that production and prices adjust instantaneously. Figure 5-7 reveals the total tax revenue.

Figure 7. Tax Revenues in the Reference Scenario + $35/Ton CO_2-e

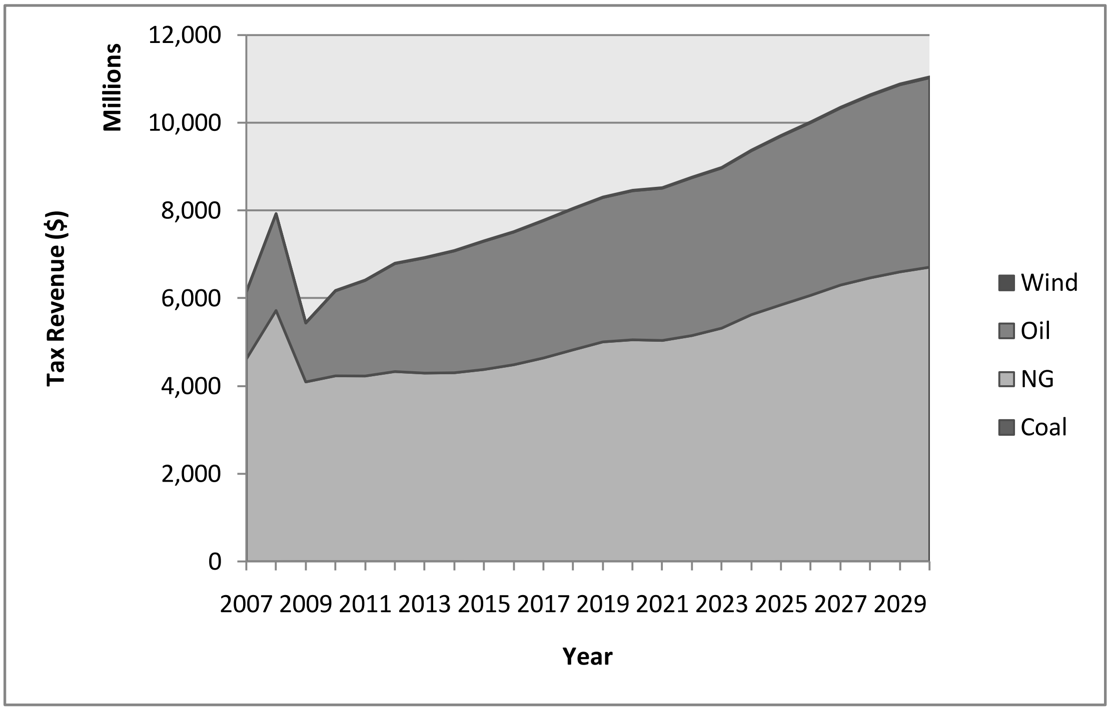


Similar to the Core Scenario from 2020-2025, coal tax revenue is greatly diminished. Coal tax revenue continues as the price of coal averages $0.12/MMBtu, which is a 78% decline from the Reference Scenario. The price of CO_2-e in this scenario is below the threshold where coal price drops to zero (~$45/ton) or production actually ceases (~$81/ton). Increased natural gas and oil tax revenues more than compensate for the loss of coal revenues and wind energy remains a bit player. Overall tax revenue increases versus the Reference Scenario due to higher price and quantity of natural gas and oil.

Reference Scenario + $70/ton CO_2-e

The Reference Scenario + $70/ton CO_2-e provides a basic simulation of the effects of CO_2-e prices higher than those in the Lieberman-Warner legislation. Similar to the Reference Scenario + $35/ton CO_2-e, the exogenous shock is applied retroactively to the Wyoming's existing energy production system and alterations to production are allowed to occur instantly.

Figure 8. Tax Revenues in the Reference Scenario +\$70/ton CO_2-e



As expected from the later years of the Core Scenario, the loss of coal revenue is nearly complete. Coal production still occurs at this level of GHG regulation, although the price is negative for production. Some revenue continues to accrue from the generation of electricity from coal. Natural gas and oil tax revenues are driven much higher than in the Reference Scenario. Wind energy remains a small factor in tax revenues. Overall total tax revenues are 82% higher than the in the Reference Scenario.

Summary

The need to examine the impacts of proposed federal greenhouse gas (GHG) regulation on Wyoming's energy derived tax revenue is rooted in the known negative externalities of fossil fuel combustion, primarily global climate change. These social costs are assumed to be incorporated into energy markets through the imposition of a cap-and-trade or other regulatory system, which creates a cost for GHG emissions. This research is an extension of previous examinations of the economic ramifications of GHG regulation, including studies conducted by the U.S. Department of Energy, Energy Information Administration (2008b), Ford (2008), and Paltsev et. al. (2008).

The analytical framework more comprehensively accounts for the dynamics and comparative statics in the system of markets between coal, natural gas, oil, and wind energy than standard input output approaches. The policy model integrates the exogenous shock of federal GHG regulation into Wyoming's existing energy production system through an Equilibrium Displacement Model (EDM). The EDM utilizes demand (own-price and cross-price) and supply elasticities to consider the impacts upon the price and quantity of Wyoming's energy resources. (Uranium, a potential winner under federal action, is not considered in the analysis due to data constraints.) The feedback effect between price and quantity are incorporated through a demand response measure, although the model is not a true general equilibrium model. The total impact on the value of production and its influences on tax revenue is through the effective tax rates, which are approximately 18-20% for fossil fuels and 3.5% for wind energy. Reference price and quantity forecasts are provided by the DOE EIA *Annual Energy Outlook 2009*, which is the most commonly accepted forecast available.

Using the policy model, four distinct scenarios are simulated, allowing for some nuances of federal climate change action to be considered. A reference case is considered where no federal action occurs. The core scenario considers the implications of the Lieberman-Warner Climate Security Act of 2007 (S.2191), which was the most prominent legislation at the commencement of this research. The scenarios considered different rates of substitution between fuels as expressed through elasticities, altered rates of growth in the wind energy sector, and the deployment of clean coal technology. Although the policy model produces a large amount of data, the most relevant results are as follows:

1. Tax revenues increase under federal regulation of GHG emissions,
2. Coal tax revenue is adversely impacted by federal action,
3. Natural gas and oil tax revenue increase,
4. Overall energy production declines with federal action, and
5. Wind energy remains a small proportion of tax revenue without additional exogenous shocks.

These five results are present in each of the seven scenarios that consider federal regulation of GHG emissions. The magnitudes of the impacts vary across scenarios but the end result is the same; *Wyoming's energy derived tax revenues increase with federal regulation of GHG emissions*. Coal is always adversely impacted due to its high carbon intensity relative to its price. Even with advances that decrease the carbon intensity of coal, the industry experiences significant decline. Energy production moves away from coal and towards natural gas and oil. The production of natural gas and oil is of higher value than coal production, although less overall energy is produced. The enhanced price and quantity of these resources more than offsets the decline in revenue from coal production. Wind energy experiences the most rapid growth of any energy resources, but it still remains a minor component of tax revenue unless other drivers force tremendous growth. The relatively minor level of tax revenue created by wind energy is a result of low rates of taxation and very low initial production.

