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Working Paper Series
Paper No. 467

Dynamically Estimating the Distributional Impacts of U.S. Climate Policy with NEMS: A Case Study of the Climate Protection Act of 2013

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Abstract

We present a new method that enables users of the federal government's flagship energy policy model (NEMS) to dynamically estimate the direct cost impacts of climate policy across U.S. household incomes and census regions. Our approach combines NEMS output with detailed household expenditure data from the Consumer Expenditure Survey, improving on static methods that assess policy impacts by assuming household energy demand remains unchanged under emissions pricing scenarios. To illustrate our method, we evaluate a recent carbon fee-and-dividend proposal introduced in the U.S. Senate, the Climate Protection Act of 2013 (S. 332). Our analysis indicates this bill, if enacted, would have cut CO_2 emissions from energy by 17% below 2005 levels by 2020 at a gross cost of less than 0.5% of GDP, while simultaneously reducing direct energy expenditures for typical households making less than $120,000 per year and average households in all regions of the United States.

1. Introduction

Analyzing the costs and benefits of U.S. climate policy raises complex methodological problems. Many tools are available to estimate the national economic, environmental, and fiscal impacts of proposed policies, yet none of the standard national energy models is capable of projecting the costs of climate policy across household income levels. With increasing interest in the cost of climate policy for low-income households, including the development of policy proposals designed to mitigate these impacts, policymakers need new analytical tools.

Here, we describe a new method by which users of a prominent energy model can better evaluate the distributional impacts of prospective climate policies. Our approach focuses on the National Energy Modeling System (NEMS), the federal government's flagship energy-economic model. NEMS is widely used by academics, policymakers, and consultants to assess national energy and climate policies. For example, the U.S. Energy Information Administration uses NEMS to generate its Annual Energy Outlook (AEO), a report that projects energy consumption and related trends over a 20-25 year horizon (EIA, 2012a). EIA also uses NEMS to evaluate prospective energy and climate policies (EIA, 2010a, 2010b, 2009a, 2008a, 2008b, e.g., 1998).

We develop a method that couples NEMS output with data from the Consumer Expenditure Survey (CEX), which reports household energy expenditures across income levels and geography (BLS, 2013). By linking NEMS output and CEX data, we are able to dynamically estimate net changes in household energy expenditures, also known as "direct" policy costs (see Section 2.3.3 for a discussion of direct and indirect costs). This approach offers important advantages over existing methods for estimating direct costs, which generally assume that households have a static demand for energy, despite the introduction of a price on carbon dioxide (CO_2) emissions. For example, Metcalf (1999) calculates the incidence of a carbon tax across household income levels using CEX data. Metcalf estimates the effect of a carbon tax on the

price of goods and services in the national economy by propagating it through an input-output matrix of inter-industry transactions. The impact on households depends on these price changes and the consumption patterns across household incomes, which are described in the CEX data. Notably, his method assumes both that the structure of the economy and the composition of household expenditures remains unchanged, a feature that many other papers in the field share (e.g., Hassett et al., 2009; Mathur and Morris, 2014; Metcalf, 2009). Our approach is most closely related to Blonz et al. (2011), who estimate the distribution of climate policy costs across household income levels by combining CEX data on consumption patterns with projections of future consumption derived from energy-economic models. Specifically, Blonz et al. use EIA's reference forecast (based on NEMS) to project changes in consumption outside the electricity sector and an RFF model (Haiku) to project changes in electricity consumption. As a result, one of the model drivers is static (EIA's reference forecast for non-electricity) and another is dynamic (RFF's policy scenario for electricity). Yet CEX data show that electricity represents only a quarter of average American household energy expenditures, suggesting the need for dynamic analysis of additional expenditures.

Our approach offers a modest but important improvement over past work in two respects. First, we integrate dynamic modeling results for all energy-related household consumption over multiple years. This allows us to include expected changes in household energy-related consumption in our estimate of direct policy costs. Second, we use the federal government's own energy model, NEMS. Both features enable comparison of our results with standard government forecasts and official government policy analysis. Our dynamic estimates of direct costs can be combined with other researchers' estimates of indirect costs (e.g., Mathur and Morris, 2014) to assess the full impact on consumer welfare, or compared against relevant portions of the results

from stand-alone general equilibrium models (Goulder and Hafstead, 2013; Williams et al., 2014) that are used to assess the distributional impacts of prospective climate policies.

To illustrate our method's applications, we analyze a recent carbon fee-and-dividend policy proposed in the U.S. Senate. A distributional analysis is particularly relevant for policies of this nature because they are designed to protect the lowest-income households from increased energy costs through lump-sum tax revenue rebates. The Climate Protection Act of 2013 (S. 332), introduced by Senators Barbara Boxer (D-CA) and Bernie Sanders (I-VT), would have imposed a carbon pollution fee on CO_2 emissions from fossil fuels. The fee would have started in 2014 at \$20 per metric ton of CO_2 and rising at 5.6% per year in nominal terms through 2023 (Boxer and Sanders, 2013). Under the bill, 60% of revenue collected from the carbon fee would be returned to legal residents of the United States in the form of monthly dividends. The bill also included a number of energy policy programs, including those designed to protect trade-exposed industries (\$75 billion), provide financial assistance to weatherize low-income homes (\$50 billion), job training and transition assistance (\$10 billion), energy R&D (\$20 billion), and energy finance (\$50 billion). Collectively, these expenditures would have accounted for about 16% of total carbon revenues that would have been collected over the first ten years of the policy. The balance of carbon revenues (about 24%) would have been used to reduce the federal government's deficit, per the Senate PAYGO rules (CBO, 2009).[1]

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[1] Technically, the bill first apportions 60% of revenues for rebates, then allocates specific amounts to policy programs, and finally directs the remaining revenue to deficit reduction. Thus, the deficit reduction depends on the total revenue raised. We show in Section 3.3 that just over 24% of total revenues would be available for deficit reduction, suggesting compliance with U.S. Senate pay-as-you-go (PAYGO) rules is feasible. According to PAYGO rules, legislation that imposes new taxes or fees on the economy must discount its expected revenues by 25% to account for the indirect reductions in federal income and payroll taxes (CBO, 2009).

Our paper is organized as follows. Section 2 describes the energy economic model (NEMS) and external CEX household data used in this study, along with our method for integrating these analytical tools. Next, we apply our method to the Climate Protection Act of 2013. Section 3 describes the environmental, economic, and fiscal results of our modeling work, including a detailed treatment of how the Act would impact household-level expenditures on energy across income levels and geographic regions. We discuss the results and review key assumptions in Section 4. Finally, Section 5 summarizes our findings and suggests directions for future work.

