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Analyzing the Changing US Carbon Policy Landscape

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The landscape for US carbon policy has evolved significantly over the past several years. As recently as 2009, there were multiple legislative proposals moving through Congress aimed at establishing a national cap-and-trade system for reducing carbon emissions throughout the economy. However, in the wake of the financial crisis and shifting political sentiments, these market-based economic instruments have more or less been scrapped and replaced with proposals for command-and-control regulatory mandate frameworks. These federal frameworks have primarily been proposed at the sector level, in the cases of a national renewable energy standard (RES), a clean energy standard (CES), or a national fuel economy standard (CAFE), or even at a unit level. At the same time, several states and regions are developing and implementing their own versions of carbon legislation, such as the sectoral cap-and-trade Regional Greenhouse Gas Initiative (RGGI) program and the combination mandate and cap-and-trade system in California as a result of A.B. 32. Policy design is moving away from singular and comprehensive policies to multiple and narrowly-focused policy regimes. This variety of specific and potentially overlapping regulatory regimes creates a complex policy landscape with many potential unforeseen risks and unintended impacts.

Using the N_{ew}ERA Model to Evaluate Carbon Policy

The N_{ew}ERA model is NERA's proprietary energy, economic, and environmental policy analysis tool. The model combines a computable general equilibrium model (CGE) of the US economy with a detailed electricity sector dispatch and planning model. The N_{ew}ERA model includes 12 industrial sectors, 11 macroeconomic regions, and 34 electric sector power pools.[1] The modeling framework allows for a detailed treatment of the electricity sector while also capturing the macroeconomic feedback between the electric sector and the rest of the economy. This model results in an equilibrium solution where supply equals demand for all goods and services.[2] The combination of the detailed electric sector, the feedbacks from the rest of the economy and an internally-consistent equilibrium solution is vitally important in the proper evaluation of the wide assortment of carbon policies that are being discussed today.

Economic Analysis of Potential Carbon Policies

- In this paper, our objective is to evaluate and better understand the impacts of different types of carbon policies, such as cap-and-trade and non-market based mandates (command and control policies) that are aimed at the electric power and transportation sectors. Key to this evaluation is a series of comparisons of the costs and benefits resultant from implementation of these different policies.[3] We explore four such potential policies, which are briefly described as follows, and are compared against a baseline (Base) without any carbon policies:[4] Base – A no policy case that is consistent with Energy Information Administration's (EIA's) Annual Energy Outlook (AEO 2011).

- **C&T** - An economy-wide cap-and-trade scenario that calls for a 50% reduction (relative to 2005) in covered carbon emissions by 2050 and begins in 2015.[5] All reductions must be "on-system" reductions with no consideration of offsets.

- **Reg** - A regulatory policy and mandate scenario that disallows new coal-fired power plants without 90% carbon capture and storage (CCS); includes a national RES requiring generation from renewable sources to be 20% by 2020, increasing linearly to 50% by 2050; and a CAFE standard that mandates average fuel economy (existing and new) to be at least 25 miles per gallon (MPG) in 2015 and 35 MPG by 2020.

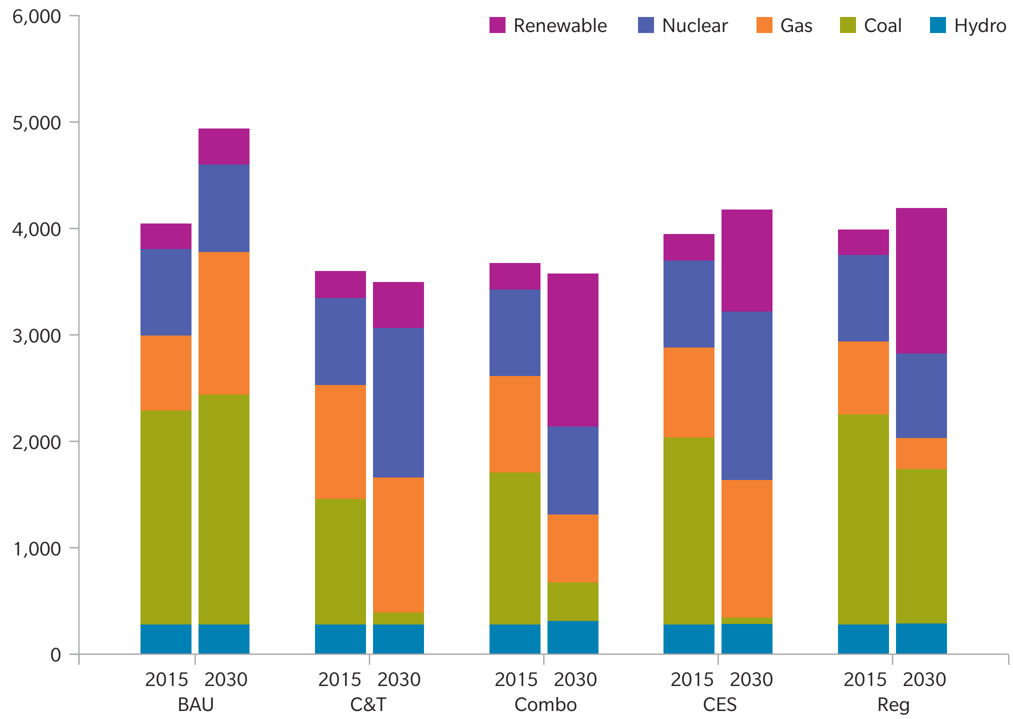
- **Combo** - A combination scenario that includes the regulatory mandates as well as the cap-and-trade scenario (C&T plus Reg).