Implications

These key results have several important implications for Wyoming's energy dependent economy. The potential for climate change legislation to be beneficial for Wyoming's economy is not a widely held belief. Admittedly, this result is superficially counterintuitive. Wyoming is the leading coal producing state and possesses one of the nation's largest coal reserves. Climate change legislation devalues this resource if utilized with existing technologies. The consumer price of oil and natural gas will also increase with an explicit price for carbon, exerting downward pressure on demand. Loss of demand would theoretically depress prices received by producers. Without consideration of feedback and substitution, wind energy appears to be the only clear winner under federal action. This basic thinking fails to consider the interrelationship between energy resources.

The diversity and accessibility of Wyoming's energy resources is unrivalled in the U.S. This range of available energy resources insulates Wyoming against federal action that targets GHG emissions. As fossil fuels are exhaustible resources, it behooves the state to extract and sell the resources at the highest possible value, considering both current and future generations (with appropriate discount values). Federal climate change legislation enhances the value of natural gas and oil reserves. These resources are extracted at a higher value, although extraction occurs at the expense of coal. Coal that is not mined in the timeframe of this simulation is not lost. It remains available for future utilization when technological innovation (i.e., clean coal technology) or scarcity of substitutes (i.e., natural gas) improves its cost competitiveness. Wyoming benefits from a federal regulatory construct that increases the value of its collective fossil fuel reserves.

Admittedly, the benefit is felt on the aggregate level. Regional and local impacts of a rapidly declining coal industry could be devastating parts of this state. However, some coal producing areas are also blessed with significant natural gas and oil resources, which could mitigate some of the declines in coal production. There would still be large-scale structural changes and unemployment with the loss of the coal industry. The regional considerations are not within the scope of this analysis, but the political and economic difficulties perpetuated by this change in Wyoming's energy production system should not be ignored.

The relative unimportance of the wind energy created tax revenue is also important to consider. In the absence of altered market conditions that stimulate additional wind energy growth, the tax revenue created by wind energy is dwarfed by fossil fuels even under stringent federal GHG regulation. Under its existing tax structure, wind energy cannot readily replace the revenue created by fossil fuels. This is not to diminish the potential for the growth of revenue created by wind energy. The local taxes, landowner payments, and job creation could certainly have regional significance. The development and operation of wind energy also creates a sustainable revenue base that will not be depleted in the future.

State Level Policy Action

Policymakers can take proactive measures to maintain or enhance Wyoming's energy derived tax revenue when shocked by federal climate change legislation. State level research, tax policy, and economic development goals can be altered to enhance Wyoming's fiscal position in a carbon-constrained economy. Five policies should be considered to help mitigate the impact of federal action:

1. Promote research and development of clean coal technology including carbon capture,
2. Expand research into the extraction of unconventional natural gas and oil reserves,
3. Increase the effective tax rate on wind energy,
4. Encourage further development of electricity generation,
5. Embrace federal climate change action to strengthen Wyoming's market position.

This list includes numerous activities already being conducted by State entities, but the looming threat of federal action should add urgency to these missions. If coal can be made competitive with natural gas, the value of Wyoming's fossil fuels could be extended over a longer timeframe. Wyoming's massive coal reserves could continue to be developed at a pace that would provide lasting prosperity.

Natural gas and oil experience an increase in demand in all scenarios involving GHG regulation. The model assumes that the reserves of these resources are replaced at a rate equaling 95% of extraction. Finding additional resources could become more challenging as older, readily accessible reserves are depleted. Therefore, state support for enhanced oil recovery and advanced natural gas extraction techniques is prudent. The value of these resources increases in a carbon constrained future; therefore it benefits the state to maximize the reserves available for extraction at the higher value.

Additional taxation of wind energy was recently adopted in Wyoming includes a generation tax of $1/MWh and an accerated reinstatement of sales tax on equipment. Raising the tax rate on wind energy could increase tax revenues for Wyoming; it certainly would in the simulations conducted in this policy model. Wind is unique in that the resource is more widely dispersed than fossil fuel reserves. Wyoming must be careful not to drive beneficial development to other states with lower tax rates and/or better incentives. Also wind energy, like all renewable resources, is unique in that energy, and tax revenue, not harvested in the present is permanently lost.

Similar to wind energy generation, electricity generation from fossil fuels should also be encouraged. The tax revenue from electricity generation provides additional energy-derived tax revenue and multiplier effects. Electricity is value-added production that could increase tax revenue without requiring an expansion in production or increase in price of energy resources.

These policy recommendations are designed to recognize that economic analysis and policymaking are not always compatible. Still, the policy recommendations are rooted in applied economic research and data, not political aims. The ideal economic solution is often not politically feasible. For example, with proper consideration of discount values and risk preferences, it could benefit Wyoming to curtail current oil and natural gas production with the expectation that the real value of these resources will be greater in the future under federal GHG regulation. Revenue-maximizing limits on production would be difficult to legislate and enforce; therefore it is not a practical recommendation. The aforementioned recommendations require political courage, as support for federal GHG regulation would be generally unpopular. The recommendations seek to make decision makers aware of relevant information can either support their position (favor federal action) or require appropriate refutation (against federal action). Regardless of political position, the strength and merit of policy decisions is enhanced.

Further Research

The policy model created to examine the fiscal impacts of federal climate change legislation on Wyoming is merely a starting point for additional applied research. The model can be enhanced in both design and parameter selection. Ongoing research will improve the model and add to the academic literature in the field of energy economics and policy modeling. One issue is that he published literature lacks recent studies of elasticities. Many of the studies on elasticity of demand (own-price and cross-price) are dated. Additional research to consider national and regional demand elasticities would be especially useful for coal and wind energy. Moreover, they do not necessarily account for the effect of forward markets on elasticity estimates. Wind energy's distinction from standard electricity is seldom separated in the published literature. Ideally elasticities of demand could be obtained specifically for the Rocky Mountain West's energy production, particularly coal. Elasticities of supply are even more difficult to obtain. Information regarding how production responds to price change and expectations would enhance policy simulations.

Also the development of shale gas in other parts of the country could reduce demand for Wyoming's gas reserves given the relative remoteness of the resource. If demand for Wyoming gas drops because of these developments then State Government revenues could see a real decline. However, given the pipeline capacity in the state is doubtful that any precipitous drop in demand will occur.

Finally, the existing model could be improved through utilizing a more advanced form of forecasting Wyoming's energy production than maintaining its proportion of production found in 2007. The use of DOE EIA *Annual Energy Outlook 2009* information provides the least controversial forecasts, but other forecasts, particularly from private entities, could be utilized. This could allow for more dynamic growth for some resources, such as wind and natural gas, or allow for slower growth for others, such as oil. Unfortunately, no readily available estimates of Wyoming's energy production through 2030 are available. A more advanced production simulation could better represent Wyoming's energy future.

The application of the policy model could also be expanded. Tax revenue may not be the most important issue to Wyoming policymakers. How the tax revenue is allocated to public investment is particularly interesting. Wyoming utilizes a complex formula to allocate revenues from energy extraction to different functions. Changes in the proportion of revenue coming from one resource, for example coal, could adversely impact a sector of public investment that is tied to coal revenue. This sector may not benefit from increased revenue from other sources, such as natural gas. In the STELLA model, this would require an additional stock and flow, with appropriate converters, for each resource sub-model.

