ISSUE BRIEF

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GDP, Consumption, Jobs, and Costs: Tracking the Effects of Energy Policy

Alan J. Krupnick and David McLaughlin[1]

Currently, politicians and the press are engaged in a national debate over the impacts of energy policy, and measure these impacts in new "green" jobs and by increases in gross domestic product (GDP). Economists are also engaged in this debate; however they use *welfare costs* to measure the impacts of energy policy on society as a whole. Policymakers and the media may be somewhat familiar with the term welfare cost, but otherwise have little insight into what it means and how it is used. However, they are aware of the high-stakes surrounding economic growth and job creation—and in the current political discourse, this is often linked to energy policy.

The purpose of this discussion paper is to inform this fractious and, in our view, often misleading debate about the effects of energy policies on macroeconomic metrics like employment and GDP. We do this first by defining what is meant and not meant by these metrics, then by showing how these metrics compare for a large number of energy policies, as modeled using the National Energy Modeling System with modifications by Resources for the Future (NEMS–RFF). We conclude that none of these metrics move reliably with welfare costs, and therefore these macroeconomic metrics (within the context of NEMS results) should not be considered reliable proxies for examining the true welfare cost of policies. This conclusion may well apply to results from other models, but that analysis is beyond the scope of this effort.

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The Metrics

REAL GDP

This is the sum total of the money value of all output (termed *goods and services*) in the economy in a given year. Both nominal and real GDP are composed of consumption, investment, and government spending components and net exports. However, real consumption, investment, government expenditures, and net exports will not sum to real GDP because of *chain-weighting*.[2] Each unit of output has a price and quantity associated with it, at least in principle. So GDP can go up with an increase in a commodity's price or an increase in the quantity produced (and consumed), or it could rise with a price increase large enough to more than compensate for a fall in output and vice versa.

Consumers and politicians alike seem to believe that an increase in GDP is an important sign of economic growth and prosperity, which it often is. However, GDP can increase for undesirable reasons as well. For example, a new crime wave that result in purchases by businesses of long-lived security systems would show up in the investment component, and purchases by consumers to enhance their security, such as bars on the windows, would be logged under consumption. In this case, GDP goes up, but would society be better off relative to the prior, lower-crime period when GDP was lower? Also, GDP misses important items that affect the well-being of society. For example, it misses the degradation of natural resources, the depletion of energy resources, and the effects of pollution on health and the environment. Many economists, politicians, and government officials have argued for years for the development of a broader system of national income accounts (from which GDP is calculated) that would take such effects into account—a system termed *integrated economic and environmental satellite accounts* (IEESA). However, after a fledgling attempt by the Bureau of Economic Analysis, Congress shut down the effort to create an IEESA system (Abraham et al. 2005).

CONSUMPTION

We examine the consumption component of GDP on its own, given that the Energy Information Administration (EIA) considers this the most reliably modeled of the monetary indicators of economic growth in NEMS. We use it below because of problems in calculating the effects of policies on GDP (specifically the investment component) using NEMS.

INVESTMENT

We examine the investment component of GDP, even though in NEMS this component does not pick up all of the investment changes induced by an introduced policy.[3] This element includes

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[2] NEMS employs chain-weighting to calculate the components of real GDP by weighting the quantity of goods sold by expenditures in a given year. This avoids valuing all goods sold in projected years at base year prices (Energy Information Administration [EIA] 2010).

[3] There are complications inherent in calculating overall investment as a component of GDP within the NEMS model. Investment in the Macroeconomic Activity Module (MAM) is obtained from the National Income and Product Accounts produced by the Bureau of Economic Analysis, whereas the other modules in NEMS, for example the Electricity Market Module, forecast investment in structures, equipment, and some operating costs based on historical data from other sources. The difficulty in accurately modeling the effect of a policy on overall investment lies in aggregating the individual components of investment in the MAM and the other modules correctly, while also accounting for investment losses from

investments in durable equipment, additions to capital assets, new construction, and additions to inventory.

NET EXPORTS

This is the difference between the value of exported goods and services and the value of imported goods and services. If a policy causes oil- or carbon-intensive products to become more expensive, these changes in prices will affect trade in them: specifically, exports will fall and imports will rise, other things being equal.

GOVERNMENT SPENDING

This element of GDP is a forecast of government expenditures based on current spending policy, updated with any changes in government spending resulting from the policy scenario being examined. Any observed changes would occur because of the linkage with some automatic spending programs and the economy. Importantly, certain government spending programs currently in place may logically end within the NEMS–RFF time horizon. However, if the sunset provisions for these policies are not explicitly defined, NEMS–RFF includes spending for these programs for the duration of the analysis. The government spending metric is included for completeness.

JOBS

Many metrics can fall under the "jobs" heading. When the number of jobs in an economy—or, for our purposes, the change in the number of jobs associated with a policy—is assessed, one must of course include full-time jobs and make adjustments for part-time jobs. Depending on how jobs are calculated, issues of the size of the labor force, labor participation rates, and unemployment rates might also come into play.

A related term is "green jobs." Because there is, as yet, no generally accepted definition of a green job,[4] we focus on changes in the overall number of jobs, as reported in NEMS–RFF.

Assessing the change in the number of jobs is tricky because people are so mobile and our economy is so dynamic. People leave one job and go to another; an individual who has left a job may be replaced, or the job may be eliminated. People who have been working full-time may now be working part-time.[5] A new job may replace an existing position or may represent a newly created job. If an economy is fully employed (which economists usually define as having around a 5 percent unemployment rate), then the economy is so tight and constrained by its labor force that no new jobs are created by any policy change. Instead, people are simply rearranged within the job market.

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prematurely retiring operating capital. EIA understands this problem; improvements in these connections are under construction (personal communication, Kay Smith, EIA, March 29, 2011).

[4] The Bureau of Labor Statistics (BLS) is engaged in an effort to measure green jobs based on their own definition. The BLS defines green jobs as: (a) jobs in which the products provided or services rendered benefit the environment or conserve natural resources or (b) jobs for which the duties are to enhance the establishments' production processes to be more environmentally friendly or to use fewer natural resources (BLS 2010).

[5] The employment estimates used in this analysis include salaried employees, as well as self-employed persons, private household workers, agricultural workers, unpaid family workers, and workers on leave without pay. Additionally, the estimates count only once those individuals who have multiple jobs.

Ultimately, even if one can measure job changes with confidence, is this a metric that carries with it an unambiguous link to economic growth and prosperity? In an economic downturn, such as our current recession, many people take pay cuts to keep their jobs. Yet, a strict count of jobs misses this important information, which means that the cut in our prosperity is larger than measured by job cuts. One way around this problem with jobs is to use the wage bill—that is, the number of jobs times the average wage (Schneck et al. 2010). However, NEMS–RFF does not provide this output.

The number of jobs is a *stock* concept, in contrast to GDP and its components and welfare costs, which are *flow* concepts. A stock is measured as a quantity at a given moment in time (e.g., capital stock), and a flow is a rate or quantity measured over time representing an accumulation, depreciation or depletion of a stock (e.g., consumption or investment). In measuring the effects of a policy change on flows, we sum the NEMS–RFF output for each year for this metric (discounted, see below) with and without the policy and then take the difference as the change in that metric associated with the policy. This procedure cannot be followed for jobs, however. Suppose a policy created one new job the first year and no new jobs after that. Each year, this one new job would show up in NEMS–RFF output and, summing over 20 years, the model would indicate that 20 new jobs were created when only one new job was actually created. Alternatively, we could examine the number of baseline jobs in a given year and compare that to the number of jobs under a particular policy in that year, where the difference would be the number of additional jobs created by the policy in that year—but summing these differences would not be appropriate for similar reasons.

NEMS provides labor force and employment forecasts based on two surveys produced by the Bureau of Labor Statistics: the Household Survey and the Payroll Survey. In this paper, we use labor force forecasts from the Household Survey of 60,000 households, with information regarding the civilian non-institutional population. We first calculated the annual number of employed civilian workers for each year by taking the difference between the civilian labor force and the unemployed civilian workers. We calculated the number of unemployed civilian workers by multiplying the unemployment rate by the civilian labor force. We then took the difference between the numbers of employed workers for each policy scenario and for the reference case to obtain the change in the number of employed workers.

We chose to compare time profiles of jobs for each year for selected groupings of policies without summing any differences over years. Because we must use time profiles to compare jobs across policies, when we want to compare the jobs metric with other metrics, we use the latter's time profiles.

WELFARE COST

Welfare cost is the value of the resources society gives up to take a course of action, such as reducing dependence on foreign oil or meeting a carbon dioxide (CO_2) emissions cap (see, for example, Just et al. 2004). In the present paper, welfare costs summarize the costs to the economy of all different actions taken either to reduce fossil fuel use or to reduce overall carbon emissions for each policy scenario. For example, this would include the direct costs associated with producing electricity with cleaner but more expensive fuels. Welfare costs also include the less obvious costs to households from driving less or using fewer energy-using products and services than they would otherwise prefer.

It is often easier to define welfare costs by what they are not. They are not measured by changes in GDP, as welfare economics in general is associated with impacts on private consumption and production, but GDP includes investment and government spending. As noted above, GDP also fails to capture nonmarket values, such as environmental damages, that are captured by welfare costs.

Welfare costs also are not measured in terms of job losses in industries most directly affected by new policies. Many of those jobs are usually made up by other sectors of the economy after a period of time.

The measurement of welfare costs (as well as that of the other metrics described above) is not affected by who pays; thus, transfers between producers and consumers or between consumers and the government are not welfare costs. This means also that tax revenues raised through oil or gasoline taxes are not part of welfare costs, nor are subsidy payments for hybrid electric vehicles or geothermal heat pumps; these are simply transfers from one segment of society to another.