- **CES** - A CES that requires electric generators to supply a mandated share of electricity from "clean" sources with credits for nuclear and natural gas-fired generation.[6] The generators can either supply self-generated clean electricity or buy clean energy credits from generators that produce more than the mandated amount of clean electricity. For this scenario, we assume a CES that requires electricity generation from qualifying clean sources to be 45% in 2015, increasing to 95% by 2050.

Electricity Generation Mix Will Evolve Differently

The most intuitive and readily apparent result is that the change in generation mix in the electric sector will likely be quite different under each of the policies. This is because each policy provides for a different mix of incentives and penalties for the various types of existing and new generating capacity. Figure 1 shows the generation mix for each of the scenarios (and the baseline) in 2015 and 2030.

Figure 1: **National Generation Mix in TWh by Type and Scenario**



Examining the results in detail reveals notable technology-specific differences from policy to policy. While coal-fired generation does not fare particularly well in any case, it survives much better in the Reg scenario than in the others. Under the Reg scenario, use of coal is not directly penalized and instead there is buildup of renewables to meet the RES at the expense of natural gas. Natural gas fares well in the C&T and CES scenarios, but is not a significant part of the generation mix in the Combo and Reg scenarios. The reasons for this are that in the C&T scenario natural gas is the least carbon-intensive fossil fuel, while in the CES scenario natural gas receives a credit that makes it relatively more attractive than coal.[7] Nuclear fares best in the C&T and CES scenarios as it is carbon free and receives no penalties for its use. Lastly, renewables fare best in the Combo and Reg scenarios due to the RES policy, which mandates increased construction of renewables. Each of the policies attempts to reduce carbon emissions (among other ancillary goals),[8] but by utilizing significantly different means to achieve that goal leads to widely varying end results. These different long-run electricity system outlooks may also have varying implications on how supporting infrastructure, such as transmission and distribution systems, would have to be developed in order to support a particular policy choice. As we discuss below, these different system outlooks lead to very different total policy costs, and not just different winners and losers in the generation mix.

Natural Gas Prices Respond to Economy-wide Natural Gas Demand

The total cost of policies is heavily influenced by changes in the demand and prices for natural gas and other fuels. The shifts in the natural gas market in particular affect energy prices faced by all sectors of the economy and the cost of production of goods and services. As seen in Figure 1, natural gas generation in the electric sector faces an uncertain future. Even ignoring the uncertainties in natural gas supply, the level of demand for and the price of natural gas will evolve differently under each policy. Once again, there are very different incentives and penalties for natural gas in the electric sector for each of the policies, and in all other sectors for the policies inclusive of cap-and-trade. Figure 2 shows the 2030 economy-wide changes in natural gas demand and how that translates to the Henry Hub natural gas price.