Additional sources of tax revenue in the energy production system could also be included, notably uranium production and carbon sequestration revenue. Uranium price and production could grow in a carbon constrained economy, as nuclear energy becomes more cost competitive. This could provide another source of tax revenue. The module for uranium would be very similar to the extraction of other nonrenewable resources. Information on production and prices could readily be incorporated into the model.

More complex would be the addition of revenues from carbon sequestration. As the price of GHG emissions increases, the option of sequestering emissions may become viable. Geologically sequestering CO_2 could create another resource tax revenue stream for Wyoming.

Just as production is taxed, so could sequestration, as a non-renewable resource (storage space) is being utilized. Currently the effective tax rate or potential amount of carbon sequestration is unknown, but this module could be added as a theoretical exercise to reveal more opportunities for tax revenue in a carbon constrained economy. The revenue impacts of other forms of mitigation, such as terrestrial sequestration offsets, could also be incorporated in the model.

These improvements and additions to this existing thesis research would provide a fuller, more complete, picture of the impacts of federal GHG regulation on Wyoming's energy-derived tax revenue. The initial policy model presented in this thesis is still beneficial for policymakers and stakeholders in Wyoming's energy economy. This research is also important to all Wyomingites, as the creation of energy-derived tax revenue helps to fund the high-quality of life that Wyoming citizens have come to expect.

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APPENDIX

STELLA model:

```
Coal Sub-Model
Coal_Electrcity_Production(t) = Coal_Electrcity_Production(t - dt) + (coal_for_electricity) * dt
INIT Coal_Electrcity_Production = 0
INFLOWS:
coal_for_electricity =
MMBTU_to_MWH*coal_generating_efficiency*coal_utilization_for_electricity*coal_extracting
Coal_Electricity_Tax_Revenue(t) = Coal_Electricity_Tax_Revenue(t - dt) + (coal_taxing_electricity -
coal_electricity_transfer) * dt
INIT Coal_Electricity_Tax_Revenue = 0
INFLOWS:
coal_taxing_electricity = coal_selling_electricity*coal_tax_rate_electrcity
OUTFLOWS:
coal_electricity_transfer = coal_taxing_electricity
Coal_Electricity__Revenue(t) = Coal_Electricity__Revenue(t - dt) + (coal_selling_electricity -
coal_taxing_electricity) * dt
INIT Coal_Electricity__Revenue = 0
INFLOWS:
coal_selling_electricity = coal_eia_price_of_elec_estimates*coal_for_electricity
OUTFLOWS:
coal_taxing_electricity = coal_selling_electricity*coal_tax_rate_electrcity
Coal_I&I_Tax_Revenue(t) = Coal_I&I_Tax_Revenue(t - dt) + (coal_taxing_i&i - coal_I&I__transfer) * dt
INIT Coal_I&I_Tax_Revenue = 0
INFLOWS:
coal_taxing_i&i = coal_creating_wealth*coal_tax_rate_i&i
OUTFLOWS:
coal_I&I__transfer = coal_taxing_i&i
Coal_Indirect_&_Induced_Revenue(t) = Coal_Indirect_&_Induced_Revenue(t - dt) + (coal_creating_wealth -
coal_taxing_i&i) * dt
INIT Coal_Indirect_&_Induced_Revenue = 0
INFLOWS:
coal_creating_wealth =
coal_electricity__multiplier*coal_selling_electricity+coal_production__multiplier*coal_selling
OUTFLOWS:
coal_taxing_i&i = coal_creating_wealth*coal_tax_rate_i&i
Coal_Production(t) = Coal_Production(t - dt) + (coal_extracting) * dt
INIT Coal_Production = 0
INFLOWS:
coal_extracting = coal_extraction*.95
Coal_Production_Revenue(t) = Coal_Production_Revenue(t - dt) + (coal_selling - coal_taxing__production) * dt
INIT Coal_Production_Revenue = 0
INFLOWS:
coal_selling = coal_extracting*(coal_price+coal_isolated_demand_response)
OUTFLOWS:
coal_taxing__production = coal_selling*coal_tax_rate_production
Coal_Production_Tax_Revenue(t) = Coal_Production_Tax_Revenue(t - dt) + (coal_taxing__production -
coal_production_transfer) * dt
INIT Coal_Production_Tax_Revenue = 0
INFLOWS:
coal_taxing__production = coal_selling*coal_tax_rate_production
OUTFLOWS:
coal_production_transfer = coal_taxing__production
```