The welfare cost concept has been endorsed by governments around the world for purposes of evaluating regulations, government investments, taxes, and other policies. In the United States, a series of executive orders, dating from the Carter administration to the present, has made it mandatory for government agencies to perform cost–benefit analyses using welfare economics to determine if their planned major regulations are justified from society's point of view. Hundreds of regulatory impact analyses are performed every year, with welfare cost estimates as a key component.

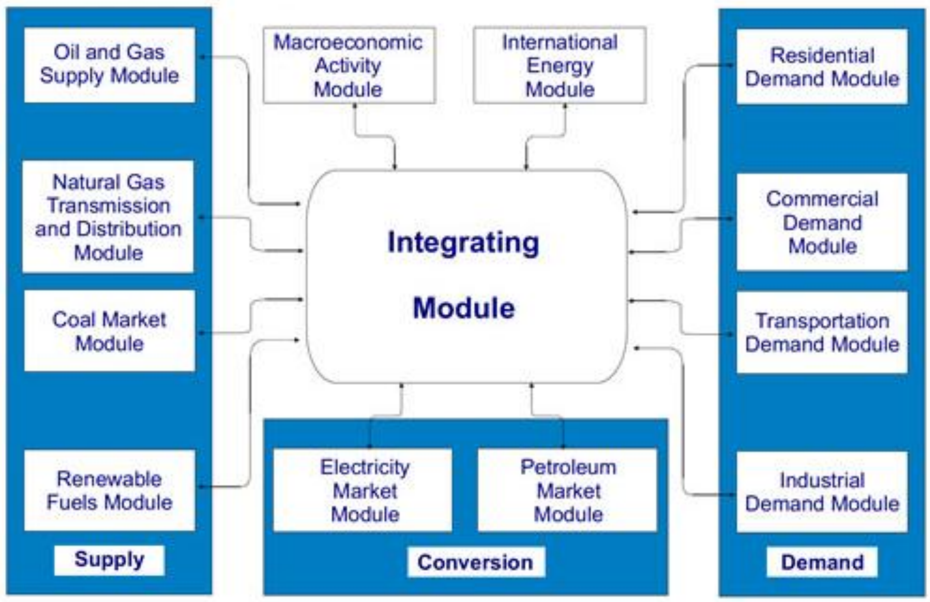
Modeling Policies and Measuring Macro Metrics in NEMS–RFF

We made slight modifications to NEMS (based on the *2009 Annual Energy Outlook* [EIA 2009a]), maintained and used by EIA, for our forecasting and policy analyses; these changes resulted in the NEMS–RFF model. Nearly all modeling efforts of U.S. energy policies rely on EIA for baseline forecasts and, although a number of other energy–economic models are available, only NEMS has the sectoral disaggregation and detail needed to model the diverse range of policies considered here.

NEMS is an energy systems model, also often referred to as a *bottom-up* model. Such models incorporate considerable detail on a wide spectrum of existing and emerging technologies across the energy system, while also balancing supply and demand in all (energy and other) markets of the economy.

NEMS is modular in nature (Figure 1), with each module representing individual fuel supply, conversion, and end-use consumption for a particular sector. The model solves iteratively until the delivered prices of energy are in equilibrium. Many of the modules contain extensive data: industrial demand is represented for 21 industry groups, for example, and light-duty vehicles are disaggregated into 12 classes and distinguished by vintage. The model also has regional disaggregation, taking into account, for example, state electric utility regulations.

Figure 1. Visual Representation of NEMS Modules



Source: EIA (2009b).

The model also incorporates existing regulations, taxes, and tax credits, all of which are updated regularly. The detail in the model allows for scrutiny and interpretation of specific policies, such as a production tax credit for a particular renewable fuel or a change in appliance efficiency standards.

To model the effects of specific policies, researchers change various *levers* within NEMS. For example, automobile fuel economy standards are incorporated into the NEMS transportation module, along with the costs of various technologies to achieve higher fuel efficiency. The costs incurred to meet a tighter standard will be captured as the model solves for a new equilibrium with altered vehicle stock, miles traveled, gasoline consumption, and prices.

Although NEMS is a powerful and flexible tool, like any model, it has limitations. For the purpose of this study, a key weakness is that NEMS does not provide estimates of welfare costs associated with policy scenarios. We used NEMS–RFF output to estimate welfare costs (Krupnick et al. 2010); however, these were "offline" calculations—in other words, those that we made outside of the model. Second, as mentioned above, NEMS does a poor job registering the effects of changes in investments associated with a policy. Because investment is part of GDP, this limitation passes on to GDP and job growth as well.

NEMS does have policy levers and the flexibility to make choices on how to allocate the tax and allowance revenues collected from modeled policies. For most policies, NEMS requires the user to explicitly code the transfer of revenues to a variable containing other additional indirect business taxes. However, for carbon pricing policies, NEMS permits the user to make decisions about the uses of revenues through various policy levers. For the carbon pricing policies reported in this paper, as modeled in NEMS–RFF, the lever was configured such that revenues were used to maintain deficit neutrality—meaning that if a policy raised the deficit, revenues from that policy would first be used to offset that change. The remainder would then be distributed to consumers, where it raises their incomes and potentially stimulating more consumption. Our carbon tax policies result in the use of 5 to 10 percent of revenues to maintain deficit neutrality with the rest of the revenue returned to the economy.

Summarizing the Metrics over Time

Policies usually act over a number of years. Some policies, like those affecting travel demand, have immediate costs and effects on oil use or CO_2 emissions, whereas others have high up-front costs, followed by years of energy savings and reductions in oil use and CO_2 emissions. Therefore, we want to express welfare costs, consumption, and GDP effects with different time profiles over the NEMS–RFF forecasting period (2010–2030) in a consistent and comparable manner.

Because incurring costs in the future is less costly from today's vantage point than incurring the same costs today,[6] we want to give credit to policies that delay their costs more than other policies (given the same undiscounted costs for both). In other words, costs incurred in the future must be discounted back to the present; thus, we must calculate what is termed the *present discounted value* (PDV). To make this calculation requires that one choose a discount rate as well as a reference year to which to discount; in this case, the chosen reference year is 2010. Typical options for the discount rate are the *social rate of discount* and the *market rate of interest*. In what is presented below, we use a 10 percent rate to discount temporal effects for policies that could involve some market failure and 5 percent assuming complete market failure. Notably, all metrics for a given policy are discounted at the same rate.

For jobs, because we are using time profiles or job creation estimates in a specific year and do not sum these numbers over time, the discount rate is irrelevant.

Policies Considered[7]

The various policies we considered are listed in Appendix A. In general, we chose policy types for their salience in policy debates, whether in policy or academic circles. We generally timed policies to start in 2010, although sometimes, for added realism, we ramped up the policies over time. Policies ended in 2030 because this is the end period for projections from NEMS–RFF. (By end, we mean that no new investments or behavior changes take place after that date.)

For the welfare cost calculations for energy efficiency (EE) policies (e.g., Corporate Average Fuel Economy [CAFE] standards or building codes), we counted the estimated value of the investments' energy savings out to 2045 or 2050, whichever is more appropriate. This reduces welfare costs below what they otherwise would be if we ignored energy savings after 2030. For

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[6] The basic reason is that interest can be earned on money saved or invested—in other words, money has a time value.

[7] The policies used in this analysis are taken from a previous analysis, *Toward a New National Energy Policy: Assessing the Options,* undertaken by the National Energy Policy Institute and RFF (Krupnick et al. 2010).

the macroeconomic metrics, however, we have no way to calculate those effects beyond 2030. Therefore, when considering GDP and welfare costs for a given EE policy, it is important to note that GDP and its components do not fully incorporate the future stream of benefits resulting from the policy beyond 2030, whereas the welfare costs do incorporate this feature. However, the discounted values of benefits beyond 2030 are small, and not our primary concern. Rather, we are concerned with how well a given macro metric preserves the ranking of policies relative to welfare cost.

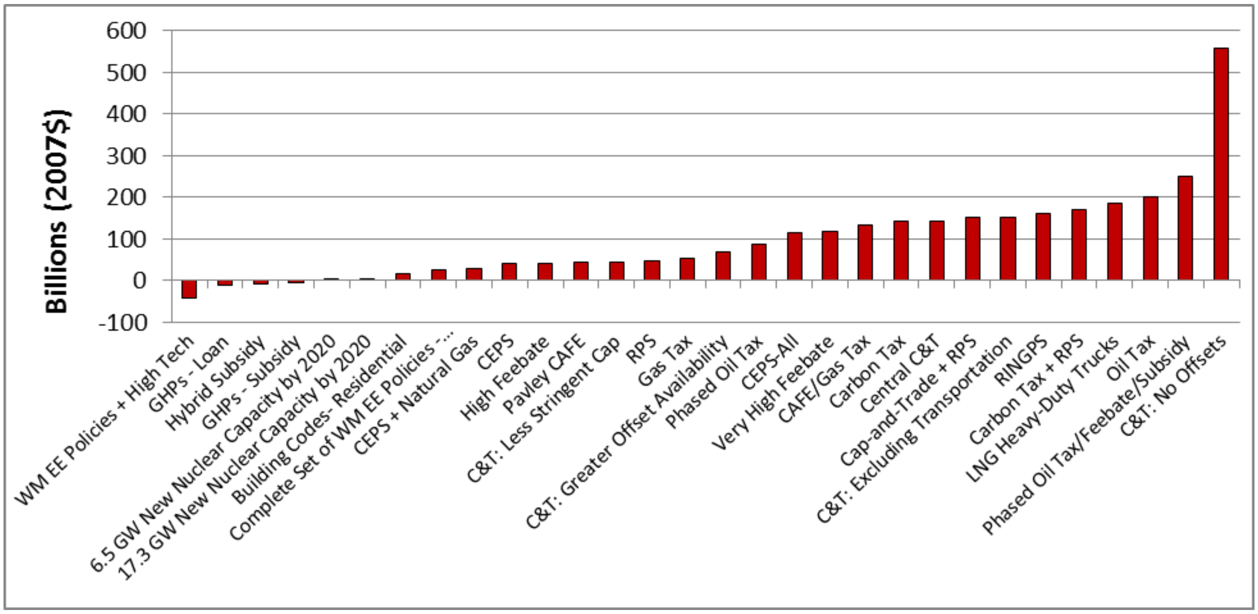
Policy stringency, likewise, was driven by saliency in the debates, as well as an eye for meeting targets for reductions in oil consumption and energy-related CO_2 emissions, as described in Krupnick et al. (2010). As an example in which salience ruled, we defined the specifics of the renewable portfolio standard (RPS) policy scenario with reference to those previously discussed in Congress. An example for which the targets helped set stringency was in our choice of the scope of the liquefied natural gas (LNG) truck mandate (10 percent LNG heavy-duty truck penetration of the new-vehicle fleet every year for 10 years, after which all new such trucks will run on LNG). Notably, some of the policies that perform best in terms of welfare cost—some of which actually deliver welfare benefits—have trivial effects on CO_2 emissions or oil reductions.