2. Model, methods, and approach

Assessing the impacts of a federal carbon price on both the U.S. economy and on individual households requires more than a single modeling tool. We use NEMS to estimate changes at the national level, projecting the emission reductions, macroeconomic impacts, and fiscal consequences of the carbon fee. These results are then combined with the Consumer Expenditure Survey (CEX), which identifies how much different households spend on energy goods and services. We estimate future energy-related expenditure by coupling NEMS projections of energy prices and consumption to their corresponding metrics in the CEX, allowing us to consistently estimate the effect of changing energy markets on household energy expenditures. The following sub-sections describe NEMS, the CEX data, and our method for combining these tools to assess the Climate Protection Act.

2.1 Energy-economic model: NEMS

NEMS is arguably the most influential U.S. energy model. EIA uses NEMS to generate the federal government's annual long-term forecast of national energy consumption and to

evaluate prospective federal energy policies (EIA, 2009b). NEMS is considered such an important tool that other models are calibrated to its forecasts, in both government and academic practice. Consequently, it has a significant influence over expert opinions of plausible energy futures. EIA uses NEMS to evaluate the impacts of proposed energy and climate policies, often at the request of Congress. Some examples include the analysis of the Kyoto Protocol greenhouse gas (GHG) emissions limits (EIA, 1998), the Lieberman–Warner Climate Security Act (EIA, 2008a), the Low Carbon Economy Act (EIA, 2008b), the Waxman–Markey American Clean Energy and Security (ACES) Act (EIA, 2009a), the American Power Act (EIA, 2010a), and Carbon Limits and Energy for America's Renewal (CLEAR) Act (EIA, 2010b).

Because of the model's prevalence, many other government, academic, and private sector studies use NEMS to assess prospective energy and climate policies. For example, the U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy (EERE) commissioned a group of national laboratory scientists to conduct a follow-up report to the EIA's study of the costs of complying with the Kyoto Protocol (Brown et al., 2001). Other examples include a prospective analysis of the impact of a federal renewable portfolio standard on U.S. energy markets (Kydes, 2007), the impacts from the 1990 Clean Air Act Amendments (Luong et al., 1998), an analysis of polices to reduce oil consumption and GHG emissions from the U.S. transportation sector (Morrow et al., 2010), the impact of climate and energy policies on the U.S. forest products industry (Brown and Baek, 2010), the effects of climate policy on freshwater withdrawals for thermoelectric power generation (Chandel et al., 2011), and energy efficiency potential in the residential and commercial building sectors (Wilkerson et al., 2013). Consulting groups, such as McKinsey & Company (Choi Granade et al., 2009; Creyts et al., 2007) and the

Rhodium Group (Houser and Mohan, 2014) also use NEMS to analyze trends and policies that affect the broader U.S. energy-economy.

The model's popularity is due in part to its massively detailed representation of the U.S. energy-economic structure, which allows for a plausible simulation of energy supplies and demand within different sectors. However, several aspects of the model create difficulties when the model is used to evaluate prospective carbon tax policies. While NEMS has some ability to estimate the geographic impacts of climate policy, these calculations are made at a high level, with results aggregated at the level of nine U.S. Census Divisions. Furthermore, understanding how policy costs fall across income levels is a key step to designing the appropriate level of compensation for policies that propose to rebate a portion of the total revenue to consumers. Yet NEMS does not analyze the impacts of prospective policies across different household income levels, nor does it track any household-level or individual consumer impacts. The model provides only aggregated output on income- and tax-related forecasts for consumers and firms. As a result, developing an estimate of the distributional impact of climate policies requires combining NEMS forecasts with external data sources.

2.2 Household energy expenditures

To assess the impact to households across income groups and location, we couple NEMS output with the U. S. Bureau of Labor Statistics' 2011 Consumer Expenditure Survey (CEX), which provides cross-sectional data on household expenditures (BLS, 2013). CEX is perhaps the most comprehensive survey on consumer expenditures, providing cross-sectional data on all household expenditures, income, and other characteristics. The annual report provides detailed expense summaries on various activities including type of foods, rent and mortgage, utilities, furnishings, apparel, healthcare, transportation, entertainment, and others. The survey data are

used by policymakers, businesses and academic researchers, and by other Federal agencies—including to regularly revise the Consumer Price Index (CPI).

2.3 Approach

Our methodology involves three steps. First, we use NEMS to forecast the impact of carbon prices on energy-related emissions, gross domestic product (GDP), energy demand, and energy prices. Second, we connect relevant NEMS output on energy demand and prices to their corresponding expenditure categories in the CEX. Specifically, we scale the energy expenditure patterns reported in the CEX data by the expected changes in residential energy prices and energy consumption due to climate policy, as projected by NEMS. This method allows us to assess policy impacts across household income levels and geography. Third, we complete our analysis of the impacts to household expenditures by rebating a portion of the total revenues to households on a per capita basis. Each step is described in more detail below.

2.3.1 Modifying and running NEMS

Applying a carbon fee within the NEMS framework is relatively straightforward. Carbon prices are set in the emissions policy data file *epmdata.txt*, which is read by the model when the code is initiated. This input requires an explicit annual carbon price series, expressed in 1987\$/kgC for each year. For detailed description of this file and the emissions policy submodule, see the NEMS Integrating Module documentation (EIA, 2010c). Consistent with the Climate Protection Act, we modeled a nominal \$20/tCO_2 price that begins in 2014 and escalates at 5.6% (nominal) each year for ten years.

In addition to specifying carbon price levels, NEMS users must tell the model how to account for the revenue collected by the climate policy. The model has several default options for how its macroeconomic calculations treat the use of carbon fee revenues. These options are set with the

mactax flag in the *scedes* (scenario description) file. The flag is subsequently used by the *mcevcode.txt* text file, which serves as an interface between the core model code and the Macroeconomic Activity Module (EIA, 2013a). The value of *mactax* can be set from 0 to 5. A value of 0 turns carbon pricing off, while settings 1 through 5 turn carbon pricing on with binary control over how revenues are recycled through the economy. Tax modes 1 and 2 return revenues to consumers and businesses, respectively, in a revenue-neutral manner; tax mode 3 applies all revenues to federal government deficit reduction; tax modes 4 and 5 return revenues to consumers and businesses, respectively, in a deficit-neutral manner.

Revenue use under the Climate Protection Act includes consumer rebates, deficit reduction, and policy expenditures; however, none of the default options in NEMS permits a mixture of these approaches, nor does any account for the re-spending effects of government policies. We found that the choice of default revenue options does not materially affect GDP, greenhouse gas emissions, or residential energy prices.[2] This result is surprising, but may reflect the relative simplicity of the NEMS macroeconomic module's treatment of tax policy, a common model limitation raised by (Fawcett et al., 2014). Many studies have suggested that the choice of mechanism for revenue recycling—such as lump-sum transfers, income tax reductions, or corporate tax reductions—should have important macroeconomic and efficiency implications and can lead to more efficient outcomes if the revenues are used to reduce the level of ordinary distortionary taxes (Goulder and Hafstead, 2013; Goulder, 2013; Williams et al., 2014).