Figure 2: **Percentage Changes in 2030 Henry Hub Prices and Economy-wide Natural Gas Demand, Relative to Projected 2030 Baseline Levels**

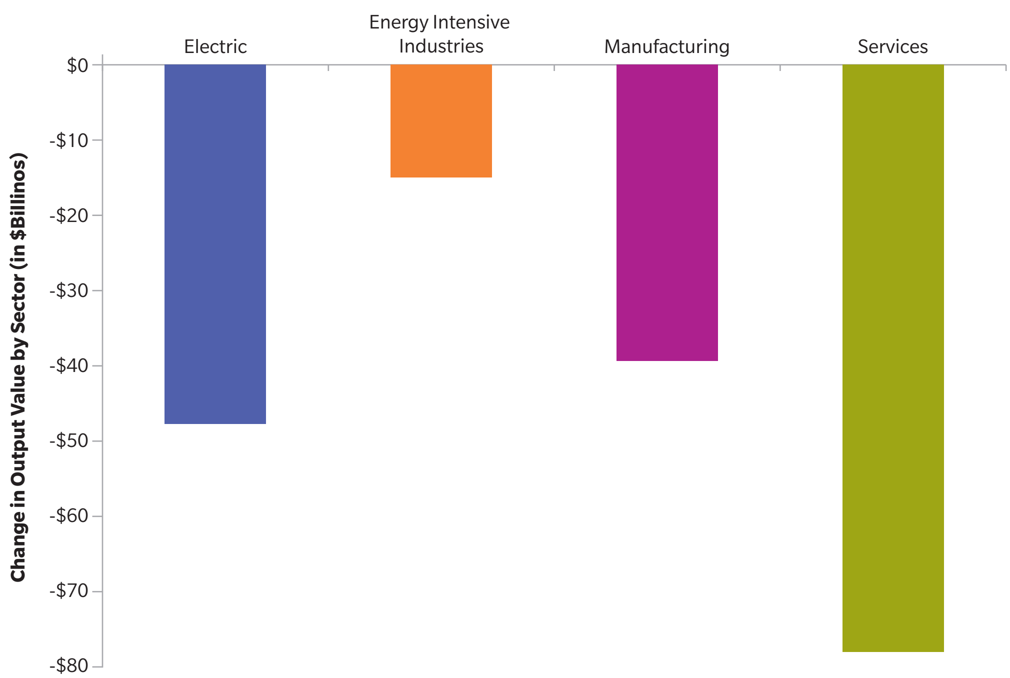
	% Change in Total Natural Gas Demand	% Change in Henry Hub Natural Gas Price
C&T	1.5%	1.5%
Combo	(15%)	(15%)
CES	10%	15%
Reg	(14%)	(14%)

While most of the scenarios primarily affect the electric sector and, therefore, the sector's demand for natural gas, the two scenarios with cap-and-trade (C&T and Combo) subject all sectors to a carbon cap and provide an incentive to use less fossil fuel, including natural gas. Despite these similarities, when comparing the two cap-and-trade scenarios we see very different impacts on natural gas markets and prices. In the Combo scenario, that disincentive applies to all parts of the economy, with a net decrease in economy-wide natural gas. By contrast, under the C&T scenario until 2030 there is a decrease in natural gas demand in the non-electric sectors of the economy, but demand for natural gas increases in the electric sector and results in an increase in the overall natural gas demand and price.[9] Likewise, comparing the CES and Reg scenarios also reveals stark differences in the otherwise similar policies because of a few key, yet relatively small, incentives (or disincentives) included in the policies. The lack of credit (or implied penalty) for coal use under the CES and fuel cost advantage of coal over natural gas in the Reg scenario result in directionally-opposite projected demand and price responses for the two scenarios. The significant differences in the demand and price changes under each scenario for an extensively used fuel such as natural gas lead to highly variable economy-wide impacts and varying total policy costs.

Sectoral Policies Have Impacts Across the Entire Economy

The general shift in carbon policies away from economy-wide economic instrument based approaches towards sectoral policies does not mean that non-covered sectors will remain unaffected. The economy-wide market shifts in natural gas demand and prices resulting from command and control policies, shown above, are examples of how a policy targeting a specific sector still influences all other sectors. A look at the CES scenario, which is a policy that applies mandates only to the electric sector, clearly shows the unintended consequences on other sectors of the economy. Figure 3 contains the change in output value in the electric sector and three other sectors in 2030.