Coal_Reserves(t) = Coal_Reserves(t - dt) + (coal_exploration - coal_extracting) * dt
INIT Coal_Reserves = 1.29008e+011
INFLOWS:
coal_exploration = coal_extracting*1
OUTFLOWS:
coal_extracting = coal_extraction*.95
Coal_Tax__Receipts(t) = Coal_Tax__Receipts(t - dt) + (coal_electricity_transfer + coal_I&I__transfer + coal_production_transfer) * dt
INIT Coal_Tax__Receipts = 0
INFLOWS:
coal_electricity_transfer = coal_taxing_electricity
coal_I&I__transfer = coal_taxing_i&i
coal_production_transfer = coal_taxing__production
coal_annual_taxes = coal_taxing_i&i+coal_taxing__production+coal_taxing_electricity
coal_carbon_intensity = coal_carbon_intensity_base*Clean_Coal_Scaler
coal_carbon_intensity_base = .10635
coal_change_in_quantity = coal_quantity_change_cross_price_ng+coal_quantity_change_cross_price_oil+coal_quantity_change_cross_price_wind+coal_quantity_change_own_price+coal_quantity__change_demand_response
coal_cp_ng_scaler = 1*Master_Elasticity_Scaler
coal_cp_oil_scaler = 1*Master_Elasticity_Scaler
coal_cp_wind_scaler = 1*Master_Elasticity_Scaler
coal_cross_price_ng_coefficient = 0.174*coal_cp_ng_scaler*Elasticity_Design
coal_cross_price_oil_coefficient = 0.37*coal_cp_oil_scaler*Elasticity_Design
coal_cross_price_wind_coefficient = 0.91*coal_cp_wind_scaler*Elasticity_Design
coal_demand_response = coal_price*(-coal_total_price_effect/100)*coal_demand_response_coefficient
coal_demand_response_coefficient = .5
coal_eia_price__scaled = coal_eia_price_estimates*coal_price_scaler
coal_elas__of_supply = .9*Elasticity_Design*Master_Elasticity_Scaler
coal_electricity__multiplier = 0.360918
coal_extraction = coal_extraction_baseline*(1+coal_change_in_quantity/100)*Coal_Elimination_Scenario_Variable
coal_extraction_baseline = coal_WY_share_of_production*coal_eia_production_estimates
coal_generating_efficiency = .5
coal_isolated_demand_response = coal_demand_response
coal_MMBTU_to__short_tons = 17.6
coal_own_price_elasticity = -.327*coal_own_scaler*Elasticity_Design
coal_own_scaler = 1*Master_Elasticity_Scaler
coal_price = coal_eia_price__scaled*coal_WY_price_discount
coal_price_change = (coal_price__premium/coal_eia_price__scaled)*100
coal_price_change_cross_price_ng = ng_price_change*coal_cross_price_ng_coefficient/(coal_elas__of_supply-coal_own_price_elasticity)
coal_price_change_cross_price_oil = coal_cross_price_oil_coefficient*oil_price_change/(coal_elas__of_supply-coal_own_price_elasticity)
coal_price_change_cross_price_wind = coal_cross_price_wind_coefficient*wind_price_change/(coal_elas__of_supply-coal_own_price_elasticity)
coal_price_change_own_price = coal_own_price_elasticity*-coal_price_change/(coal_elas__of_supply+coal_own_price_elasticity)
coal_price_scaler = 1
coal_price__change_demand_response = ((coal_demand_response/coal_eia_price__scaled)*100)
coal_price__premium = coal_carbon_intensity*Price_of_CO2
Coal_Production_short_tons = (1/coal_MMBTU_to__short_tons)*Coal_Production
coal_production__multiplier = 0.442884
coal_quantity_change_cross_price_ng = coal_price_change_cross_price_ng*coal_own_price_elasticity+coal_cross_price_ng_coefficient*ng_price_change
coal_quantity_change_cross_price_oil = coal_own_price_elasticity*coal_price_change_cross_price_oil+coal_cross_price_oil_coefficient*oil_price_change

```
coal_quantity_change_cross_price_wind = coal_price_change_cross_price_wind*coal_own_price_elasticity+coal_cross_price_wind_coefficient*wind_price_change
coal_quantity_change_own_price = coal_price_change_own_price*coal_own_price_elasticity
coal_quantity__change_demand_response = coal_price__change_demand_response*coal_own_price_elasticity
Coal_Reserves_short_tons = Coal_Reserves*(1/coal_MMBTU_to__short_tons)
coal_tax_rate_electrcity = 0.035022747
coal_tax_rate_i&i = 0.071281362
coal_tax_rate_production = 0.200729861
coal_total_effect = coal_cp_ng_scaler + coal_cp_oil_scaler + coal_cp_wind_scaler + coal_own_scaler
coal_total_price = coal_isolated_demand_response + coal_price
coal_total_price_effect = coal_price_change_own_price + coal_price_change_cross_price_ng + coal_price_change_cross_price_oil + coal_price_change_cross_price_wind
coal_utilization_for_electricity = .003270130066
coal_WY_price_discount = .369084
coal_WY_share_of_production = .7303
MMBTU_to_MWH = 0.2932997
coal_eia_price_estimates = GRAPH(TIME)
(2007, 1.27), (2008, 1.39), (2009, 1.47), (2010, 1.44), (2011, 1.44), (2012, 1.45), (2013, 1.45), (2014, 1.45), (2015, 1.42), (2016, 1.42), (2017, 1.41), (2018, 1.41), (2019, 1.40), (2020, 1.39), (2021, 1.39), (2022, 1.40), (2023, 1.41), (2024, 1.42), (2025, 1.42), (2026, 1.43), (2027, 1.44), (2028, 1.45), (2029, 1.45), (2030, 1.46)
coal_eia_price_of_elec_estimates = GRAPH(TIME)
(2007, 60.3), (2008, 66.7), (2009, 66.6), (2010, 59.8), (2011, 59.5), (2012, 58.6), (2013, 58.6), (2014, 58.3), (2015, 58.6), (2016, 59.1), (2017, 59.7), (2018, 60.6), (2019, 61.7), (2020, 62.4), (2021, 62.1), (2022, 62.3), (2023, 63.4), (2024, 64.7), (2025, 66.4), (2026, 67.8), (2027, 69.2), (2028, 70.5), (2029, 71.4), (2030, 72.5)
coal_eia_production_estimates = GRAPH(TIME)
(2007, 1.1e+10), (2008, 1.1e+10), (2009, 1.1e+10), (2010, 1.1e+10), (2011, 1.1e+10), (2012, 1.1e+10), (2013, 1.1e+10), (2014, 1.1e+10), (2015, 1.2e+10), (2016, 1.2e+10), (2017, 1.2e+10), (2018, 1.2e+10), (2019, 1.2e+10), (2020, 1.2e+10), (2021, 1.2e+10), (2022, 1.2e+10), (2023, 1.2e+10), (2024, 1.2e+10), (2025, 1.2e+10), (2026, 1.2e+10), (2027, 1.2e+10), (2028, 1.2e+10), (2029, 1.3e+10), (2030, 1.3e+10)
```

Natural Gas Model

```
NG_Electricity_Production(t) = NG_Electricity_Production(t - dt) + (ng_for_electricity) * dt
INIT NG_Electricity_Production = 0
INFLOWS:
ng_for_electricity(IN SECTOR:  Scnerarios & Sumamry)
NG_Electricity_Revenue(t) = NG_Electricity_Revenue(t - dt) + (ng_selling_electricity - ng_taxing_electricity) * dt
INIT NG_Electricity_Revenue = 0
INFLOWS:
ng_selling_electricity = ng_eia_price_elec_estimates*ng_for_electricity
OUTFLOWS:
ng_taxing_electricity = ng_selling_electricity*ng_effective_tax_rate_electricity
NG_Electricity_Tax_Revenue(t) = NG_Electricity_Tax_Revenue(t - dt) + (ng_taxing_electricity - ng_electricity_transfer) * dt
INIT NG_Electricity_Tax_Revenue = 0
INFLOWS:
ng_taxing_electricity = ng_selling_electricity*ng_effective_tax_rate_electricity
OUTFLOWS:
ng_electricity_transfer = ng_taxing_electricity
NG_I&I_Revenue(t) = NG_I&I_Revenue(t - dt) + (ng_creating_wealth - ng_taxing_i&i) * dt
INIT NG_I&I_Revenue = 0
INFLOWS:
ng_creating_wealth = (ng_selling*ng_production__multiplier)+(ng_selling_electricity*ng_electricity__multiplier)
OUTFLOWS:
ng_taxing_i&i = ng_effective_tax_rate_i&i*ng_creating_wealth
NG_I&I_Tax_Revenue(t) = NG_I&I_Tax_Revenue(t - dt) + (ng_taxing_i&i - ng_I&I__transfer) * dt
```

```
INIT NG_I&I_Tax_Revenue = 0
INFLOWS:
ng_taxing_i&i = ng_effective_tax_rate_i&i*ng_creating_wealth
OUTFLOWS:
ng_I&I__transfer = ng_taxing_i&i
NG_Production(t) = NG_Production(t - dt) + (ng_extracting) * dt
INIT NG_Production = 0
INFLOWS:
ng_extracting = ng_extraction
NG_Production_Tax_Revenue(t) = NG_Production_Tax_Revenue(t - dt) + (ng_taxing__production -
ng_production_transfer) * dt
INIT NG_Production_Tax_Revenue = 0
INFLOWS:
ng_taxing__production = ng_selling*ng_effective_tax_rate_production
OUTFLOWS:
ng_production_transfer = ng_taxing__production
NG_Reserves(t) = NG_Reserves(t - dt) + (ng_exploration - ng_extracting) * dt
INIT NG_Reserves = 30541880000
INFLOWS:
ng_exploration = ng_extracting*1
OUTFLOWS:
ng_extracting = ng_extraction
NG_Tax__Receipts(t) = NG_Tax__Receipts(t - dt) + (ng_electricity_transfer + ng_production_transfer +
ng_I&I__transfer) * dt
INIT NG_Tax__Receipts = 0
INFLOWS:
ng_electricity_transfer = ng_taxing_electricity
ng_production_transfer = ng_taxing__production
ng_I&I__transfer = ng_taxing_i&i
ng_selling = ng_extracting*(ng_price+ng_isolated_demand__response)
INFLOW TO:  NG_Production_Revenue      (IN SECTOR:  Scnerarios & Sumamry)
conversion_MMBTU_to_MWH = 0.2932997
ng_annual_taxes = ng_taxing_electricity + ng_taxing_i&i + ng_taxing__production
ng_carbon_intensity = .05854
ng_change_in_quantity =
ng_quantity_change_cross_price_coal+ng_quantity_change_cross_price_oil+ng_quantity_change_cross_price_win
d+ng_quantity_change_own_price+ng_quantity_change_demand_response
ng_cp_coal_scaler = 1*Master_Elasticity_Scaler
ng_cp_oil_scaler = 1*Master_Elasticity_Scaler
ng_cp_wind_scaler = 1*Master_Elasticity_Scaler
ng_cross_price_coal_coefficient = 0.26*ng_cp_coal_scaler*Elasticity_Design
ng_cross_price_oil_coefficient = 0.13*ng_cp_oil_scaler*Elasticity_Design
ng_cross_price_wind_coefficient = 0.65*ng_cp_wind_scaler*Elasticity_Design
ng_demand_response = ng_price*(ng_total_price_effect/100)*ng_demand_response__coeffienct
ng_demand_response__coeffienct = .5
ng_effective_tax_rate_electricity = 0.035022747
ng_effective_tax_rate_i&i = 0.071281362
ng_effective_tax_rate_production = 0.194453763
ng_eia_price_scaled = ng_eia_price_estimates*ng_price_scaler
ng_elas_of__supply = .55*Master_Elasticity_Scaler*Elasticity_Design
ng_extraction =
ng_extraction_baseline*(1+ng_change_in_quantity/100)+Natural_Gas_Response_to_Coal_Elimination
ng_extraction_baseline = ng_WY_share_of_production*ng_eia_production_estimates
ng_generating_efficiency = .5
ng_isolated_demand__response = ng_demand_response
ng_MMBTU_to_MMCF = .00097276
```