Nonetheless, having confirmed that the choice of revenue recycling modes did not affect our results, we set *mactax* to 4, which recycles all revenue back to households for the purposes of

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[2] The NEMS interface with the Macroeconomic Activity Module (MAM) is the *mcevcode.txt* file, which is used to pass values and settings to the MAM. With some additional coding in that file, these default options can be combined. However, the different revenue options do not materially affect GDP or net greenhouse gas emissions. This result is illustrated in Appendix A.7 in Wilkerson (2014).

the model's internal macroeconomic analysis. This setting is also what EIA uses for their carbon price sensitivity studies, as described in Appendix D of the AEO2013 (EIA, 2013b).

Finally, we note that our analysis is based on an independent version of the 2013 release of NEMS. To ensure the model and its third-party software components were properly installed and engaged, we confirmed that the local version of the model accurately reproduced the EIA's published baseline scenario projections. Thus, our local setup is a reliable means of assessing what EIA's official copy of NEMS would project for the same scenarios modeled here. Nevertheless, our results independent and should not be confused with official government policy analysis. Accordingly, outputs from this study are designated as coming from NEMS-Stanford, an independent and unofficial copy of the government's model.

2.3.2 Bridging NEMS forecasts with CEX data

The CEX includes approximately one hundred household expenditure line items, but only five correspond to energy-related goods and services: natural gas, electricity, fuel oil and other household fuels, gasoline and motor oil, and public and other transportation. In 2011, the average American household spent $5,171 on energy-related activities, which was 10.4% of total average household expenses. Expressed as a percentage of total energy expenditures, the average household spent about 51% on gasoline, 28% on electricity, 10% on public and other transit (including airline travel), 8% on natural gas, and the remaining 3% on fuel oils and other fuels.

As the CEX data show, however, energy expenditures vary significantly by household income level, with households in higher income brackets spending more money—though a smaller percentage of their overall income—on energy. Figure 1 illustrates energy expenditures for the average American household and the five quintiles of income distribution in 2011. Energy expenditures for average households of different income levels and in different

geographic regions are reported in Table 1. The disparity in both total quantity and relative expenditure shares on different energy types varies significantly across income quintiles. The largest variation by income in quantity of energy expenditures occurs for purchases of gasoline, while the largest percentage variation by income occurs for “other transportation,” which includes air travel. In turn, this variation illustrates the importance of assessing carbon policy impacts across income distributions.

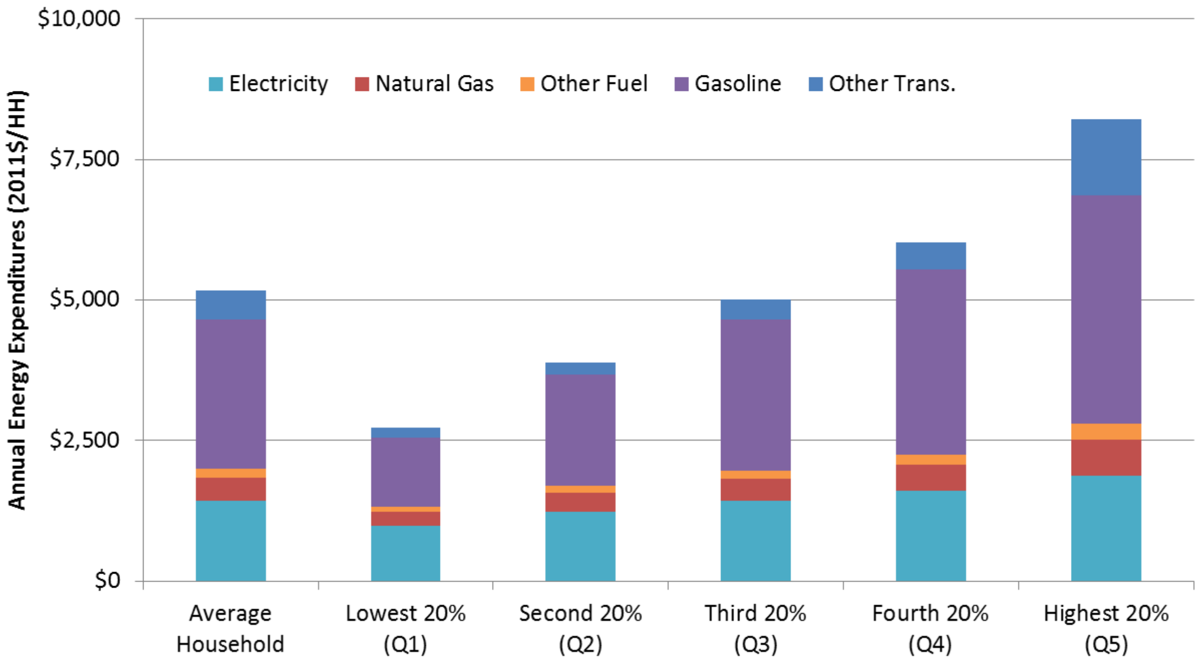


Figure 1: Average household energy expenditures by income quintile in 2011

Table 1: U.S. household energy expenditures by income and geographic region in 2011