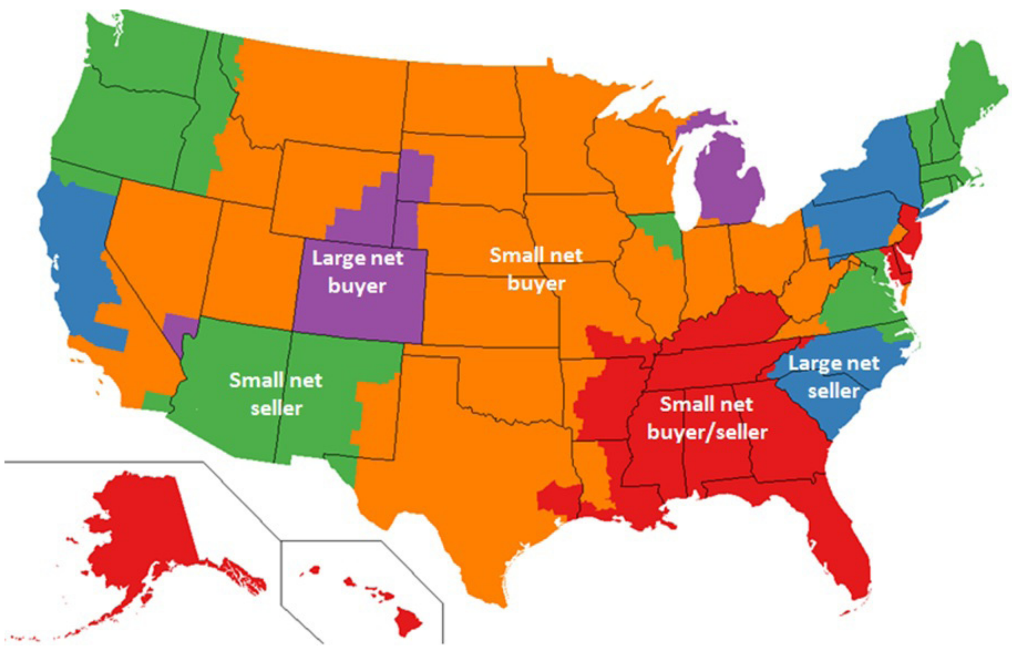
Figure 3: **Change in Value of Output under CES (in 2030)**



The CES policy increases delivered electricity prices and also drives up natural gas prices (see Figure 2). As both electricity and natural gas are important inputs for many sectors, these cost increases drive up the cost of producing goods and delivering services. Industrial sectors that are energy intensive are disproportionately impacted by these rising fuel costs. Furthermore, at the household level, increased energy costs leave consumers with less income to spend on other goods, which leads to declines in demand for goods and services.

The regional scope of the N$_{ew}$ERA model allows us to look beyond sectors in isolation and also analyze regional consequences for national policies, such as the CES, which creates regional winners and losers. The regional disparities in the macroeconomic impacts are a result of the ability to buy and sell clean energy credits. Better-positioned regions that have surplus net generation from qualifying clean energy sources will be able to sell credits while other regions will be paying for credits based on the extent of their deficit. Regions with limited qualifying clean energy sources would be net buyers, such as the Rockies region, while regions with abundant qualifying clean energy sources (particularly nuclear), such as the Southeast region, would potentially be net sellers in the CES credit market. Figure 4 maps the winners and losers for this particular policy based on the 34 electricity regions in the model.

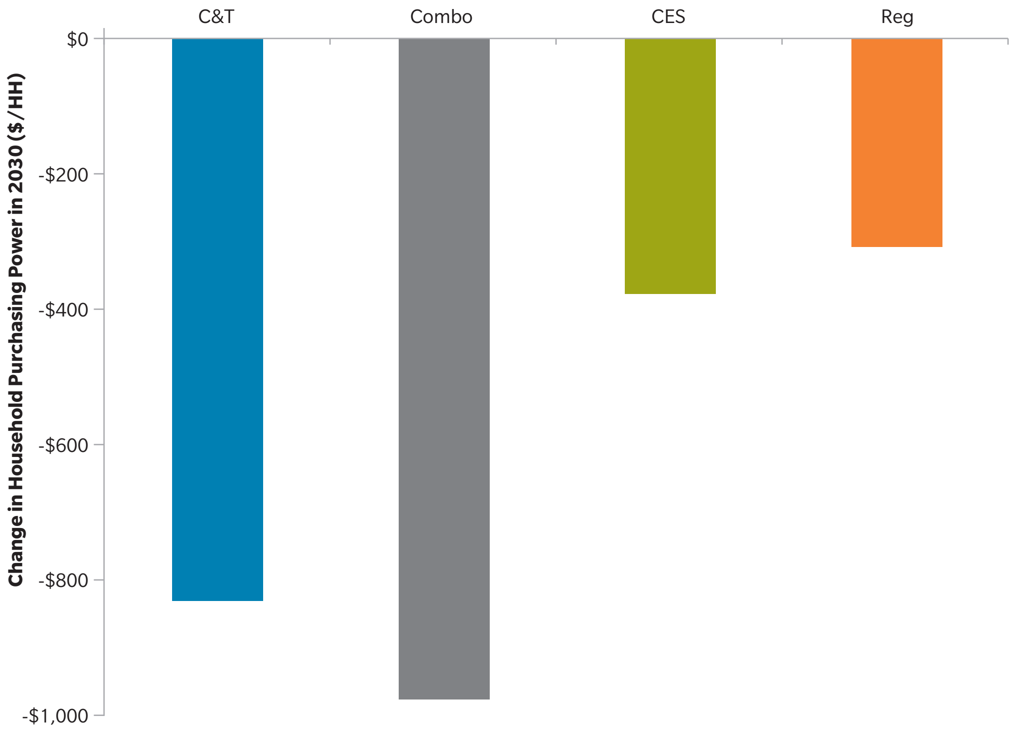
Figure 4: **Regional Winners and Losers in CES Scenario**