Finally, although we consider many of the major policy options, we do not model some important policies, such as more stringent ethanol mandates, oil import tariffs, and feed-in tariffs for renewable energy.

Results by Metric

Figure 2 presents the PDV of welfare costs for each of our 30 policies, ordered from the lowest-cost policy (which actually delivers welfare benefits) to the highest-cost policy, which is a CO_2 cap-and-trade (C&T) policy in which no offsets are permitted to meet the cap. Note that comparing these costs across policies is not advisable, as their scales are very different in terms of CO_2 emissions or oil consumption reductions. For purposes of this paper, the relevant comparisons are across metrics for given policies and how much the different metrics are correlated across policies.

Figure 2. PDV of Welfare Cost by Policy (2010–2030)



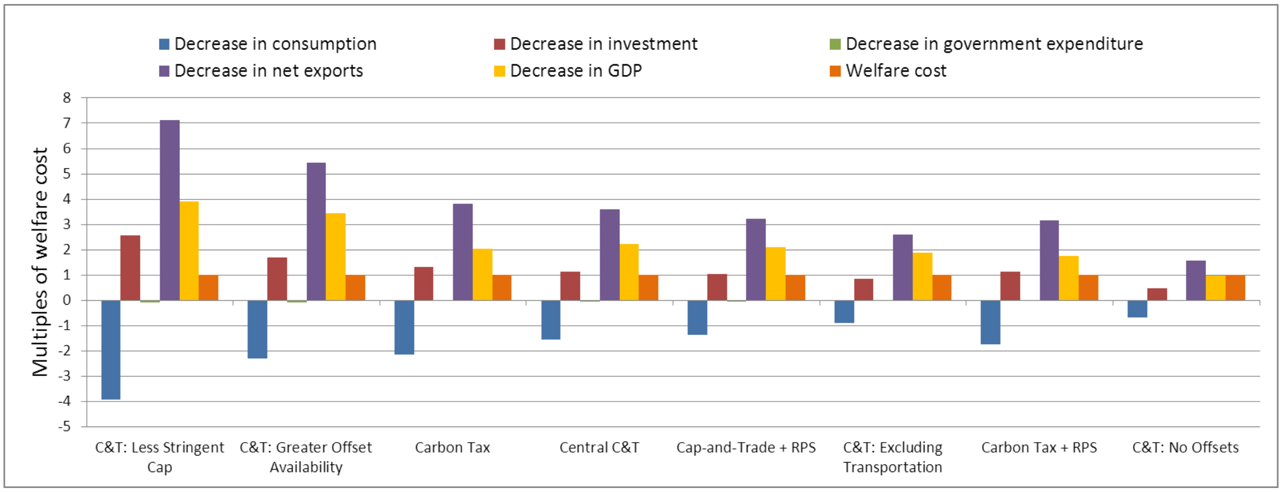
Notes: CEPS, Clean Energy Portfolio Standard; GW, gigawatt; RINGPS, Renewable and Incremental Natural Gas Portfolio Standard; WM, Waxman–Markey bill (H.R. 2454).

Figures 3.1 to 3.5 present all but the jobs metrics, organized by policy groupings and presented in the order of lowest-to-highest welfare costs within a grouping. Because we are interested in relative (rather than absolute) effects of a policy across metrics, we scale all metrics to a numéraire, which we arbitrarily choose as welfare costs. Thus, the PDV of welfare cost for a given policy is set equal to 1.0 (or negative 1.0 if the policy delivers welfare benefits) and the other metrics are presented in relation to that scale. So, if GDP changes by twice as much as welfare costs, its bar would have a height of 2.0. What is most crucial is whether the scale of a particular metric remains more or less consistent, across policies, in relation to our most important metric, welfare cost. Such consistency reflects a high correlation with welfare cost and indicates that the metric would be a good surrogate for welfare cost.

One other issue in interpreting Figures 3.1 to 3.5 has to do with showing increases and decreases by metric. Because decreases in GDP (and its components) and increases in welfare costs are generally regarded as negative, we treat GDP decreases (and decreases in its components) symmetrically with welfare costs. This means that an increase in welfare costs and a decrease in our macro metrics are registered by bars above the zero line. For instance, the bar for consumption (Figure 3.1) is below the zero line on the figure for all the policies, indicating that consumption actually increases for all the policies.

Figure 3.1 shows that, for the carbon pricing policies, consumption and net exports do not maintain a fixed proportion in relation to welfare costs across the policies. Indeed, their fractions of welfare costs shrink as the policy's welfare costs grow. This tendency is also present for GDP but is less pronounced.

Figure 3.1. Carbon Pricing Policies: Scaled Macroeconomic Metrics by Welfare Cost



This information is summarized in Table 1a, which provides Pearson product moment correlations across the metrics for the carbon pricing grouping, and Table 1b, which provides Spearman rank correlations across these metrics. The former correlation coefficients account for the size differences across metrics; the latter account only for differences in the ranking of policies. Thus, overall, two metrics yielding very similar policy rankings would have a high rank correlation but could nevertheless be poorly correlated if the size differences of the two metrics across policies are too dissimilar. The reverse is also possible.

As shown in Table 1a, GDP reduction is more highly correlated with welfare costs than with the other metrics. Also, we note that consumption and net exports are highly correlated with one another, but negatively (i.e., increases in consumption and decreases in net exports track one another fairly closely across policies in the carbon pricing group). Rankings for welfare cost are most correlated with those from investment (Table 1b), but as discussed earlier, these findings are inconclusive due to the complications inherent in modeling investment. GDP reduction is the metric exhibiting the second-strongest correlation with welfare cost among the carbon pricing policies.

Figure 3.1 shows consumption increasing, with all other metrics showing decreases along with positive welfare costs. The increase in consumption occurs because of our modeling decision to recycle the revenues from the tax or auction of allowances back to consumers in lump-sum payments after a portion of the revenues is put toward maintaining deficit neutrality.[8] The revenue recycling raises incomes for consumers, which raises their consumption. In addition, for goods like electricity that are demanded inelastically, higher energy prices (P) will lower the quantity demanded (Q), but by proportionally less than the price increase, which raises total expenditures or the value of consumption (P x Q). Depending on how the revenues from an auction or tax are used, it is quite possible that consumption can fall on net, for instance, if a sizable fraction of the revenues is being used to fund government programs.

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[8] In contrast, the Waxman–Markey C&T bill, H.R. 2454, allocates allowances directly to programs promoting EE and to local distribution companies to reduce energy costs to consumers.

Table 1a. Pearson Product Moment Correlation for Carbon Pricing Policies

	Welfare cost	Consumption	Investment	Government expenditure	Net exports	GDP
Welfare cost	1.00					
Consumption	–0.76*	1.00				
Investment	0.91*	–0.95*	1.00			
Government expenditure	–0.87*	0.75*	–0.84*	1.00		
Net exports	0.95*	–0.90*	0.98*	–0.90*	1.00	
GDP	0.98*	–-0.75*	0.91*	–0.89*	0.96*	1.00

Notes: N=8 policies. * Denotes significance at p<0.05.

Table 1b. Spearman Rank Correlation for Carbon Pricing Policies

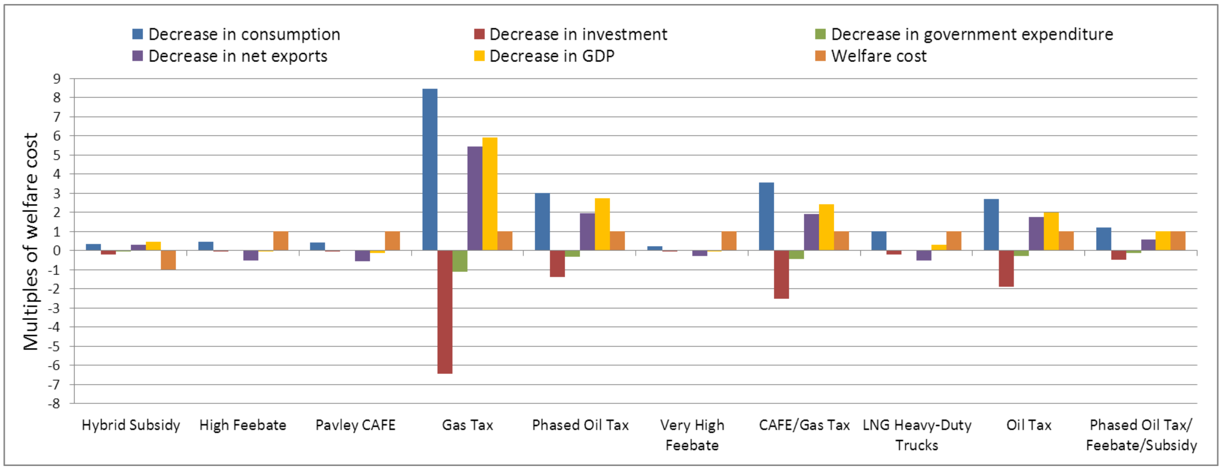
	Welfare cost	Consumption	Investment	Government expenditure	Net exports	GDP
Welfare cost	1.0000					
Consumption	–0.4286	1.0000				
Investment	0.7381*	–0.9048*	1.0000			
Government expenditure	–0.5000	0.7619*	–0.7143*	1.0000		
Net exports	0.6667	–0.9048*	0.9524*	–0.7143*	1.0000	
GDP	0.7143*	–0.6905	0.7857*	–0.9286*	0.7857*	1.0000

Note: N=8 policies. * Denotes significance at p<0.05.