ng_own_price_elasticity = -1.012*ng_own_scaler*Elasticity_Design
ng_own_scaler = 1*Master_Elasticity_Scaler
ng_price = ng_eia_price_scaled*ng_WY_price_discount
ng_price_change = ng_price__premium/ng_eia_price_scaled
ng_price_change_cross_price_coal = (coal_price_change*ng_cross_price_coal_coefficient)/(ng_elas_of__supply-ng_own_price_elasticity)
ng_price_change_cross_price_oil = ng_cross_price_oil_coefficient*oil_price_change/(ng_elas_of__supply-ng_own_price_elasticity)
ng_price_change_demand_response = ((ng_demand_response/ng_eia_price_scaled)*100)
ng_price_change_own_price = ng_own_price_elasticity*-ng_price_change/(ng_elas_of__supply-ng_own_price_elasticity)
ng_price_change__cross_price_wind = (ng_cross_price_wind_coefficient*wind_price_change)/(ng_elas_of__supply-ng_own_price_elasticity)
ng_price_scaler = 1
ng_price__premium = Price_of_CO2*ng_carbon_intensity
NG_Production_MMCF = NG_Production*ng_MMBTU_to_MMCF
ng_quantity_change_cross_price_coal = ng_price_change_cross_price_coal*ng_own_price_elasticity+ng_cross_price_coal_coefficient*coal_price_change
ng_quantity_change_cross_price_oil = ng_own_price_elasticity*ng_price_change_cross_price_oil+ng_cross_price_oil_coefficient*oil_price_change
ng_quantity_change_cross_price_wind = ng_own_price_elasticity*ng_price_change__cross_price_wind+ng_cross_price_wind_coefficient*wind_price_change
ng_quantity_change_demand_response = ng_price_change_demand_response*ng_own_price_elasticity
ng_quantity_change_own_price = ng_own_price_elasticity*ng_price_change_own_price
NG_Reserves_MMCF = NG_Reserves*ng_MMBTU_to_MMCF
ng_total_effect_elasticity = ng_cp_coal_scaler + ng_cp_oil_scaler + ng_cp_wind_scaler + ng_own_scaler
ng_total_price = ng_price + ng_isolated_demand__response
ng_total_price_effect = ng_price_change_cross_price_oil + ng_price_change_cross_price_coal + ng_price_change_own_price + ng_price_change__cross_price_wind
ng_utilization_for_electricity = .00013647
ng_WY_price_discount = .73
ng_WY_share_of_production = .096
ng_eia_price_elec_estimates = GRAPH(TIME)
(2007, 60.3), (2008, 66.7), (2009, 66.6), (2010, 59.8), (2011, 59.5), (2012, 58.6), (2013, 58.6), (2014, 58.3), (2015, 58.6), (2016, 59.1), (2017, 59.7), (2018, 60.6), (2019, 61.7), (2020, 62.4), (2021, 62.1), (2022, 62.3), (2023, 63.4), (2024, 64.7), (2025, 66.4), (2026, 67.8), (2027, 69.2), (2028, 70.5), (2029, 71.4), (2030, 72.5)
ng_eia_price_estimates = GRAPH(TIME)
(2007, 6.22), (2008, 7.78), (2009, 5.58), (2010, 5.88), (2011, 5.85), (2012, 5.97), (2013, 5.97), (2014, 6.03), (2015, 6.10), (2016, 6.20), (2017, 6.34), (2018, 6.52), (2019, 6.68), (2020, 6.56), (2021, 6.38), (2022, 6.44), (2023, 6.54), (2024, 6.86), (2025, 7.13), (2026, 7.40), (2027, 7.66), (2028, 7.87), (2029, 8.03), (2030, 8.17)
ng_eia_production_estimates = GRAPH(TIME)
(2007, 2e+10), (2008, 2.1e+10), (2009, 2.1e+10), (2010, 2.1e+10), (2011, 2.1e+10), (2012, 2.1e+10), (2013, 2.1e+10), (2014, 2.1e+10), (2015, 2.1e+10), (2016, 2.1e+10), (2017, 2.1e+10), (2018, 2.1e+10), (2019, 2.2e+10), (2020, 2.2e+10), (2021, 2.3e+10), (2022, 2.3e+10), (2023, 2.4e+10), (2024, 2.4e+10), (2025, 2.4e+10), (2026, 2.4e+10), (2027, 2.4e+10), (2028, 2.4e+10), (2029, 2.4e+10), (2030, 2.4e+10)