Command and Control Regulatory Approaches (Mandates) are an Inefficient Means to Reducing Emissions

We have found that each of the policies we have examined has costs that extend beyond their targeted sector(s). We can add up the costs across all sectors to compute the total incremental costs of each policy relative to the baseline as a metric for evaluating policies against each other. These costs have significant macroeconomic implications including a loss of purchasing power for households due to higher energy costs and decreased wages and/or lower levels of employment. Figure 5 shows the change in purchasing power for each of the scenarios, relative to the baseline.[10]

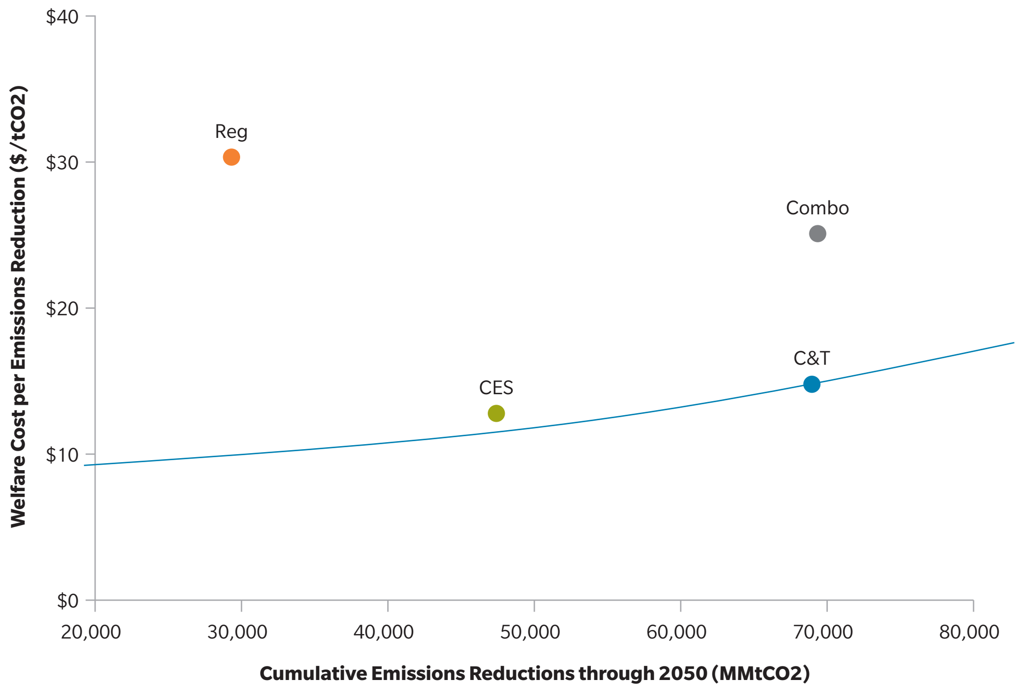
Figure 5: **Change in Household Purchasing Power Relative to Projected 2030 Baseline Levels**