As noted above, net exports fall in response to these policies—indeed, by a larger amount than domestic consumption increases. Higher electricity prices disadvantage exports and advantage imports; hence, we would expect net exports to decrease. Greater incomes would increase consumer demand for goods, resulting in greater imports and thereby reducing net exports.

In Figures 3.2 to 3.5, we repeat the same exercises as in Figure 3.1, but for oil reduction policies, renewables policies, EE policies, and the remaining types of policies, respectively. Tables 2a through 4b provide the respective Pearson and Spearman correlation coefficients for these policies. The most obvious difference between Figures 3.1 and 3.2 is that consumption increases in the carbon pricing policies and decreases in the oil reduction policies. This is at least partly because revenues are recycled for the former policies but not for the latter. It is also theoretically possible that, on net, the products affected by oil taxes are demanded more elastically than those affected by a carbon tax. However, elasticity estimates in the literature tend to be lower for oil than for carbon-intensive products.

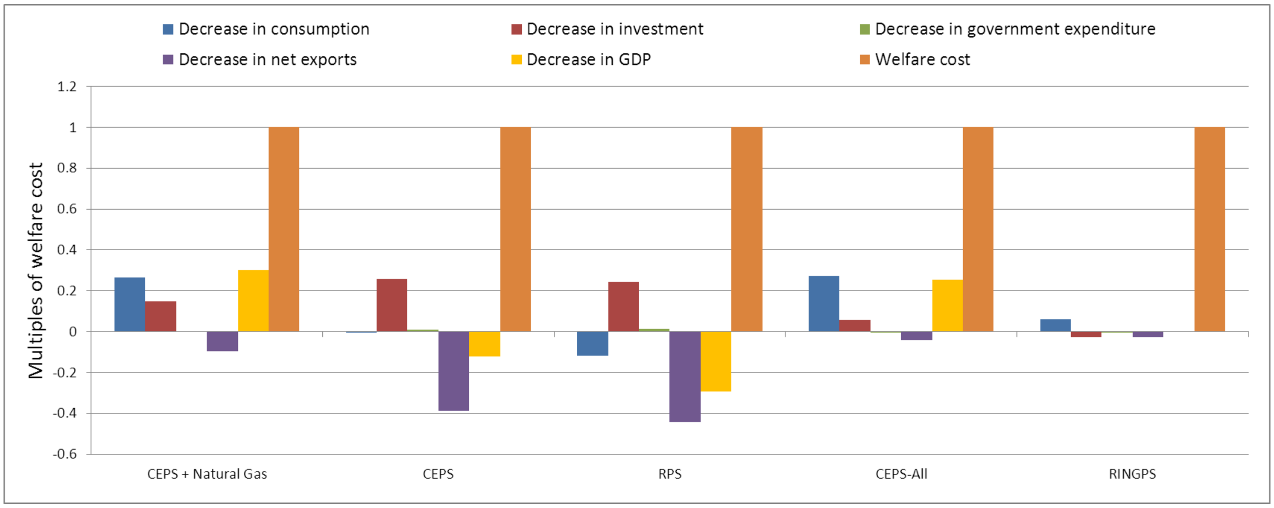
Figure 3.2. Oil Reduction Policies: Scaled Macroeconomic Metrics by Welfare Cost



Beyond these consumption effects, the scaled macroeconomic metrics for the oil reduction policies (Figure 3.2) do not exhibit the same regular pattern that we observed for carbon pricing policies (a decline in scale compared to welfare costs as welfare costs rise). However, if one considers only those oil reduction policies that are wholly or partly based on a gasoline or oil tax, the same pattern emerges. This suggests that the macroeconomic effects of a policy do not increase in proportion to an increase in welfare cost when considering the costliest policies.

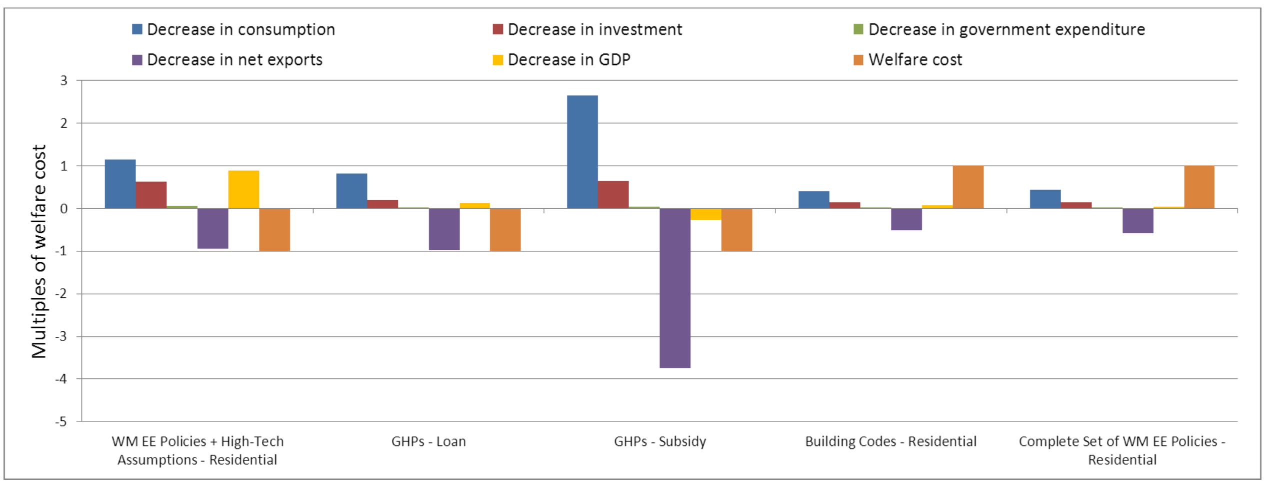
In Figure 3.3 for renewables policies, consumption increases for the RPS policy but otherwise decreases. GDP changes are positive for two policies, negative for two more, and negligible for one policy. It is unclear how these patterns can be explained. For EE policies in Figure 3.4, welfare costs are sometimes positive and sometimes negative, but net exports always increase and consumption always decreases. GDP may increase or decrease, but not in any discernable pattern relative to the directional change in welfare costs. Finally, for the new nuclear loan guarantees modeled (Figure 3.5), the pattern of change in the metrics is quite similar to that of the carbon pricing policies; the effects on the macroeconomic metrics are greater relative to welfare cost for the policy with the smaller loan guarantee.

Figure 3.3. Renewables Policies: Scaled Macroeconomic Metrics by Welfare Cost



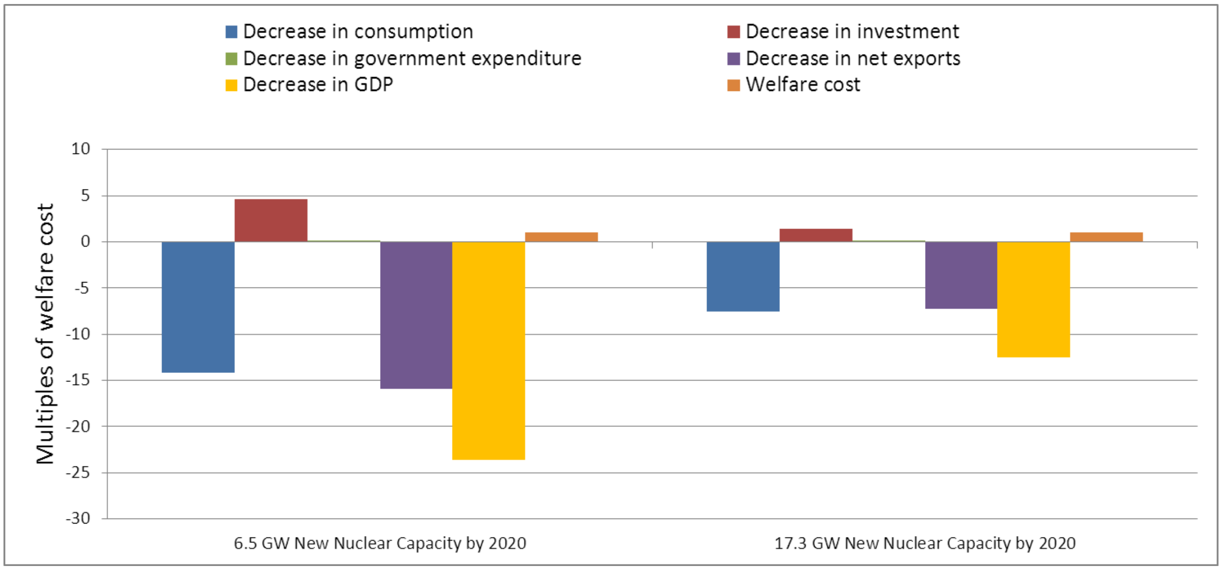
Notes: CEPS, Clean Energy Portfolio Standard; RINGPS, Renewable and Incremental Natural Gas Portfolio Standard.

Figure 3.4. EE Policies: Scaled Macroeconomic Metrics by Welfare Cost



Notes: WM, Waxman–Markey bill (H.R. 2454).