Oil Sub-Model
Oil_I&I_Tax_Revenue(t) = Oil_I&I_Tax_Revenue(t - dt) + (oil_taxing_i&i - oil_I&I__transfer) * dt
INIT Oil_I&I_Tax_Revenue = 0
INFLOWS:
oil_taxing_i&i = oil_tax_rate_i&i*oil_creating_wealth
OUTFLOWS:
oil_I&I__transfer = oil_taxing_i&i
Oil_Indirect_&_Induced_Revenue(t) = Oil_Indirect_&_Induced_Revenue(t - dt) + (oil_creating_wealth - oil_taxing_i&i) * dt

```
INIT Oil_Indirect_&_Induced_Revenue = 0
INFLOWS:
oil_creating_wealth = oil_production__multiplier*oil_selling
OUTFLOWS:
oil_taxing_i&i = oil_tax_rate_i&i*oil_creating_wealth
Oil_Production(t) = Oil_Production(t - dt) + (oil_extracting) * dt
INIT Oil_Production = 0
INFLOWS:
oil_extracting = oil_extraction
Oil_Production_Revenue(t) = Oil_Production_Revenue(t - dt) + (oil_selling - oil_taxing__production) * dt
INIT Oil_Production_Revenue = 0
INFLOWS:
oil_selling = oil_extracting*(oil_price+oil_isolated_demand__response)
OUTFLOWS:
oil_taxing__production = oil_selling*oil_tax_rate_production
Oil_Production_Tax_Revenue(t) = Oil_Production_Tax_Revenue(t - dt) + (oil_taxing__production -
oil_production_transfer) * dt
INIT Oil_Production_Tax_Revenue = 0
INFLOWS:
oil_taxing__production = oil_selling*oil_tax_rate_production
OUTFLOWS:
oil_production_transfer = oil_taxing__production
Oil_Reserves(t) = Oil_Reserves(t - dt) + (oil_exploration - oil_extracting) * dt
INIT Oil_Reserves = 4002000000
INFLOWS:
oil_exploration = oil_extracting*.95
OUTFLOWS:
oil_extracting = oil_extraction
Oil_Tax__Receipts(t) = Oil_Tax__Receipts(t - dt) + (oil_I&I__transfer + oil_production_transfer) * dt
INIT Oil_Tax__Receipts = 0
INFLOWS:
oil_I&I__transfer = oil_taxing_i&i
oil_production_transfer = oil_taxing__production
oil_annual_taxes = oil_taxing__production+ oil_taxing_i&i
oil_carbon_intensity = 0.0782125
oil_change_in_quantity =
oil_quantity_change_cross_price_coal+oil_quantity_change_cross_price_ng+oil_quantity_change_cross_price_win
d+oil_quantity_change_own_price+oil_quantity__change_demand_response
oil_cp_coal_scaler = 1*Master_Elasticity_Scaler
oil_cp_ng_scaler = 1*Master_Elasticity_Scaler
oil_cp_wind_scaler = 1*Master_Elasticity_Scaler
oil_cross_price_coal_coefficient = .1*oil_cp_coal_scaler*Elasticity_Design
oil_cross_price_ng_coefficient = 0.13*oil_cp_ng_scaler*Elasticity_Design
oil_cross_price_wind_coefficient = .04*oil_cp_wind_scaler*Elasticity_Design
oil_demand_response = oil_price*(oil_total_price_effect/100)*oil_demand_response_coefficient
oil_demand_response_coefficient = .5
oil_eia_price__scaled = oil_eia_price_estimates*oil_price_scaler
oil_elas_of_supply = .1*Master_Elasticity_Scaler*Elasticity_Design
oil_extraction = oil_extraction_baseline*(1+oil_change_in_quantity/100)
oil_extraction_baseline = oil_WY_share_of_production*oil_eia_producion_estimates
oil_isolated_demand__response = oil_demand_response
oil_MMBTU_to_barrels = 5.8
oil_own_price_elastisicity = -0.253*oil_own_scaler*Elasticity_Design
oil_own_scaler = 1*Master_Elasticity_Scaler
oil_price = oil_WY_price_discount*oil_eia_price__scaled
oil_price_change = (oil_price_premium/oil_eia_price__scaled)*100
```

oil_price_change_cross_price_coal = oil_cross_price_coal_coefficient*coal_price_change/(oil_elas_of_supply-oil_own_price_elastisicity)
oil_price_change_cross_price_ng = oil_cross_price_ng_coefficient*ng_price_change/(oil_elas_of_supply-oil_own_price_elastisicity)
oil_price_change_cross_price_wind = oil_cross_price_wind_coefficient*wind_price_change/(oil_elas_of_supply-oil_own_price_elastisicity)
oil_price_change_own_price = oil_own_price_elastisicity*-oil_price_change/(oil_elas_of_supply-oil_own_price_elastisicity)
oil_price_premium = oil_carbon_intensity*Price_of_CO2
oil_price_scaler = 1
oil_price__change_demand_response = ((oil_demand_response/oil_eia_price__scaled)*100)
Oil_Production_barrels = Oil_Production*(1/oil_MMBTU_to_barrels)
oil_production__multiplier = 0.453373
oil_quantity_change_cross_price_coal = oil_price_change_cross_price_coal*oil_own_price_elastisicity+oil_cross_price_coal_coefficient*coal_price_change
oil_quantity_change_cross_price_ng = oil_price_change_cross_price_ng*oil_own_price_elastisicity+oil_cross_price_ng_coefficient*ng_price_change
oil_quantity_change_cross_price_wind = oil_price_change_cross_price_wind*oil_own_price_elastisicity+oil_cross_price_wind_coefficient*wind_price_change
oil_quantity_change_own_price = oil_price_change_own_price*oil_own_price_elastisicity
oil_quantity__change_demand_response = oil_price__change_demand_response*oil_own_price_elastisicity
Oil_Reserves_barrels = Oil_Reserves*(1/oil_MMBTU_to_barrels)
oil_tax_rate_i&i = 0.071281362
oil_tax_rate_production = 0.188176555
oil_total_effect = oil_own_price_elastisicity + oil_cross_price_coal_coefficient + oil_cross_price_ng_coefficient + oil_cross_price_wind_coefficient
oil_total_price = oil_price + oil_isolated_demand__response
oil_total_price_effect = coal_price_change_own_price+ coal_price_change_cross_price_ng + coal_price_change_cross_price_oil + coal_price_change_cross_price_wind
oil_WY_price_discount = .792179
oil_WY_share_of_production = .029
oil_eia_price_estimates = GRAPH(TIME)
(2007, 11.4), (2008, 17.6), (2009, 10.5), (2010, 13.9), (2011, 15.3), (2012, 16.9), (2013, 17.8), (2014, 18.7), (2015, 19.4), (2016, 19.6), (2017, 19.8), (2018, 19.9), (2019, 20.1), (2020, 20.0), (2021, 20.1), (2022, 20.4), (2023, 20.2), (2024, 20.4), (2025, 20.6), (2026, 20.8), (2027, 21.2), (2028, 21.6), (2029, 21.8), (2030, 22.3)
oil_eia_producion_estimates = GRAPH(TIME)
(2007, 8.9e+09), (2008, 8.7e+09), (2009, 9.5e+09), (2010, 1e+10), (2011, 1e+10), (2012, 1e+10), (2013, 1.1e+10), (2014, 1.1e+10), (2015, 1.1e+10), (2016, 1.1e+10), (2017, 1.1e+10), (2018, 1.1e+10), (2019, 1.1e+10), (2020, 1.2e+10), (2021, 1.2e+10), (2022, 1.2e+10), (2023, 1.3e+10), (2024, 1.3e+10), (2025, 1.3e+10), (2026, 1.3e+10), (2027, 1.4e+10), (2028, 1.4e+10), (2029, 1.4e+10), (2030, 1.4e+10)