The two scenarios with cap-and-trade have the highest costs because they also have the largest carbon emission reduction targets and therefore result in the greatest increase in energy costs. (The cap-and-trade programs' costs are not higher because of the need to purchase permits because our analysis returns all of the value of the permits back into the economy.) It is important to note that the addition of the regulatory policies to the cap-and-trade (the Combo scenario) only makes the cap-and-trade policy more costly due to additional distortions that the regulatory components of the policy introduce into the economy.[11]

The loss of household purchasing power alone does not provide a good measure of the cost effectiveness of a policy in removing emissions from the economy. A more appropriate measure would involve normalizing the welfare costs[12] relative to the realized carbon emissions reductions. This metric allows us to compare the four scenarios based on their average welfare cost per ton of CO2 removed and their total cumulative tons reduced.[13] Figure 6 contains this comparison. The most efficient policy will have a lower cost per ton removed, while also reducing more tonnage. The curve in the figure shows how the efficiency of cap-and-trade varies with overall emissions reductions achieved.[14]

Figure 6: **Average Cost per Ton Removed and Cumulative Tons of CO2 Reduced**



An economy-wide cap-and-trade (with banking) policy proves to be the least-cost, or economically most efficient, means of reducing emissions from an economy.[15] Under this approach, sectors with higher costs of abatement make fewer emission reductions while sectors with lower marginal costs of abatement make more reductions and sell them to sectors with higher abatement costs. This ability to trade equalizes the cost across all covered sectors in the economy and reduces the targeted level of emissions at the least cost. Thus we find that C&T is the most cost effective of the four policies as a way to achieve a carbon reduction goal, even though it has among the largest of the economic impacts.

In comparison, the other policies examined tend to be far more expensive while achieving far fewer emission reductions as sector-specific policies mandate non-optimal abatement or fail to induce emissions reductions where they are cheapest first. Additionally, mandates layered on top of cap-and-trade introduce increased distortions into the economy and lead to further costs above and beyond the cap-and-trade cost. This conclusion demonstrates the necessity and value of evaluating sector-specific policies within a framework of how sectors interact on a macroeconomic scale. Only by taking into account the feedback of economic impacts across all sectors and regions can the total cost of a policy be calculated. When examined through this lens, it is clear how targeted sectoral policies and/or mandates are a far less efficient method of achieving emissions reductions than an economy-wide cap-and-trade policy.

N_{ew}ERA Integrated Model

NERA developed the N_{ew}ERA model to forecast the impact of policy, regulatory, and economic factors on the energy sectors and the economy. When evaluating policies that have significant impacts on the entire economy, one needs to use a model that captures the effects as they ripple through all sectors of the economy and the associated feedback effects. The N_{ew}ERA model combines a macroeconomic model incorporating all sectors of the economy (except for the electric sector) with a detailed electric sector model. This combination allows for a complete understanding of the economic impacts of different policies on all sectors of the economy.

The macroeconomic model incorporates all production sectors and final demand of the economy. Policy consequences are transmitted throughout the economy as sectors respond until the economy reaches equilibrium. The production and consumption functions employed in the model enable gradual substitution of inputs in response to relative price changes, thus avoiding all-or-nothing solutions.

The main benefit of the integrated framework is that the electric sector can be modeled in great detail yet through integration the model captures the interactions and feedbacks between all sectors of the economy. Electric technologies can be well represented according to engineering specifications. The integrated modeling approach also provides consistent price responses since all sectors of the economy are modeled. In addition, under this framework we are able to model electricity demand response.

There are great uncertainties about how the US natural gas market will evolve, and the N_{ew}ERA model is designed explicitly to address the key factors affecting future natural gas supply and prices. One of the major uncertainties is the availability of shale gas in the United States. To account for this uncertainty and the subsequent effect it could have on the domestic and international markets, the N_{ew}ERA model includes resource supply curves for US natural gas. The model also accounts for foreign imports and US exports of natural gas, by using a supply (demand) curve for US imports (exports) that represents how the global LNG market price would react to changes in US imports or exports.

The electric sector model is a detailed model of the electric and coal sectors. Each of the more than 17,000 electric generating units in the United States is represented in the model. The model minimizes costs while meeting all specified constraints, such as demand, peak demand, emissions limits and transmission limits. The model determines investments to undertake and unit dispatch. Because the N_{ew}ERA model is an integrated model of the entire US economy, electricity demand can respond to changes in prices and supplies.

The steam coal sector is represented within the N_{ew}ERA model by a series of coal supply curves and a coal transportation matrix. The N_{ew}ERA model represents the domestic and international crude oil and refined petroleum markets.