Market Segment	Households				Expenditure: Total	Expenditure: Energy		Energy Expenditure by Fuel Type: $/HH, % of energy expenditures, indexed to average consumer — Natural Gas			Electricity			Fuel oil & Other Fuel			Gasoline & Motor Oil			Other Transportation		
	thous.	% of total	pph[1]	Income[2]	$/HH	$/HH	% of Total	$/HH	% of energy	Index[3]	$/HH	% of energy	Index[3]	$/HH	% of energy	Index[3]	$/HH	% of energy	Index[3]	$/HH	% of energy	Index[3]
Average Household																						
Avg. Consumer Unit	122,287	100%	2.5	$61,673	$49,705	$5,171	10.4%	$420	8.1%	1.00	$1,423	27.5%	1.00	$157	3.0%	1.00	$2,655	51.3%	1.00	$516	10.0%	1.00
By Income Quintiles																						
Lowest 20 % (Q1)	24,435	20%	1.7	$10,074	$22,001	$2,722	12.4%	$243	8.9%	0.58	$985	36.2%	0.69	$85	3.1%	0.54	$1,227	45.1%	0.46	$182	6.7%	0.35
Second 20 % (Q2)	24,429	20%	2.2	$27,230	$32,092	$3,876	12.1%	$338	8.7%	0.80	$1,234	31.8%	0.87	$119	3.1%	0.76	$1,981	51.1%	0.75	$204	5.3%	0.40
Third 20 % (Q3)	24,473	20%	2.6	$45,563	$42,403	$5,016	11.8%	$386	7.7%	0.92	$1,429	28.5%	1.00	$140	2.8%	0.89	$2,694	53.7%	1.01	$367	7.3%	0.71
Fourth 20 % (Q4)	24,520	20%	2.8	$72,169	$57,460	$6,015	10.5%	$472	7.8%	1.12	$1,603	26.7%	1.13	$170	2.8%	1.08	$3,295	54.8%	1.24	$475	7.9%	0.92
Highest 20 % (Q5)	24,430	20%	3.2	$153,326	$94,551	$8,217	8.7%	$659	8.0%	1.57	$1,863	22.7%	1.31	$270	3.3%	1.72	$4,073	49.6%	1.53	$1,352	16.5%	2.62
By Region																						
Northeast (NE)	22,538	18.4%	2.4	$69,334	$54,547	$5,661	10.4%	$596	10.5%	1.42	$1,338	23.6%	0.94	$487	8.6%	3.10	$2,510	44.3%	0.95	$730	12.9%	1.41
Midwest (MW)	27,107	22.2%	2.4	$59,394	$47,192	$5,031	10.7%	$600	11.9%	1.43	$1,225	24.3%	0.86	$121	2.4%	0.77	$2,632	52.3%	0.99	$453	9.0%	0.88
South (S)	44,901	36.7%	2.5	$57,205	$45,699	$5,204	11.4%	$243	4.7%	0.58	$1,763	33.9%	1.24	$70	1.3%	0.45	$2,794	53.7%	1.05	$334	6.4%	0.65
West (W)	27,741	22.7%	2.6	$64,909	$54,745	$4,853	8.9%	$387	8.0%	0.92	$1,135	23.4%	0.80	$64	1.3%	0.41	$2,569	52.9%	0.97	$698	14.4%	1.35
By Household Income																						
Less than $5k (HH1)	4,978	4.1%	1.7	-$995	$22,960	$2,578	11.2%	$241	9.3%	0.57	$909	35.3%	0.64	$49	1.9%	0.31	$1,148	44.5%	0.43	$231	9.0%	0.45
$5k to <$10k (HH2)	5,449	4.5%	1.7	$8,155	$20,884	$2,470	11.8%	$201	8.1%	0.48	$900	36.4%	0.63	$100	4.0%	0.64	$1,112	45.0%	0.42	$157	6.4%	0.30
$10k to <$15k (HH3)	8,170	6.7%	1.6	$12,803	$19,959	$2,667	13.4%	$229	8.6%	0.55	$1,006	37.7%	0.71	$87	3.3%	0.55	$1,172	43.9%	0.44	$173	6.5%	0.34
$15k to <$20k (HH4)	7,745	6.3%	2.0	$17,955	$24,806	$3,220	13.0%	$316	9.8%	0.75	$1,127	35.0%	0.79	$113	3.5%	0.72	$1,487	46.2%	0.56	$177	5.5%	0.34
$20k to <$30k (HH5)	14,460	11.8%	2.2	$25,136	$30,398	$3,830	12.6%	$324	8.5%	0.77	$1,215	31.7%	0.85	$132	3.4%	0.84	$1,971	51.5%	0.74	$188	4.9%	0.36
$30k to <$40k (HH6)	13,328	10.9%	2.4	$34,750	$36,769	$4,299	11.7%	$371	8.6%	0.88	$1,302	30.3%	0.91	$97	2.3%	0.62	$2,247	52.3%	0.85	$282	6.6%	0.55
$40k to <$50k (HH7)	11,347	9.3%	2.6	$44,196	$40,306	$4,977	12.3%	$380	7.6%	0.90	$1,433	28.8%	1.01	$142	2.9%	0.90	$2,679	53.8%	1.01	$343	6.9%	0.66
$50k to <$70k (HH8)	17,376	14.2%	2.7	$58,070	$50,034	$5,471	10.9%	$427	7.8%	1.02	$1,516	27.7%	1.07	$158	2.9%	1.01	$2,961	54.1%	1.12	$409	7.5%	0.79
$70k to <$80k (HH9)	7,385	6.0%	2.8	$72,895	$57,977	$6,003	10.4%	$462	7.7%	1.10	$1,600	26.7%	1.12	$169	2.8%	1.08	$3,345	55.7%	1.26	$427	7.1%	0.83
$80k to <$100k (HH10)	10,456	8.6%	3.0	$86,417	$65,390	$6,643	10.2%	$522	7.9%	1.24	$1,662	25.0%	1.17	$187	2.8%	1.19	$3,612	54.4%	1.36	$660	9.9%	1.28
$100k to <$120k (HH11)	7,045	5.8%	3.2	$105,125	$76,496	$7,298	9.5%	$603	8.3%	1.44	$1,710	23.4%	1.20	$228	3.1%	1.45	$3,921	53.7%	1.48	$836	11.5%	1.62
$120k to <$150k (HH12)	6,107	5.0%	3.1	$127,734	$87,239	$8,048	9.2%	$598	7.4%	1.42	$1,760	21.9%	1.24	$267	3.3%	1.70	$4,150	51.6%	1.56	$1,273	15.8%	2.47
$150k and more (HH13)	8,440	6.9%	3.2	$232,086	$123,056	$9,551	7.8%	$779	8.2%	1.85	$2,147	22.5%	1.51	$331	3.5%	2.11	$4,267	44.7%	1.61	$2,027	21.2%	3.93

Notes: [1] People per household
[2] After taxes
[3] Indexed to Avg. Consumer Unit

In order to link CEX and NEMS, the energy-related expenditures in the CEX data are matched to their corresponding outputs from NEMS, as shown in Table 2. Note that while NEMS output includes detailed output that corresponds to most energy consumption data series in CEX, we were unable to match a direct proxy for "public and other transportation"—a category that includes significant air travel. As a result, we assumed percentage changes in expenditures in this category would be comparable to those for gasoline. Indeed, the relative price trends for gasoline and the mixture of gasoline, diesel, and jet fuel in the "public and other transportation" category should be quite similar. It is nevertheless possible that the price elasticity of demand differs across fuels or transportation services, in which case our assumption would introduce bias.

Table 2: Correspondence between CEX and NEMS

CEX Series	NEMS Output
Natural gas	Residential natural gas prices and quantities
Electricity	Residential electricity prices and quantities
Fuel oil and other fuels	Consumption-weighted average of residential prices and quantities for propane, kerosene, and distillate fuel oil
Gasoline and motor oil	Retail gasoline prices and population-weighted shares of national consumption of gasoline for light duty vehicles
Public and other transportation	Retail gasoline prices and population-weighted shares of national consumption of gasoline for light duty vehicles.