Scnerarios & Sumamry
NG_Production_Revenue(t) = NG_Production_Revenue(t - dt) + (ng_selling - ng_taxing__production) * dt
INIT NG_Production_Revenue = 0
INFLOWS:
ng_selling (IN SECTOR: Natural Gas Model)
OUTFLOWS:
ng_taxing__production (IN SECTOR: Natural Gas Model)
ng_for_electricity = ng_extracting*ng_utilization_for_electricity*conversion_MMBTU_to_MWH*ng_generating_efficiency
INFLOW TO: NG_Electricity_Production (IN SECTOR: Natural Gas Model)
Clean_Coal_Scaler = Coal_Carbon_Intensity_Scaler
Coal_Elimination_Scenario_Variable = Coal_Elimination_Quantity
Elasticity_Design = Type_of_Elasticity
Master_Elasticity_Scaler = 1

Natural_Gas_Response_to_Coal_Elimination = IF(Coal_Elimination_Scenario=1 AND Price_of_CO2>50) THEN (Coal_Production_Lost*.5)
ELSE (0)
ng_electricity__multiplier = 0.360918
ng_production__multiplier = 0.453373
Price_of_CO2 = type_of_GHG_Regulation
total_annual_taxes = wind_annual_taxes+ oil_annual_taxes + ng_annual_taxes + coal_annual_taxes
total_taxes = Coal_Tax__Receipts + NG_Tax__Receipts + Oil_Tax__Receipts + Wind_Tax_Receipts
Wind_Energy__Production_Scenario = Type_of_WInd_Growth
Wind_Response_to_Coal_Elimination =
IF(Price_of_CO2>50 AND Coal_Elimination_Scenario=1) THEN
(Coal_Production_Lost*.5*conversion_MMBTU_to_MWH
)
ELSE (0)
Clean Coal
Clean_Coal_Carbon_Intensity_Scaler = .5
Clean_Coal_Scenario = 1
Coal_Carbon_Intensity_Scaler = IF(Clean_Coal_Scenario=1) THEN(Clean_Coal_Carbon_Intensity_Scaler)
ELSE(Status_Quo_Coal_Carbon_Intensity)
Status_Quo_Coal_Carbon_Intensity = 1
Coal Elmination
Coal_Elimination = 0
Coal_Elimination_Quantity = IF(Coal_Elimination_Scenario=1 AND Price_of_CO2>50) THEN(Coal_Elimination)
ELSE(Status_Quo_Coal_Elim)
Coal_Elimination_Scenario = 1
Coal_Production_Lost = coal_extraction_baseline*(1+coal_change_in_quantity/100)
Status_Quo_Coal_Elim = 1
Federal GHG Regulation
Price_of_CO2_Reference = 0
regulation_of_GHG = 1
type_of_GHG_Regulation = IF(regulation_of_GHG=0)THEN(Price_of_CO2_Reference)
ELSE(Price_of_CO2__Core)
Price_of_CO2__Core = GRAPH(TIME)
(2007, 0.00), (2008, 0.00), (2009, 0.00), (2010, 0.00), (2011, 0.00), (2012, 10.0), (2013, 12.5), (2014, 15.0), (2015, 17.5), (2016, 20.0), (2017, 22.5), (2018, 25.0), (2019, 27.5), (2020, 30.0), (2021, 33.1), (2022, 36.2), (2023, 39.3), (2024, 42.4), (2025, 45.5), (2026, 48.6), (2027, 51.7), (2028, 54.8), (2029, 57.9), (2030, 61.0)
Scaled Elasticities
Increasing_Elasticity = 1
Type_of_Elasticity = IF(Increasing_Elasticity=1)THEN(Inelastic_to_Elastic_Scaler)
ELSE(Uniform_Elasticity)
Uniform_Elasticity = 1
Inelastic_to_Elastic_Scaler = GRAPH(TIME)
(2007, 1.00), (2008, 1.00), (2009, 1.00), (2010, 1.00), (2011, 1.00), (2012, 0.5), (2013, 0.667), (2014, 0.833), (2015, 1.00), (2016, 1.00), (2017, 1.00), (2018, 1.00), (2019, 1.00), (2020, 1.00), (2021, 1.00), (2022, 1.00), (2023, 1.00), (2024, 1.00), (2025, 1.00), (2026, 1.00), (2027, 1.00), (2028, 1.00), (2029, 1.00), (2030, 1.00)
Wind Energy Growth
fossil_fuel_annual_extraction = coal_extracting + ng_extracting + oil_extracting
Type_of_WInd_Growth = IF(Wind_Energy_Growth=1)THEN(Wind_Energy_Production_Forced)
ELSE(Wind_Status_Quo)
Wind_Energy_Growth = 1
Wind_Energy_Production_Forced =
Wind_Energy__Growth_Rate*fossil_fuel_annual_extraction*conversion_MMBTU_to_MWH
Wind_Status_Quo = wind_production_baseline
Wind_Energy__Growth_Rate = GRAPH(TIME)
(2007, 0.01), (2008, 0.0183), (2009, 0.0269), (2010, 0.0355), (2011, 0.0442), (2012, 0.0528), (2013, 0.0614), (2014, 0.0701), (2015, 0.0787), (2016, 0.0873), (2017, 0.096), (2018, 0.105), (2019, 0.113), (2020, 0.122), (2021, 0.131),

(2022, 0.139), (2023, 0.148), (2024, 0.156), (2025, 0.165), (2026, 0.174), (2027, 0.182), (2028, 0.191), (2029, 0.2), (2030, 0.2)