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The N_{ew}ERA model outputs include demand and supply of all goods and services, prices of all commodities, and terms of trade effects (including changes in imports and exports). The model outputs also include gross regional product, consumption, investment, disposable income, and changes in "job equivalents" based on labor wage income.

Policy Analysis Capabilities

The N_{ew}ERA model has the capability to evaluate a range of current and proposed policies. Because the NERA team has developed the N_{ew}ERA model, we are intimately familiar with how the model responds to various constraints and therefore are able to logically and effectively represent policies designed by regulators within our model.

As examples of policy capabilities, the N_{ew}ERA model can represent the following policies and types of policies:

- Emission taxes or prices;
- Emission cap-and-trade policy (e.g., Title IV, CSAPR);
- Renewable portfolio standards (state, regional, or national);
- Efficiency standards in electric and non-electric sectors (e.g., MACT, heat rate standards, CAFE);
- Mandated construction of new builds or retrofits (or requirements to retrofit or retire);
- Financial incentives (e.g., for renewables or for electric vehicles); and
- Low carbon/renewable fuel standards (e.g., LCFS and RFS).

Notes

[1] For this paper, we used a one-region US model for the macroeconomic modeling of all sectors except the electricity sector. The electricity sector was modeled at the fully-detailed power pool level. Additional details on the N_{ew}ERA model are available at: http://www.nera.com/67_7607.htm.

[2] Tuladhar et al. (2009) used a similar modeling methodology to analyze macroeconomic impacts of US carbon policies for different emissions pathways. Tuladhar, S.D., M. Yuan, P. Bernstein, W.D. Montgomery, and A. Smith, "A top-down bottom-up modeling approach to climate change policy analysis," Energy Economics, Volume 31, July 2009.

[3] We do not attempt to model potential benefits associated with improvement in the environment as a result of reduction in greenhouse gases. As a result, this is not a cost-benefit analysis.

[4] The scenarios presented in this paper are not intended to model any specific proposals that have been discussed and debated in the past or proposals that are currently being discussed.

[5] Covered carbon emissions are those from fossil fuel combustion only and do not include emissions from other greenhouse gases such as methane, nitric acid and HFCs.

[6] We assume that generation from nuclear, biomass, landfill gas, wind (onshore and offshore), and solar (thermal and PV) all qualify as "clean" energy sources. These clean energy sources are given 100 percent credit while generation from coal with CCS is given 90 percent credit and generation from natural gas is given 50 percent credit.

[7] CES policy can be viewed as a carbon policy with different implied penalty weights on fossil fuels. Under a carbon cap policy fossil fuels are penalized according to their carbon content.

[8] Other ancillary goals could include energy security, inducing employment though "green jobs", and subsidizing new technologies.

[9] However, over time as the carbon price increases even natural gas becomes unfavorable resulting in lower overall demand for natural gas.

[10] The change in purchasing power as measured by increased costs per household indicates the loss in an average U.S. household's income relative to current (2010) income.

[11] The cost impacts of the C&T and Reg scenarios combined does not equal the Combo scenario costs. In fact, the Combo scenario cost impact is lower because the carbon price is lower as are the energy prices.

[12] We use a monetary measure of welfare effect to evaluate the costs of a policy.

[13] While the more economically appropriate measure of comparison would be the marginal cost of abatement, it is nearly impossible to determine the marginal cost of abatement in all of the policies except the cap and trade policy where the marginal cost of abatement is equivalent to the market price for CO2 allowances. Although the average cost of abatement for Combo is higher than C&T, the marginal cost of abatement for the Combo scenario would be lower than the C&T. This occurs because the CAFE standard alone calls for a large reduction and hence there is less abatement left to be achieved by the cap-and-trade policy. So even though Combo would have a lower carbon price it would come with higher welfare costs.

[14] While the cap-and-trade scenario we present above at first glance looks to be less efficient than a CES, this is actually due to the overall higher level of emissions reductions achieved. If the cap were set at the same stringency as the CES, then the cost efficiency of cap-and-trade would be superior. The curve that passes through the C&T represents a locus of points that traces the efficient cost of abatement.

[15] The banking provision allows the flexibility to abate more in periods that have lower emissions cap stringency and save permits for use at periods when the emissions cap level much more stringent and costly. It provides flexibility in timing as to when to abate over the model horizon. An emission tax would be functionally equivalently to a cap-and-trade policy with optimal banking.

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