Figure 3.5. Nuclear Power Policies: Scaled Macroeconomic Metrics by Welfare Cost



Note: GW, gigawatts.

The Pearson product moment correlation coefficient results in Tables 2a, 3a, and 4a, and the Spearman rank correlation coefficients in Tables 2b, 3b, and 4b, bear out the lack of regularity noted above, where correlation coefficients between metrics and welfare costs for oil reduction, renewables, and EE policies are much weaker than those for the carbon pricing policies; further, these correlation coefficients are not statistically significant. Consumption would be the metric most strongly correlated with welfare cost for the oil reduction and EE policies; however, we cannot be confident that the relationship is different from zero because neither one is significant. This is primarily due to the small sample size for each policy type.

Table 2a. Pearson Product Moment Correlation for Oil Reduction Policies

	Welfare cost	Consumption	Investment	Government expenditure	Net exports	GDP
Welfare cost	1.00					
Consumption	0.52	1.00				
Investment	–0.33	–0.97*	1.00			
Government expenditure	–0.31	–0.96*	0.99*	1.00		
Net exports	0.28	0.92*	–0.95*	–0.98*	1.00	
GDP	0.49	0.98*	–0.94*	–0.97*	0.96*	1.00

Note: N=10 policies. * Denotes significance at p<0.05.

Table 2b. Spearman Rank Correlation for Oil Reduction Policies

	Welfare cost	Consumption	Investment	Government expenditure	Net exports	GDP
Welfare cost	1.000					
Consumption	0.7212*	1.000				
Investment	–0.6606*	–0.9758*	1.000			
Government expenditure	–0.212	–0.7333*	0.7576*	1.000		
Net exports	0.200	0.7455*	–0.7818*	–0.9879*	1.000	
GDP	0.576	0.9152*	–0.9394*	–0.8182*	0.8424*	1.000

Note: N=10 policies. * Denotes significance at p<0.05.

Table 3a. Pearson Product Moment Correlation for Renewable Policies

	Welfare cost	Consumption	Investment	Government expenditure	Net exports	GDP
Welfare cost	1.00					
Consumption	0.54	1.00				
Investment	–0.76	–0.32	1.00			
Government expenditure	–0.77	–0.94*	0.61	1.00		
Net exports	0.47	0.71	–0.75	–0.79	1.00	
GDP	0.35	0.97*	–0.23	–0.86	0.74	1.00

Note: N=5 policies. * Denotes significance at p<0.05.

Table 3b. Spearman Rank Correlation for Renewable Policies

	Welfare cost	Consumption	Investment	Government expenditure	Net exports	GDP
Welfare cost	1.00					
Consumption	0.50	1.00				
Investment	–0.30	–0.70	1.00			
Government expenditure	–0.50	–1.00*	0.70	1.00		
Net exports	–0.10	0.60	–0.90*	–0.60	1.00	
GDP	0.10	0.90*	–0.60	–0.90*	0.70	1.00

Note: N=5 policies. * Denotes significance at p<0.05.

Table 4a. Pearson Product Moment Correlation for EE Policies

	Welfare cost	Consumption	Investment	Government expenditure	Net exports	GDP
Welfare cost	1.00					
Consumption	–0.82	1.00				
Investment	–0.80	0.99*	1.00			
Government expenditure	–0.79	0.98*	1.00*	1.00		
Net exports	0.79	–0.98*	–0.96*	–0.94*	1.00	
GDP	–0.80	0.98*	0.99*	1.00*	–0.92*	1.00

Note: N=5 policies. * Denotes significance at p<0.05.

Table 4b. Spearman Rank Correlation for EE Policies

	Welfare cost	Consumption	Investment	Government expenditure	Net exports	GDP
Welfare cost	1.00					
Consumption	–0.50	1.00				
Investment	–0.30	0.900*	1.00			
Government expenditure	–0.10	0.30	0.60	1.00		
Net exports	0.50	–1.00*	–0.90*	–0.30	1.00	
GDP	–0.70	0.10	0.20	0.60	–0.10	1.00

Note: N=5 policies. * Denotes significance at p<0.05.

Tables 5a and 5b summarize how closely the metrics track one another in an absolute sense and across all 30 policies. We find that GDP reduction is a fairly good proxy for welfare costs, with a correlation of actual cost differences of 0.73 and a Spearman ranked correlation coefficient of 0.65, both of which are significant at the 95 percent confidence level. The other metrics do poorly against welfare costs and against one another. In particular, consumption, EIA's preferred macroeconomic metric, correlates poorly against welfare costs. However, this low correlation between welfare costs and the macro indicators can be at least partly explained by the different ways in which revenue recycling is handled for the carbon pricing versus oil tax policies. When we exclude the carbon pricing policies, we find that consumption reduction fairs better, with a correlation of actual cost differences of 0.60 and a Spearman ranked correlation coefficient of 0.62, and GDP reductions fair slightly worse, with a correlation of 0.58 and a Spearman ranked correlation coefficient of 0.43.

Table 5a. Pearson Product Moment Correlation for All 30 Policies

	Welfare cost	Consumption	Investment	Government expenditure	Net exports	GDP
Welfare cost	1.00					
Consumption	–0.16	1.00				
Investment	0.20	–0.98*	1.00			
Government expenditure	–0.29	–0.70*	0.75*	1.00		
Net exports	0.70*	–0.39*	0.35	–0.36	1.00	
GDP	0.73*	–0.03	0.01	–0.64*	0.92*	1.00

Note: N=30 policies. * Denotes significance at p<0.05.

Table 5b. Spearman Rank Correlation for All 30 Policies

	Welfare cost	Consumption	Investment	Government expenditure	Net exports	GDP
Welfare cost	1.00					
Consumption	–0.04	1.00				
Investment	0.03	–0.87*	1.00			
Government expenditure	–0.55*	0.06	0.02	1.00		
Net exports	0.55*	–0.45*	0.38*	–0.84*	1.00	
GDP	0.65*	–0.04	0.13	–0.78*	0.80*	1.00

Note: N=30 policies. * Denotes significance at p<0.05.

In the next analysis in this series, we use regression techniques to sort out whether a reliance on GDP (or consumption) as a surrogate for welfare cost is more reliable for one policy type than for others. We accomplish this by regressing the PDV of GDP reductions on welfare costs for all policies and by regressing GDP reductions on welfare costs while controlling for policy type. We include the interaction term between policy type and GDP to determine whether GDP is better at "explaining" the variation in welfare cost for certain policy types. Tables 6a and 6b display these results. For the regressions using absolute costs and macroeconomic variables, GDP is highly significant in its association with welfare costs but consumption is not. Adding policy type-specific intercepts as dummy variables and allowing slopes to vary by including interaction terms for each policy category results in a significant interaction with the carbon pricing policy type; this supports our casual observation about the greater regularity of relationships between GDP and welfare costs for carbon pricing policies than for other policy types.[9]

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[9] This result disappears when an outlier policy (C&T with No Offsets) is removed from the dataset.

Table 6a. Regression of Macroeconomic Metrics on Welfare Cost

Variable	Model 1a	Model 1e
Consumption	–0.09	
GDP		0.50***
Constant	98.85***	29.59
N	30	30
Adjusted R-square	–0.01	0.51

Note: * p<0.1; ** p<0.05; *** p<0.01.

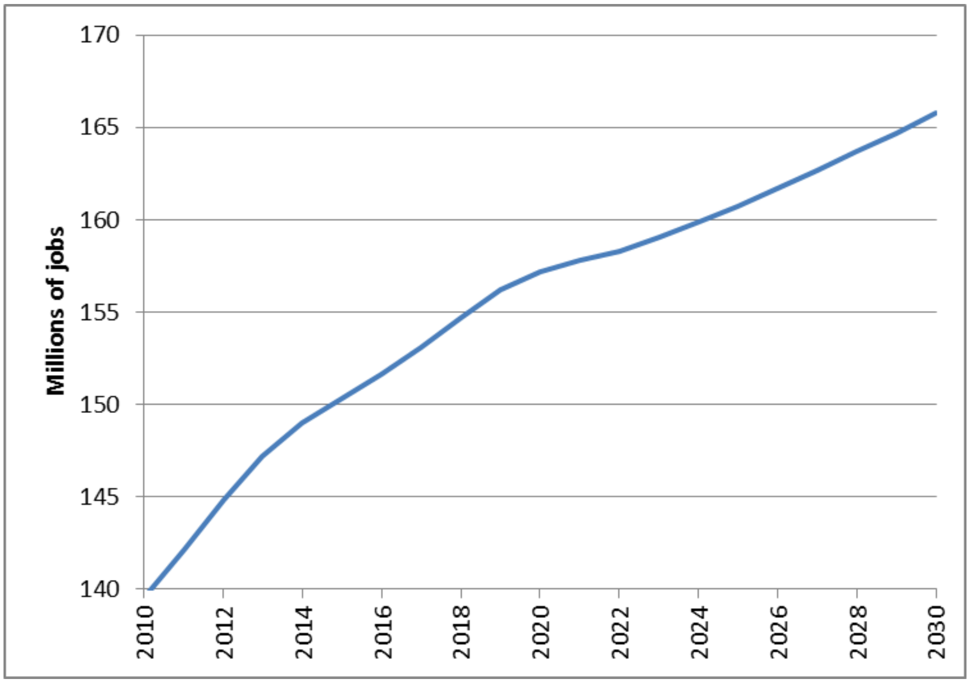
Table 6b. Regression of Macroeconomic Metrics on GDP with Policy Category Controls and Interactions

Variable	Model 2a	Model 2b	Model 2c	Model 2d	Model 2e
GDP	0.34***	0.62***	0.56***	0.47***	0.50***
Carbon pricing	–315.93***				
GDP*carbon pricing	1.13***				
Oil reduction		56.5			
GDP*oil reduction		–0.37*			
Renewables			62.76		
GDP*renewables			0.65		
EE				–36.02	
GDP*EE				–1.77	
Nuclear					–31.62
GDP*nuclear					–0.6
_cons	43.83***	15.15	11.58	42.96*	30.74
N	30	30	30	30	30
r2_a	0.72	0.54	0.52	0.51	0.48

Note: * p<0.1; ** p<0.05; *** p<0.01.