Next, we use NEMS forecasts for residential energy expenditures to project trends based on historic CEX household expenditures. Each scenario in NEMS produces a forecast of energy prices (P) and a total aggregate consumption (Q) for each major fuel types (f). The product of this price and quantity forecast in a given region (or the U.S. as a whole) is the total cost for each fuel within the residential sector for a given year (y). Equation 1 shows the difference in total

expenditure between the Reference and a policy scenario represents the annual cost of the policy for each fuel type (C_f^y). These impacts correspond to what economists have called the "direct component" of total impacts (Hassett et al., 2009; Mathur and Morris, 2014).

$$C_f^y = (P \cdot Q)_f^y\Big|_{policy} - (P \cdot Q)_f^y\Big|_{reference} \qquad \textbf{Eq. 1}$$

Linking the CEX data is a matter of scaling the CEX 2011 household energy expenditure data (E_f^{2011}) by the total aggregate expenditure from NEMS in the same year (See Equation 2). This produces a per-household share of total residential energy expenditure.

$$\frac{E_f^{2011}}{(P \cdot Q)_f^{2011}} \qquad \textbf{Eq. 2}$$

The direct cost to household energy expenditures in a given year is therefore the sum of the products of Equations 1 and 2 for all five fuel types (*f*).

$$\text{Household Direct Cost}_y = \sum_f \left(E_f^{2011} \cdot \frac{(P \cdot Q)_f^y}{(P \cdot Q)_f^{2011}} \right) \qquad \textbf{Eq. 3}$$

This method works well when NEMS outputs are of equal or higher resolution as the CEX survey data. Although each of its component modules uses a different resolution when making internal calculations, NEMS generally reports most results at the national level and for each of nine Census Divisions, whereas CEX reports published data for four Census Regions. Thus, when linking the CEX Region data to NEMS, we first aggregate the nine Census Divisions from NEMS into the appropriate Census Region (see Table 3).

Table 3: Correspondence between Census Regions and Census Divisions

Census Region	Census Division	States Included
Northeast (NE)	New England (01)	ME, NH, VT, MA, RI, CT
	Middle Atlantic (02)	NY, PA, NJ
Midwest (MW)	East North Central (03)	WI, MI, IL, IN, OH
	West North Central (04)	MO, ND, SD, NE, KS, MN, IA
South (S)	South Atlantic (05)	DE, MD, DC, VA, WV, NC, SC, GA, FL
	East South Central (06)	KY, TN, MS, AL
	West South Central (07)	OK, TX, AR, LA
West (W)	Mountain (08)	ID, MT, WY, NV, UT, CO, AZ, NM
	Pacific (09)	AK, WA, OR, CA, HI

In contrast, where the CEX data are more finely resolved than NEMS output, we use an index method. Table 1 includes an index (or multiplier), which identifies how much a particular market segment spent compared to the average American household. For example, the lowest earning quintile bracket (Q1) spent $243 on natural gas in 2011, whereas the average household spent $420.Thus, the index for Q1's natural gas consumption was 0.58 ($243/$420). To estimate changes in household expenditures where CEX data are more finely resolved than NEMS output (e.g., consumption by income distribution), we scale the product of Equations 1 and 2, as applied to the national average household, by the appropriate index.

2.3.3 Net impacts to household energy expenditures

The methods described above identify the per-household direct policy cost across different types of households. To assess the net impacts of a fee-and-dividend policy on household expenditures, we also model the revenue rebated to households. The Climate Policy Act would have required that 60% of total revenue collected be rebated to legal residents. We assume the bill would have issued rebates on a per capita basis. Thus, the per capita rebate is applied to

households based on the average number of occupants (see Table 1). Accordingly, the net impact to household energy expenditures is defined as the difference between the increase in direct energy costs and the rebate under the fee-and-dividend policy. Notably, we report only direct costs, which do not include impacts to employment, GDP, or any other macroeconomic changes. Static estimates of indirect costs suggest that they could add an additional 50 to 100% above the direct cost estimate for the different household income categories, though indirect costs are significantly less regressive than are direct costs (Mathur and Morris, 2014: Table 1). In addition, like other papers that project CEX data forward with model results, this study assumes that income distribution patterns do not change during the forecast period.

3. Results

3.1 Avoided carbon dioxide emissions from fossil fuel use

Our analysis indicates that the carbon pollution fee implemented under the Climate Protection Act would significantly reduce energy-related CO_2 emissions across the U.S. economy in the next decade. Over the first ten years of the program (2014-2023), the bill would have avoided aggregate emissions by more than 4,200 MMt CO_2, relative to the reference scenario. Emission reductions occur rapidly during the first two years of implementation, slowing to a more gradual decline in subsequent years. This reduction is in stark contrast to the baseline scenario, in which energy-related CO_2 emissions are expected to increase during the next decade, following sharp declines in the period from 2008 to 2011 (see Figure 2).