Wind Sub-Model
Wind_Electrcity_Production(t) = Wind_Electrcity_Production(t - dt) + (wind_for_electricity) * dt
INIT Wind_Electrcity_Production = 0
INFLOWS:
wind_for_electricity = wind_development
Wind_Electricity_Tax_Revenue(t) = Wind_Electricity_Tax_Revenue(t - dt) + (wind_taxing_electricity - wind_electricity_transfer) * dt
INIT Wind_Electricity_Tax_Revenue = 0
INFLOWS:
wind_taxing_electricity = wind_tax_rate_electrcity*wind_selling_of_electricity
OUTFLOWS:
wind_electricity_transfer = wind_taxing_electricity
Wind_Electricity__Revenue(t) = Wind_Electricity__Revenue(t - dt) + (wind_selling_of_electricity - wind_taxing_electricity) * dt
INIT Wind_Electricity__Revenue = 0
INFLOWS:
wind_selling_of_electricity = wind_for_electricity*(wind_price_added_value_scaler+wind_isolated_demand_response)
OUTFLOWS:
wind_taxing_electricity = wind_tax_rate_electrcity*wind_selling_of_electricity
WInd_I&I_Tax_Revenue(t) = WInd_I&I_Tax_Revenue(t - dt) + (wind_taxing_i&i - wind_I&I_transfer) * dt
INIT WInd_I&I_Tax_Revenue = 0
INFLOWS:
wind_taxing_i&i = wind_tax_rate_i&i*wind_creating_wealth
OUTFLOWS:
wind_I&I_transfer = wind_taxing_i&i
Wind_Indirect_&_Induced_Revenue(t) = Wind_Indirect_&_Induced_Revenue(t - dt) + (wind_creating_wealth - wind_taxing_i&i) * dt
INIT Wind_Indirect_&_Induced_Revenue = 0
INFLOWS:
wind_creating_wealth = wind_electricity__multiplier*wind_selling_of_electricity
OUTFLOWS:
wind_taxing_i&i = wind_tax_rate_i&i*wind_creating_wealth
Wind_Reserves(t) = Wind_Reserves(t - dt) + (wind_renewal - wind_for_electricity) * dt
INIT Wind_Reserves = 545000000
INFLOWS:
wind_renewal = wind_for_electricity
OUTFLOWS:
wind_for_electricity = wind_development
Wind_Tax_Receipts(t) = Wind_Tax_Receipts(t - dt) + (wind_electricity_transfer + wind_I&I_transfer) * dt
INIT Wind_Tax_Receipts = 0
INFLOWS:
wind_electricity_transfer = wind_taxing_electricity
wind_I&I_transfer = wind_taxing_i&i
wind_annual_taxes = wind_taxing_i&i + wind_taxing_electricity
wind_carbon_intensity = 0
wind_change_in_quantity = wind_quantity_change_cross_price_coal+wind_quantity_change_cross_price_ng+wind_quantity_change_cross_price_oil+wind_quantity_change_own_price+wind_quantity__change_demand_response
wind_cp_coal_scaler = 1*Master_Elasticity_Scaler
wind_cp_ng_scaler = 1*Master_Elasticity_Scaler
wind_cp_oil_scaler = 1*Master_Elasticity_Scaler
wind_cross_price_coal_coefficient = 0.13*wind_cp_coal_scaler*Elasticity_Design

wind_cross_price_ng_coefficient = 0.53*wind_cp_ng_scaler*Elasticity_Design
wind_cross_price_oil_coefficient = 0.01*wind_cp_oil_scaler*Elasticity_Design
wind_demand_response_coefficient = .5
wind_demand_response_MWH = wind_price_added_value_scaler*(wind_total__price_effect/100)*wind_demand_response_coefficient
wind_development = Wind_Energy__Production_Scenario*(1+(wind_change_in_quantity/100))+Wind_Response_to_Coal_Elimination
wind_elas_of_supply = .5*Master_Elasticity_Scaler*Elasticity_Design
wind_electricity__multiplier = 0.360918
wind_isolated_demand_response = wind_demand_response_MWH
wind_own_price_elastisicity = -0.263*wind_own_scaler*Elasticity_Design
wind_own_scaler = 1*Master_Elasticity_Scaler
wind_price_added_value_scaler = (1+wind_added_value)*wind_eia_price_of_electricity*wind_price_scaler
wind_price_change = ((wind_price__premeium*(1/conversion_MMBTU_to_MWH))/wind_price_added_value_scaler)*100
wind_price_change_cross_price_coal = wind_cross_price_coal_coefficient*coal_price_change/(wind_elas_of_supply-wind_own_price_elastisicity)
wind_price_change_cross_price_ng = wind_cross_price_ng_coefficient*ng_price_change/(wind_elas_of_supply-wind_own_price_elastisicity)
wind_price_change_own_price = wind_own_price_elastisicity*(-wind_price_change)/(wind_elas_of_supply-wind_own_price_elastisicity)
wind_price_change__cross_price_oil = wind_cross_price_oil_coefficient*oil_price_change/(wind_elas_of_supply-wind_own_price_elastisicity)
wind_price_scaler = 1
wind_price__change_demand_response = ((wind_demand_response_MWH/wind_price_added_value_scaler)*100)
wind_price__premeium = Price_of_CO2*wind_carbon_intensity
wind_production_baseline = wind_WY_share_of_production*wind_eia_producion_estimates
Wind_Production_MMBTU = Wind_Electrcity_Production*(1/conversion_MMBTU_to_MWH)
wind_quantity_change_cross_price_coal = wind_price_change_cross_price_coal*wind_own_price_elastisicity+wind_cross_price_coal_coefficient*coal_price_change
wind_quantity_change_cross_price_ng = wind_price_change_cross_price_ng*wind_own_price_elastisicity+wind_cross_price_ng_coefficient*ng_price_change
wind_quantity_change_cross_price_oil = wind_price_change__cross_price_oil*wind_own_price_elastisicity+wind_cross_price_oil_coefficient*oil_price_change
wind_quantity_change_own_price = wind_own_price_elastisicity*wind_price_change_own_price
wind_quantity__change_demand_response = wind_own_price_elastisicity*wind_price__change_demand_response
Wind_Reserves_MMBTU = Wind_Reserves*(1/conversion_MMBTU_to_MWH)
wind_tax_rate_electrcity = 0.012537536
wind_tax_rate_i&i = 0.071281362
wind_total_effect = wind_cross_price_oil_coefficient+ wind_cross_price_coal_coefficient + wind_cross_price_ng_coefficient + wind_own_price_elastisicity
wind_total_price_of_electricity = wind_price_added_value_scaler+ wind_isolated_demand_response
wind_total__price_effect = wind_price_change_cross_price_coal + wind_price_change_cross_price_ng + wind_price_change__cross_price_oil + wind_price_change_own_price
wind_WY_share_of_production = .017038
wind_added_value = GRAPH(TIME)
(2007, 0.05), (2008, 0.0478), (2009, 0.0457), (2010, 0.0435), (2011, 0.0413), (2012, 0.0391), (2013, 0.037), (2014, 0.0348), (2015, 0.0326), (2016, 0.0304), (2017, 0.0283), (2018, 0.0261), (2019, 0.0239), (2020, 0.0217), (2021, 0.0196), (2022, 0.0174), (2023, 0.0152), (2024, 0.013), (2025, 0.0109), (2026, 0.0087), (2027, 0.00652), (2028, 0.00435), (2029, 0.00217), (2030, 0.00)
wind_eia_price_of_electricity = GRAPH(TIME)

(2007, 60.2), (2008, 66.7), (2009, 66.4), (2010, 59.4), (2011, 59.0), (2012, 58.2), (2013, 58.2), (2014, 58.3), (2015, 58.5), (2016, 59.0), (2017, 59.7), (2018, 60.7), (2019, 61.8), (2020, 62.3), (2021, 62.2), (2022, 62.6), (2023, 63.6), (2024, 64.8), (2025, 66.4), (2026, 68.0), (2027, 69.7), (2028, 71.0), (2029, 71.8), (2030, 72.8)
wind_eia_producion_estimates = GRAPH(TIME)
(2007, 1.1e+08), (2008, 1.8e+08), (2009, 2.7e+08), (2010, 2.7e+08), (2011, 2.8e+08), (2012, 2.9e+08), (2013, 2.9e+08), (2014, 2.9e+08), (2015, 2.9e+08), (2016, 3.1e+08), (2017, 3.1e+08), (2018, 3.1e+08), (2019, 3.1e+08), (2020, 3.2e+08), (2021, 3.3e+08), (2022, 3.4e+08), (2023, 3.6e+08), (2024, 3.7e+08), (2025, 3.9e+08), (2026, 4.1e+08), (2027, 4.1e+08), (2028, 4.4e+08), (2029, 4.4e+08), (2030, 4.5e+08)