Lastly, we compare the performance of a jobs metric across policies and then across other metrics. Figure 4.1 shows employment in the Reference case, which rises, steadily propelled by growth in the labor force.

Figure 4.1. Employment under the Reference Case



Figures 4.2 to 4.6 provide time profiles of employment changes caused by policies in each policy group relative to the Reference case. Figure 4.2 shows that the employment impacts of carbon pricing policies are quite similar in their overall pattern: an equal rise in 2012, a dip in 2014, steady increases in employment until 2024 to 2026, and shrinking jobs thereafter.[10] The policies are fairly indistinguishable in their employment effects until the last few years of the simulations, when the most stringent and costly policy in terms of welfare costs (C&T without offsets) leads to the greatest job losses by 2030 (one million fewer jobs compared to the same year in the Reference case)—this in spite of the beneficial effects of revenue recycling on consumption.

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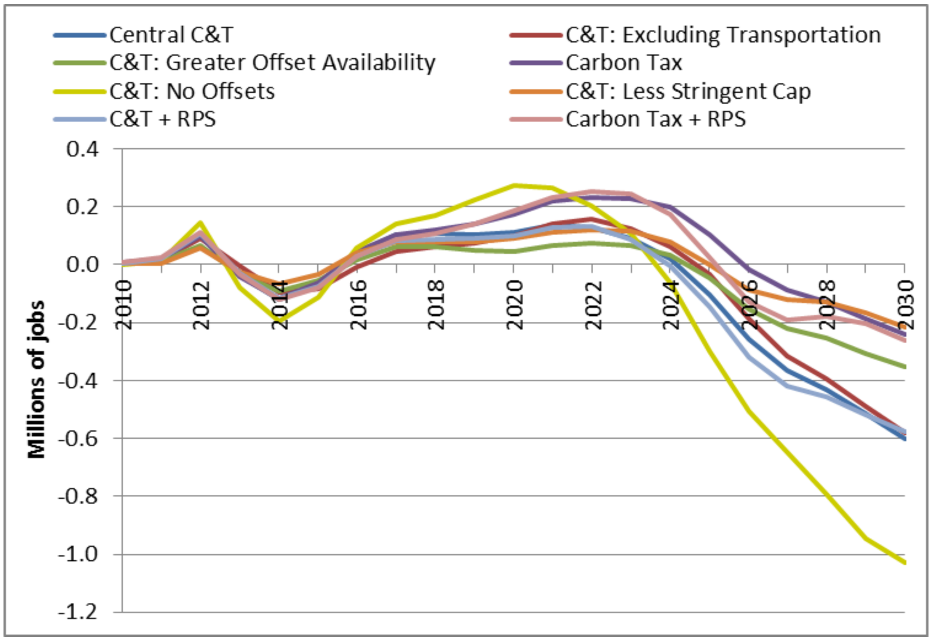
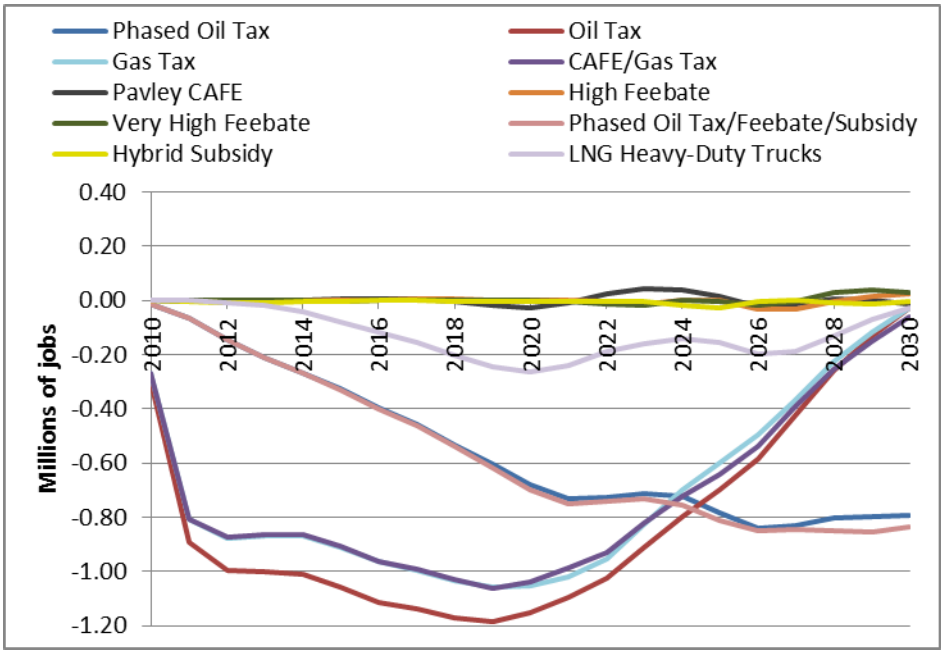
[10] The increase in 2012 is an artifact of the NEMS model and should be ignored.

Figure 4.2. Carbon Pricing Policy Employment Time Profiles



In contrast, Figure 4.3 for oil reduction policies shows no effects on employment from Pavley CAFE and feebate policies, but fairly dramatic and immediate negative effects of the tax policies, which recover losses relative to the Reference case by 2030. This steep initial decline in employment may occur, in part, because the tax revenues collected are not recycled to consumers. As expected, phasing of oil taxes results in a more gradual decline in jobs. Unexpectedly, in this phased case, jobs compared to the Reference case do not recover.

Figure 4.3. Oil Reduction Policy Employment Time Profiles



From Figure 4.4, we see that the least effective renewables/portfolio standard policies (RPS, the Clean Energy Portfolio Standard [CEPS], and CEPS–natural gas [NG]), have minor effects on employment. The two portfolio standard policies that are more effective at reducing CO_2 (the Renewable and Incremental Natural Gas Portfolio Standard [RINGPS] and CEPS–All) have very different profiles of employment. The former policy results in at most (in 2026) a 200,000 job deficit compared to the Reference case, but then employment nearly matches Reference case levels in 2030. For CEPS–All, however, employment is larger than the Reference case over much of the forecast period (at most by 150,000 jobs in 2022 and 2023), but by 2025 the policy has fewer jobs relative to the Reference case and jobs appear to head down through 2030.[11]

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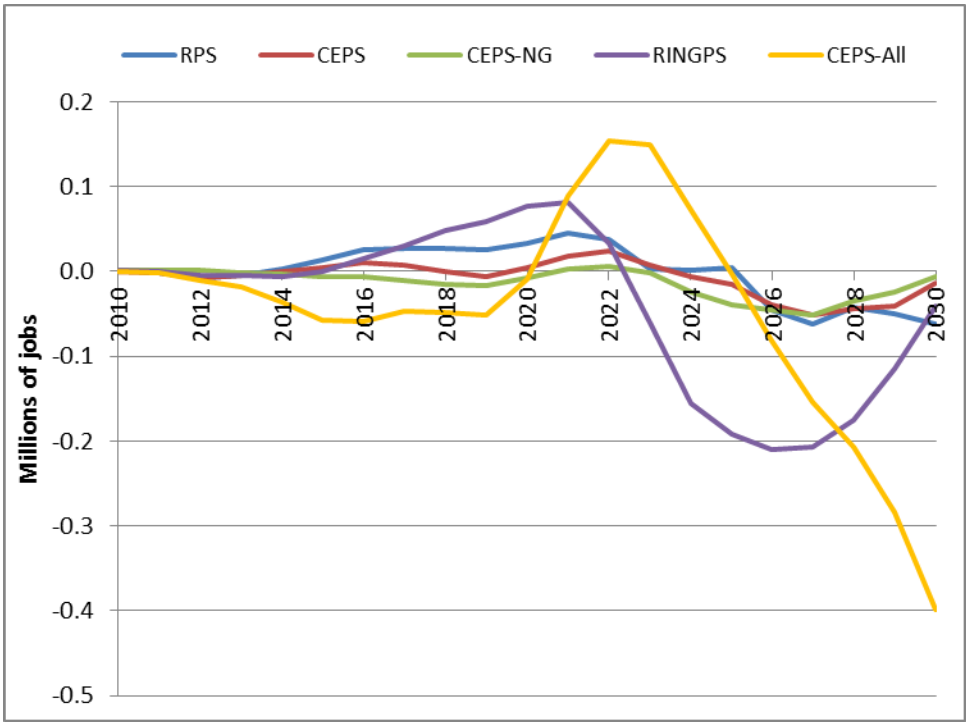
[11] At least one reason for this downturn could be the changes in cumulative additions to electric power sector capacity relative to the baseline. The two data series remain relatively flat from 2010 until 2017, increase thereafter before peaking in 2021, and decline through the end of the forecast period (2030). However, we would expect increases in employment to lead capacity additions; therefore further analysis is needed.

Figure 4.4. Renewables Policy Employment Time Profiles



Figures 4.5 and 4.6 cover the EE and nuclear policies. Jobs gains are minimal for these relatively ineffective policies, except for the Waxman–Markey[12] (WM) EE policies + High Tech, which is modeled as a best case penetration of EE measures in buildings and elsewhere in the economy. Employment gains are relatively strong for the case of nuclear loan guarantees, which result in 17.3 additional gigawatts (GW) of new capacity, relative to a policy that promises much smaller loan guarantees.

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[12] This name refers to the Waxman–Markey bill, H.R. 2454, from which these policies are modeled.