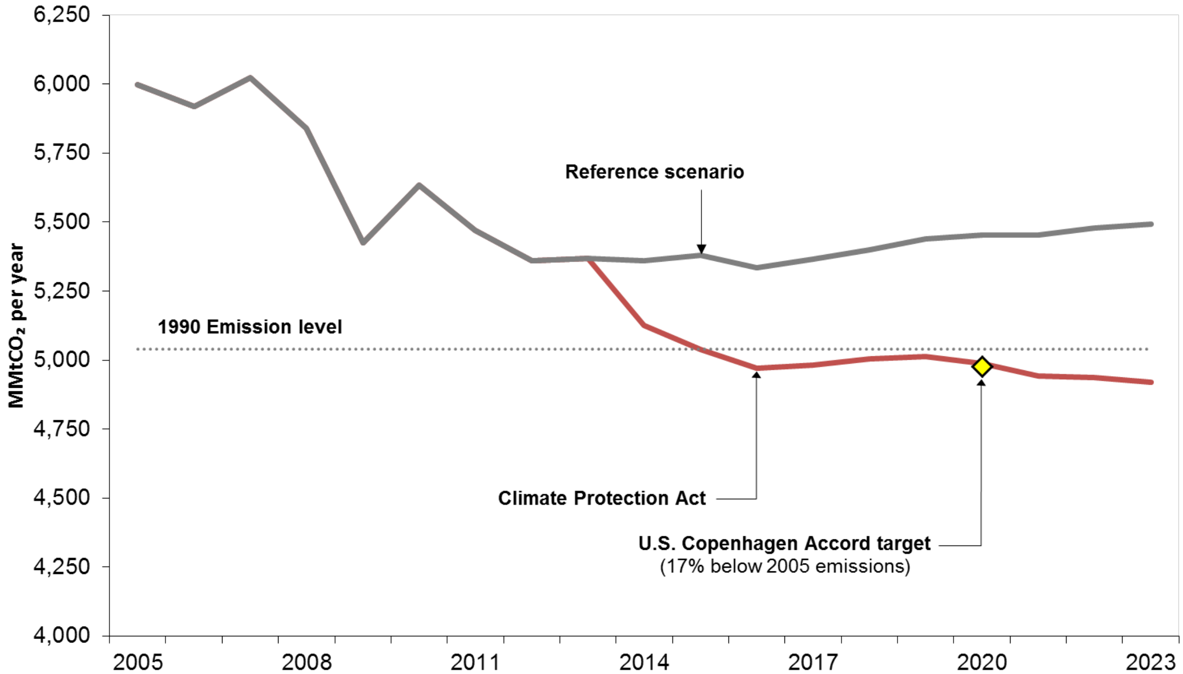


Figure 2: Estimated reductions in energy-related CO_2 emissions

Due to the Climate Protection Act, U.S. CO_2 emissions from energy in 2023 would have been 575 $MMtCO_2$ (10.5%) less than in the reference scenario. By pricing CO_2 emissions, the Climate Protection Act would have extended the reduction in emissions observed since 2007, marking that year as the peak for national emissions of CO_2 from energy use.

Under the Copenhagen Accord (UNFCCC, 2010), the U.S. has committed to reduce its economy-wide GHG emissions to "in the range of 17% below" 2005 levels by 2020. Although the Climate Protection Act does not mandate any specific reductions levels, NEMS-Stanford projects that the carbon fee would have reduced energy-related CO_2 emissions in 2020 by 8.5% (464 $MMtCO_2$) below reference scenario emissions. This is equivalent to 16.8% (1,009 $MMtCO_2$) below 2005 energy-related CO_2 emissions, putting the U.S. within reach of its pledge under the Copenhagen Accord. Note that the U.S. commitment under the Copenhagen Accord could be read to cover emissions of six greenhouse gases (CO_2, methane, nitrous oxide,

hydrofluorocarbons, perfluorocarbons, and sulfur hexafluoride), whereas NEMS projects only energy-related CO_2 emissions, a subset of emissions that accounts for approximately 79% of gross and 91% of net GHG emissions in the United Sates (EIA, 2012b).

We also review how the emission reductions would have been achieved. Figure 3 shows that almost all of the avoided emissions would come from changes in the electricity supply sector—87% of total avoided emissions over the policy's first decade. Changes in demand for petroleum and natural gas outside of the electricity sector account for 6.5% and 6.2% of total reductions, respectively, while changes in direct-use coal provides less than 1% of emission reductions.

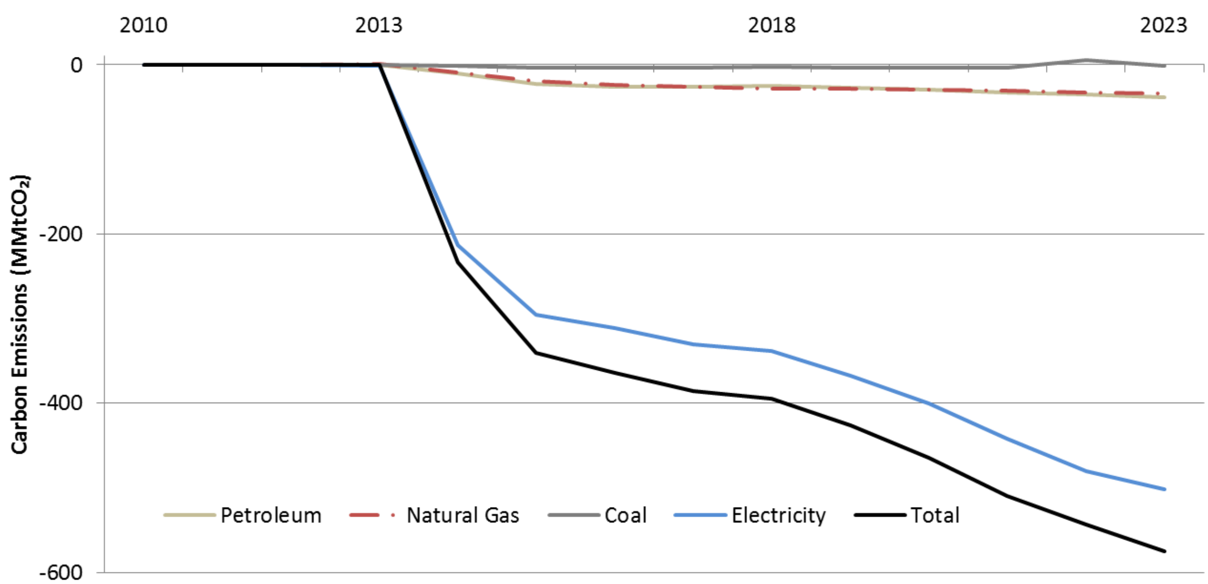
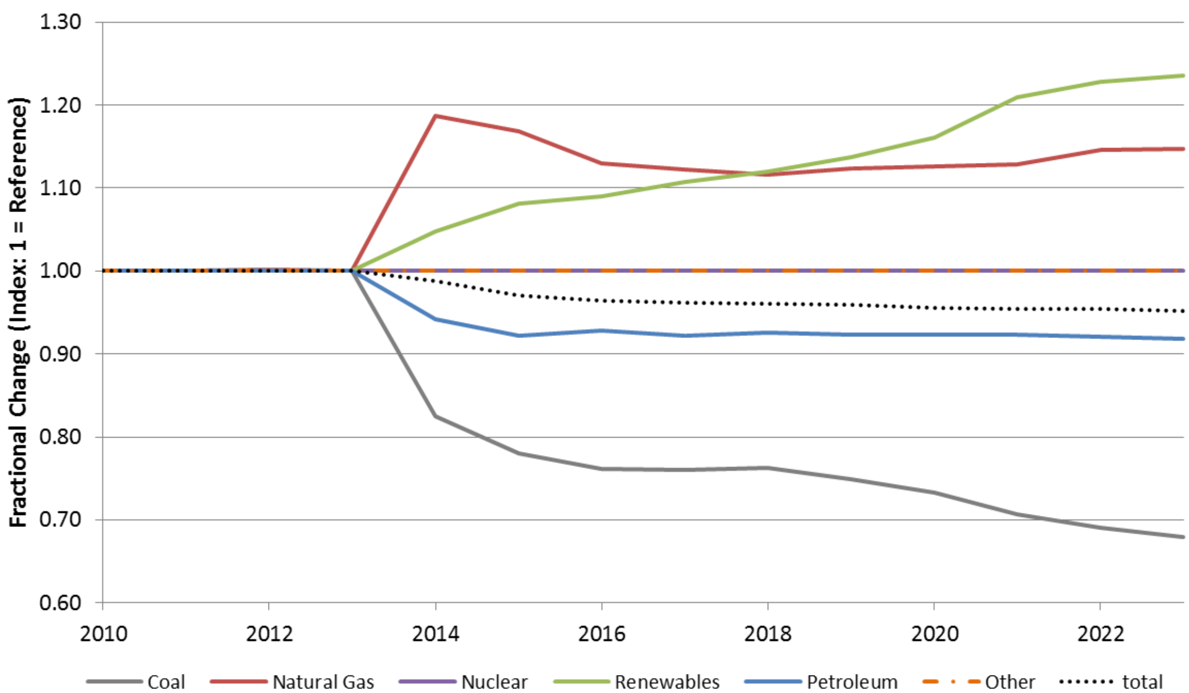


Figure 3: Avoided emissions by fuel type

Figure 4 provides additional detail, illustrating changes in the quantity of fuels used to generate electricity under the Climate Protection Act. NEMS-Stanford projects an immediate response to the policy in which generation switches away from coal-fired and toward natural gas-fired power plants. In the first year of the policy, an 18% reduction in coal use is matched with 19% increase in natural gas use. These two resources represent 40% and 27% of total electricity

generation (respectively) in 2013 (see Figure 5). Despite significant fuel-switching activities, however, total electricity generation falls by only about 5%, compared to the reference scenario, with most demand reduction occurring within the first few years. This result is consistent with earlier studies that suggest that changes in end-use energy efficiency as projected by NEMS are primarily driven by user inputs, not energy prices (Wilkerson et al., 2013). Thus, when NEMS-Stanford includes a price for CO_2 emissions, the model projects that the electricity sector switches from coal to gas on the margin. Since many natural gas power plants currently have spare capacity, the electricity sector can immediately re-dispatch production; in addition, the model projects that some coal plants would retire in response to the carbon price.[3]



[3] We note that coal power plant retirement occurs three years after the carbon price is introduced, which likely reflects the model structure. Although NEMS calculates whether power plants will stay in operation or retire, uneconomic conditions must subsist for three years before the model allows retirement. While this assumption may be sensible for considering normal market reactions to commodity prices, it may not hold in the case of an explicit change in government policy.

Figure 4: Change in energy generation fuels between Reference scenario and Climate Protection Act scenario

After an initial re-dispatching, coal-fired generation continues to decline slowly as more renewable generation increases over the policy period. (Note that the renewables category includes conventional hydroelectric, geothermal, wood, wood waste, biogenic municipal waste, landfill gas, other biomass, solar, and wind power.) Renewable resources made up 13% of electricity generation in 2013, and are projected to expand to 19% under the policy. In contrast, the use of petroleum decreases slightly, but this effect is minor because petroleum accounts for less than half a percent of total generation. Generation from nuclear and other energy resources is unchanged; the "other" category includes pumped storage, non-biogenic municipal waste, refinery gas, still gas, batteries, chemicals, hydrogen, pitch, purchased steam, sulfur, and miscellaneous technologies.

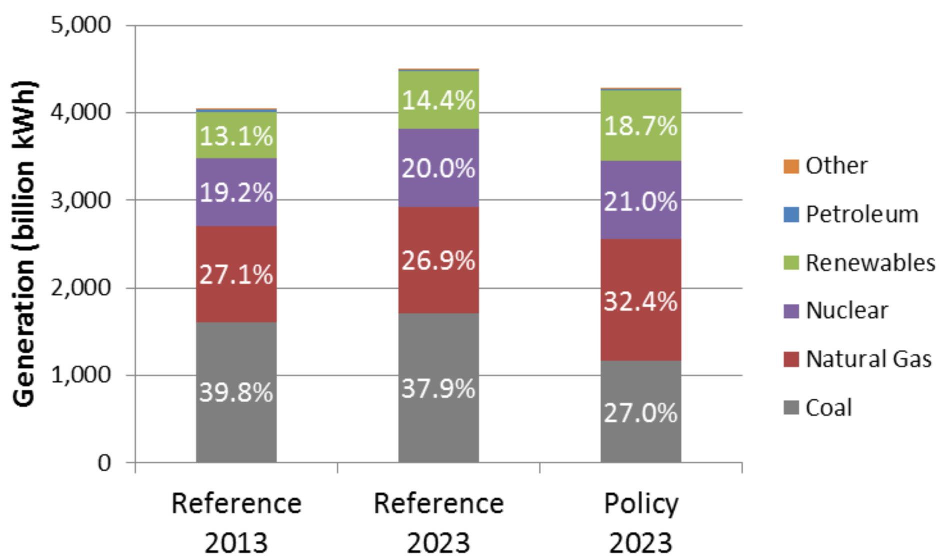


Figure 5: Electricity supply by fuel under the reference and policy scenarios

Finally, we compare our projected emission savings with what the Environmental Protection Agency (EPA) expects from its proposed Clean Air Act § 111(d) regulations limiting carbon pollution at existing power plants (EPA, 2014a: Table 10). Expressed in terms of the

percentage reduction from their respective baseline scenarios, the emissions savings in the electricity sector from each policy are quite similar (see Table 4). Comparing the policies in more detail is complicated, however, as the baseline emission projections differ between the EPA and Climate Policy Act modeling—despite the fact that EPA's model, IPM, is benchmarked to the same vintage of NEMS we employ here (EPA, 2014b: Section 3.1.1).[4] Because EPA's regulations would apply only to the electricity sector, we report emissions savings from the Climate Protection Act for this sector individually; we also report savings across all sectors because the fee-and-dividend policy would apply to all fossil fuels and therefore would generate additional emission reductions in other sectors.

Table 4: Comparing carbon dioxide emission reductions under EPA and Climate Protection Act policies (MMtCO$_2$)

	Comparison of policy emissions							
	2020				2030			
	Baseline Emissions	Policy Emissions	Delta Savings	Percent Savings	Baseline Emissions	Policy Emissions	Delta Savings	Percent Savings
EPA 111(d)[1]	2,161	1,777	384	17.8%	2,256	1,701	555	24.6%
NEMS Electricity Sector[2]	2,291	1,850	441	19.3%	2,417	1,802	615	25.5%
NEMS All Sectors[3]	5,452	4,942	510	9.3%	5,519	4,864	655	11.9%

Notes: [1] Based on results from the 'State Compliance' scenario for CAA 111(d) (EPA, 2014a: Table 10)
[2] This study's electricity sector projections
[3] This study's economy-wide projections

3.2 Macroeconomic impacts

The Climate Protection Act carbon pollution fee would have caused a relatively modest impact on the trajectory of U.S. GDP growth (see Figure 6). Full results are reported in Table 6. During the first decade of program implementation, differences between U.S. GDP projections

[4] Note also that the carbon fee escalates for the first ten years of the policy only, and is then held constant going forward. Because emission reductions increase with the carbon price, the Climate Protection Act would have achieved most of its emission savings by 2023. In contrast, EPA regulations would require a gradual decrease in emissions from 2020 to 2030.

for the baseline and the Climate Protection Act policy scenario range between 0.22% of GDP and 0.78% of GDP. At the end of the ten-year period (in 2023), GDP is $20.5 trillion in the reference scenario, compared with $20.4 trillion in the policy scenario. The change in GDP represents a delay in wealth accumulation of about three months. Thus, although the emission reductions produced by a carbon price are significant, adjustments in the economy as a whole appear to be relatively inexpensive.