Figure 4.5. EE Policy Employment Time Profiles

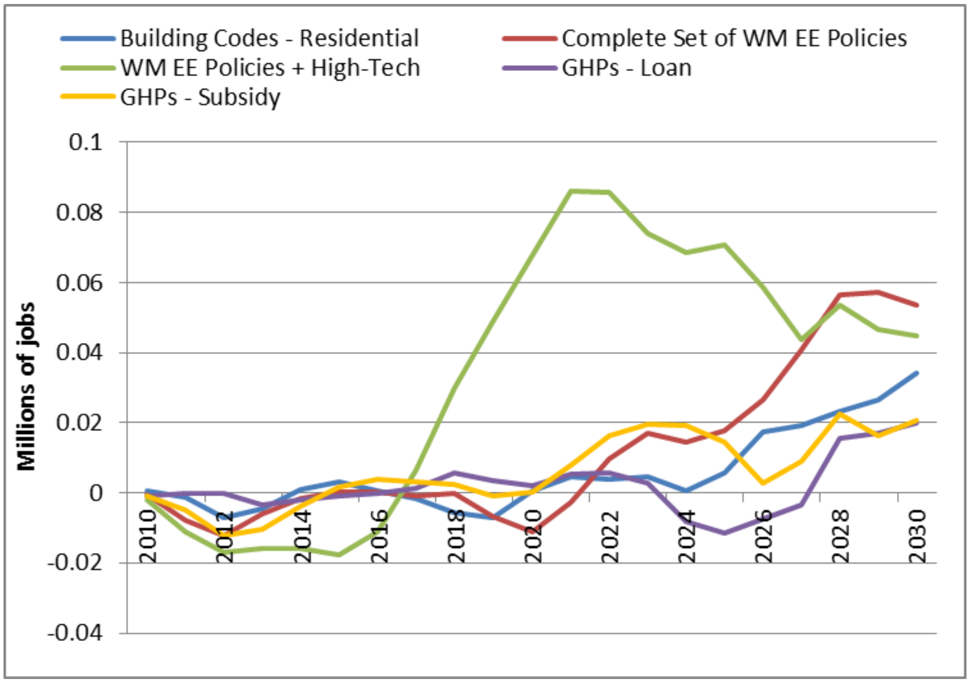
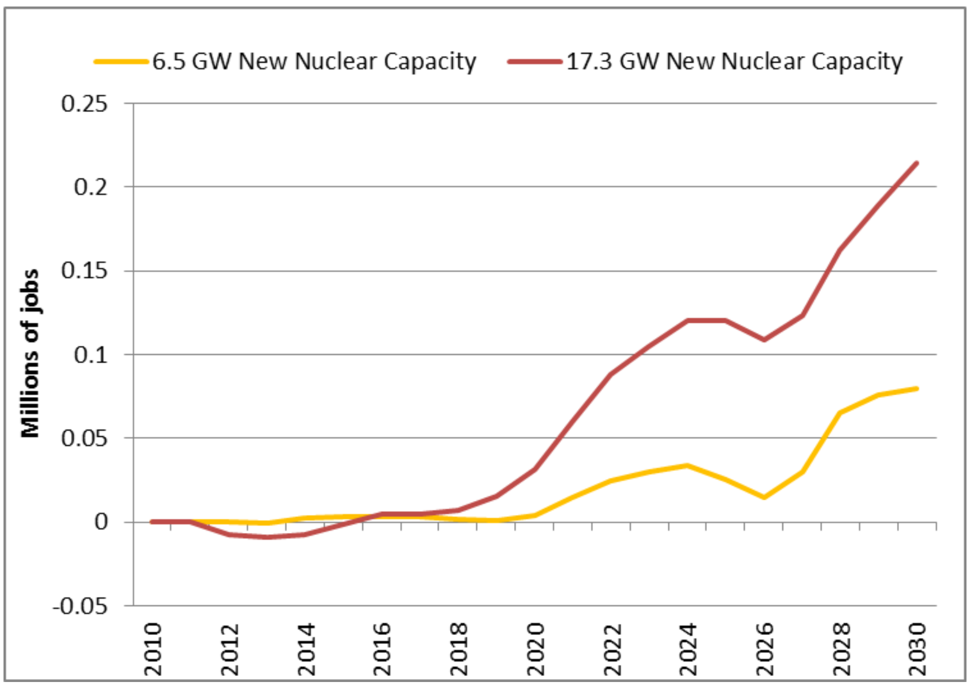


Figure 4.6. Nuclear Policy Employment Time Profiles



Finally, Figures 5.1 and 5.2 compare time profiles of welfare costs, GDP, and consumption (on the left-hand axis) to that of jobs (on the right-hand axis). As above, a positive GDP or consumption change reflects a *decrease* in these metrics. Figure 5.1 (our Central C&T policy) shows that jobs changes mirror changes in consumption (when consumption increases, jobs increase and vice-versa). But from 2024 on, job growth becomes negative, whereas consumption remains equally above baseline levels from 2026 on. GDP remains below baseline by $20 billion or so over the forecast period. Welfare costs rise steadily to nearly $20 billion by 2030.

Figure 5.2 shows the effects of CEPS–All on our four key metrics over time. Jobs more or less follow the movement of GDP and consumption (but on the graphs they move as mirror images): increases in GDP and consumption lead to increases in jobs and vice-versa. The increases in GDP, consumption, and employment between 2019 and 2025 relative to the Reference case could possibly be due to the last push of the electricity sector toward compliance with the clean energy standard requirements by 2025. At the same time, note how welfare costs are rising throughout Figure 5.2, having no apparent relationship with the other three metrics.

Figure 5.1. Central C&T Macroeconomic Time Profile Relative to Reference Case

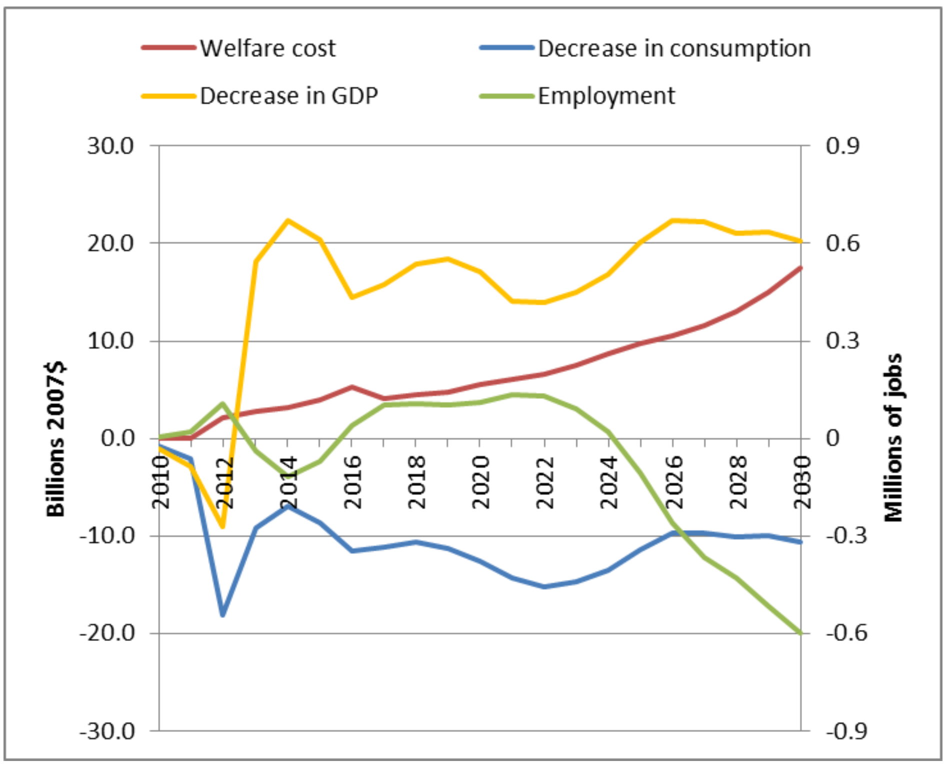
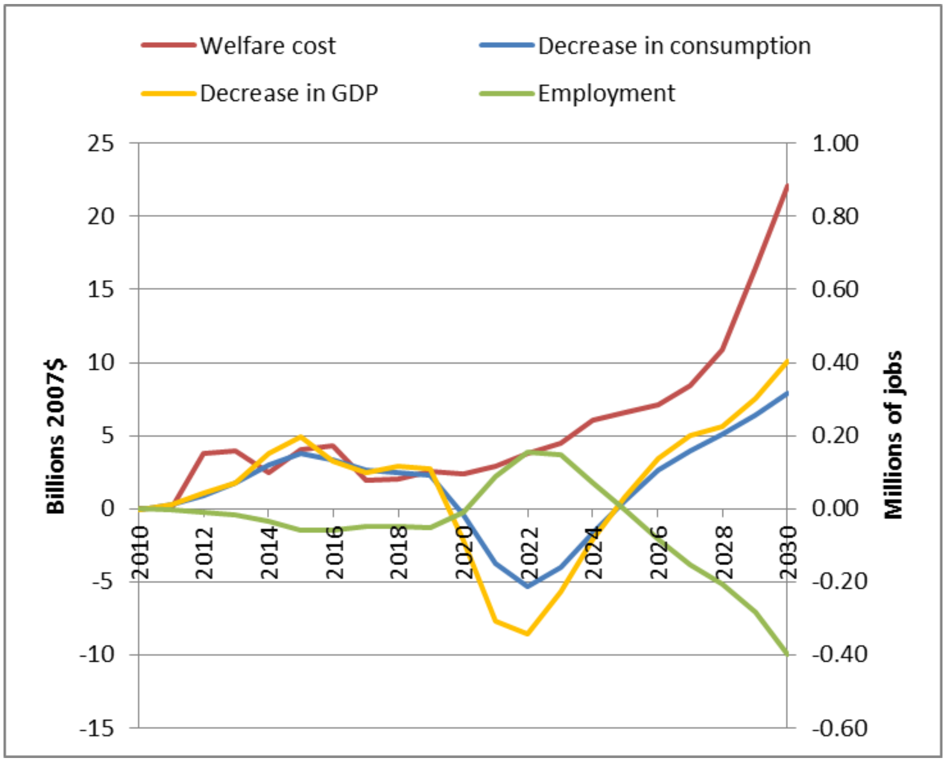


Figure 5.2. CEPS–All Macroeconomic Time Profile Relative to Reference Case



Conclusions

Taking an efficiency perspective, the appropriate metric for judging the impacts of a policy is its effect on social welfare, or its welfare costs. But this concept is difficult to communicate to lawmakers, stakeholders, and the press, let alone the general public, who are often more interested in macroeconomic indicators such as GDP and jobs. The point of this discussion paper is to determine, using one of the most well-known and respected economywide models of the United States (NEMS, as modified by RFF), how well a diverse set of macroeconomic metrics match up with one another when examining alternative energy policies. If a particular macroeconomic metric provides the same ranking of policies as a welfare cost metric, we can consider it a reasonable surrogate for welfare cost. If not, perhaps we can shed some light on the usefulness of these macroeconomic metrics.

Indeed, we find that we can't have our cake and eat it too, at least with respect to NEMS–RFF and the 30 policies we modeled. No macroeconomic metric is very closely correlated with, or provides very similar policy rankings to, welfare costs. Moreover, the macroeconomic metrics are very complicated to interpret. The model produces cycles of job creation and loss, and consumption and GDP increase for some policies and decrease for others for reasons that are not readily apparent. Further, macro metrics for revenue-raising policies appear to be largely driven by decisions over how revenues are used rather than the policies themselves and the underlying economic fundamentals represented by demand and supply elasticities.

Ultimately, these findings argue for greater skepticism in the public debates about using macroeconomic indicators to rank policies and more use of welfare cost as a metric. Because job losses and net exports, for instance, are important metrics in their own right—for the window they offer on distributional consequences of policies—we argue for supplementing them with welfare cost estimates.

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Appendix A: Policies Considered in This Study

Policies modeled	
Reference case	The Reference case is based on the *Annual Energy Outlook 2009* Stimulus Reference (The American Recovery and Reinvestment Act of 2009) and also includes an advancing of fuel economy standards mandating that new light-duty vehicles achieve 35.5 mpg from 2020 to 2016.
CO_2 pricing policies	
Central C&T	Reduces all GHGs by 17 percent below 2005 levels in 2020 and 40 percent below this base by 2030; covers all energy-related CO_2 and all industrial and agricultural sources of non-CO_2 GHG emissions; covers all major sectors; allows 500 million tons each for domestic and international offsets per year; allows banking and borrowing of allowances with a zero bank balance in 2030; and auctions allowances, returning the revenue to households in lump-sum rebate checks.
C&T: Excluding Transportation	Requires the same total cumulative reductions under the cap as for the Central C&T case, but excludes the transportation sector from the policy.
C&T: Alternative Cases for Offset Availability	One case allows one billion tons each of domestic and international offsets per year, and the other does not allow the use of any offsets in meeting the overall cap.
C&T: Less Stringent Cap	Required cumulative reductions for all GHGs are 33 percent lower than in the Central C&T case.
Carbon Tax	A tax per ton of CO_2 emissions that mimics the time path of allowance prices under the Central C&T policy.
C&T + RPS	Combines the 25 percent RPS with the Central C&T policy.
Carbon Tax + RPS	Combines the 25 percent RPS with the Carbon Tax policy.
C&T: No Offsets	Central C&T policy with no offsets.
Oil Reduction policies	
Gasoline Tax	Raises the gasoline tax by $1.27/gallon in 2010 and increases it in real terms at an annual rate of 1.5 percent per year, adding $1.73 to the cost of a gallon by 2030. The revenues from this tax, and taxes or auctioned allowances described below, are returned in lump-sum payments to individuals (they are therefore considered revenue-neutral).
Oil Tax	Applies the above level of gasoline tax to all refined oil products used in the United States, including imported petroleum products (exported products are exempt). The tax is based on Btu equivalence. This tax is revenue-neutral.
Phased Oil Tax	A variant of the Immediate Oil Tax case that eventually reaches $1.73/ gallon of gasoline equivalent on all oil products by 2030. This tax begins at 8 cents/gallon in 2010 and rises by approximately 8 cents/gallon each year through 2030. This tax is revenue-neutral.
"Pavley" CAFE	Features an increase of 3.7 percent per year in fuel economy standards for both cars and light trucks for 2017 through 2020. From 2021 to 2030, the policy further tightens standards by 2.5 percent per year, reaching an average standard of 52.2 mpg for light-duty vehicles in 2030.

High Feebate	Features a fee assessed on vehicles that do worse than the Pavley CAFE standard in each year and a rebate for those vehicles that do better. The basic rate is $2,000 per 0.01 gallons/mile, phased in progressively between 2017 and 2021 and thereafter rising (in real terms) at 2.5 percent per year, so that it reaches $2,969 per 0.01 gallons/mile in 2030.
Very High Feebate	Sets the feebate rates in each year exactly twice as large as in the High Feebate case.
Hybrid Subsidy	Establishes a vehicle purchase subsidy of $3,000 for each 0.01 gallon/mile saved between the HEV or PHEV and its gasoline-equivalent vehicle, with the subsidy constant in real terms from 2010 to 2030.
Pavley CAFE/Gas Tax	Combines the Pavley CAFE policy with the Gasoline Tax.
Phased Oil Tax/ Feebate/Hybrid Subsidy	Combines the Phased Oil Tax, High Feebate, and Hybrid Subsidy.
LNG Heavy-Duty Trucks	Assumes that 10 percent of new Class 7 and 8 heavy-duty trucks bought in 2011 run on natural gas, rising to 20 percent of new trucks bought in 2012, up to 100 percent of new trucks bought in 2020 and beyond. This case is modified in one of the policy combinations to rise at half the penetration rate (rising by 5 percent per year to reach 100 percent by 2030 rather than 2020). This scenario can be viewed as a policy mandate or a subsidy.
Renewable energy technologies	
RPS	Calls for 25 percent of total generation (excluding generation from hydro and MSW plants) to come from non-hydro renewables nationwide by 2025, with interim targets leading up to this ultimate goal. Renewable energy credits are used to achieve these targets.
CEPS	Broadens the portfolio standard to include other “clean” fuels besides renewables, including incremental generation from nuclear power plants and from natural gas and coal plants that have CCS technology.
CEPS–NG	Broadens the CEPS to include new natural gas capacity (without CCS) in the portfolio. New natural gas capacity receives a fraction of a clean energy credit, dependent on the CO_2 emissions from the technology.
RINGPS	Combines a 25 percent RPS with a 20 percent Incremental Natural Gas Portfolio Standard, meaning that 25 percent of total electricity generation (excluding generation from hydro and MSW plants) must come from renewables and 20 percent must come from new natural gas plants.
CEPS–All	Seeks to replicate the share of generation produced by technologies other than coal (with the exception of coal with CCS) obtained under the Central C&T policy. The scope of CEPS–All is larger than that of CEPS and includes generation from new and existing non-coal generators. Unlike the CEPS and CEPS–NG policies, this policy has no cap on the price of clean energy credits, and the clean generation share target is applied to all generation, including hydro and MSW.
EE policies	
Building Codes – Residential	Calls for a 30 percent reduction in energy use by new buildings upon enactment of the law, a 50 percent reduction from residential buildings by 2014 and from commercial

	buildings by 2015, and a 5 percent reduction at 3-year intervals thereafter up until 2029. This policy is consistent with the building code provisions in the WM bill, H.R. 2454.
Complete Set of WM EE Policies – Residential	Adds retrofit requirements; standards for outdoor lighting, portable light fixtures, and incandescent reflector lamps; and new standards and testing procedures for appliances in accordance with the building code provisions, similar to those represented by EIA's analysis of the WM bill.
WM EE Policies + "High-Tech" – Residential	A modification of the set of WM EE policies that assumes accelerated technical progress (beyond that already found in the Reference case) across the board. This manifests in higher efficiencies for most energy-using equipment.
Residential GHPs – Subsidy	Models a $4,000 direct consumer subsidy for the purchase and installation of a GHP system in the residential sector.
Residential GHPs – Loan	Models a zero-interest $4,000 loan for the purchase and installation of a GHP system in the residential sector, paid back over a seven-year period.
Nuclear power: loan guarantee	
6.5 GW of New Nuclear by 2020	Reduces the ROE assumed in NEMS–RFF from 17 percent (in the Reference case) to 14 percent, which leads to an expansion of 6.5 GW of nuclear power capacity by 2020.
17.3 GW of New Nuclear by 2020	Reduces the ROE assumed in NEMS–RFF from 17 percent (in the Reference case) to 11 percent, which expands nuclear power capacity by 17.3 GW by 2020.

Notes: Btu, British thermal unit; C&T, Cap-and-Trade; CAFE, Corporate Average Fuel Economy; CCS, carbon capture and storage; CEPS, Clean Energy Portfolio Standard; CO_2, carbon dioxide; EE, energy efficiency; EIA, Energy Information Administration; GHG, greenhouse gas; GW, gigawatt; HEV, Hybrid Electric Vehicle; LNG, Liquefied Natural Gas; mpg, miles per gallon; MSW, municipal solid waste; NG, Natural Gas; PHEV, Plug-in Hybrid Electric Vehicle; RINGPS, Renewable and Incremental Natural Gas Portfolio Standard; ROE, return-on-equity; RPS, Renewable Portfolio Standard; WM, Waxman–Markey.