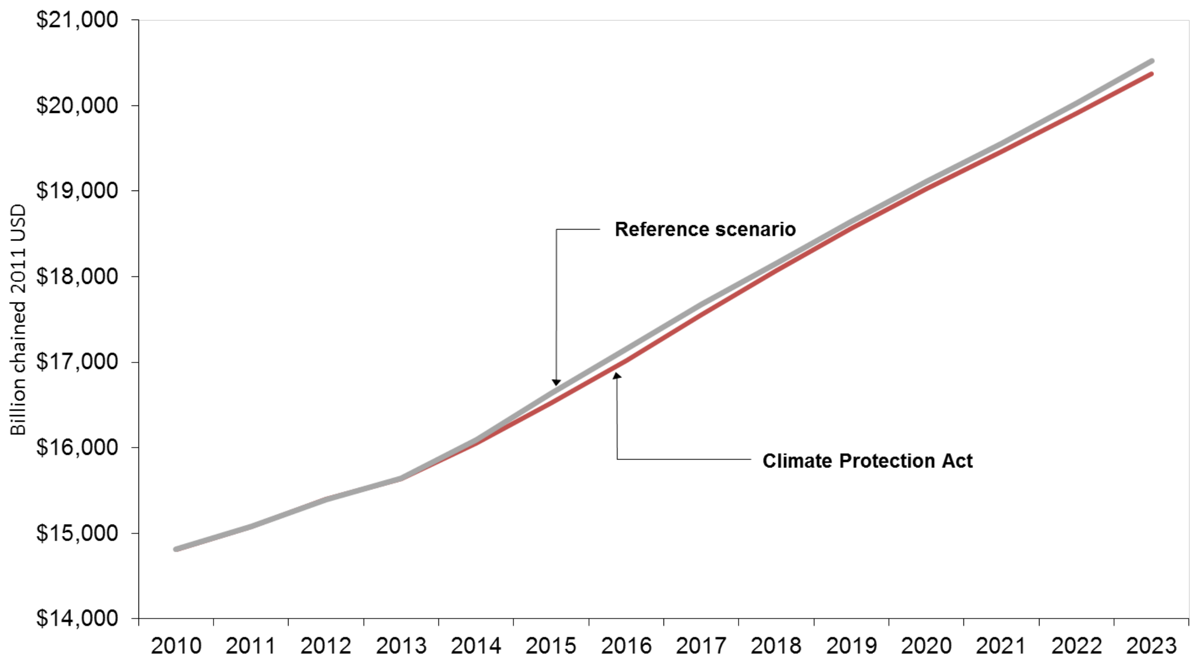


Figure 6: Impacts to U.S. GDP due to implementation of the Climate Protection Act.

3.3 Fiscal impacts

NEMS-Stanford projects that the carbon fee would raise $1.29 trillion over ten years. Rebating 60% of the revenue would transfer $774 billion back to households. In addition, $205 billion (16%) would be allocated to policies that invest in energy efficiency in homes and industry, job training, renewable energy, and energy research (see Table 5). The remaining $311 billion (24%) would be allocated to deficit reduction. See Table 6 for the full fiscal results.

Table 5: Policy expenditures under the Climate Protection Act (billion nominal USD over a ten year horizon)

Provision	Amount	Purpose
§ 103(c)(1)	$75	Cost mitigation for energy-intensive and trade-exposed industries
§ 103(c)(2)	$50	Weatherization of low-income homes
§ 103(c)(3)	$10	Job training, education, and transition assistance for former employees of fossil fuel industries
§ 103(c)(4)	$20	Energy research and development (ARPA-E)
§ 201(e)(1)	$50	Grants, loans, and loan guarantees for energy projects

One important limitation of this analysis is the simulation does not include the carbon equivalency fee provisions (§101) aimed at imposing the carbon pollution fee on embodied carbon in imported goods. Nor are rebates of the fee on exported fossil fuels modeled (§101). Thus, this analysis is limited to a purely domestic perspective on fiscal impacts of the proposed legislation.

Table 6: Environmental, macroeconomic, and fiscal results

Macroeconomic Impact Summary	2013[1]	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	Total[2]	CAGR[3]
Emissions price (nominal 2011 USD/tCO₂)													
Climate Protection Act	$0.00	$20.00	$21.12	$22.30	$23.55	$24.87	$26.26	$27.73	$29.29	$30.93	$32.66		5.6%
Emissions (MMtCO₂)													
Reference Scenario	5369	5361	5381	5335	5367	5400	5438	5452	5452	5480	5494	54161	0.3%
Climate Protection Act		5127	5039	4971	4981	5006	5012	4988	4942	4936	4919	49922	-0.5%
Δ Emissions		-234	-341	-365	-386	-395	-426	-464	-510	-543	-575	-4238	
Δ Emissions (% from Reference)		-4.4%	-6.3%	-6.8%	-7.2%	-7.3%	-7.8%	-8.5%	-9.4%	-9.9%	-10.5%		
GDP (Billion chained 2011 USD)													
Reference Scenario	$15,642	$16,089	$16,639	$17,149	$17,674	$18,153	$18,640	$19,112	$19,557	$20,027	$20,518		2.74%
Climate Protection Act		$16,054	$16,526	$17,015	$17,557	$18,065	$18,562	$19,027	$19,454	$19,906	$20,375		2.68%
Δ GDP		-$36	-$114	-$134	-$117	-$88	-$78	-$85	-$102	-$121	-$143		
Δ GDP (% from Reference)		-0.2%	-0.7%	-0.8%	-0.7%	-0.5%	-0.4%	-0.4%	-0.5%	-0.6%	-0.7%		
Revenues (Billion nominal 2011 USD)													
Total		$103	$106	$111	$117	$124	$132	$138	$145	$153	$161	$1,290	5.1%

notes
[1] 2013 Values are the same for Reference and policy scenario
[2] Ten-year undiscounted sum total where appropriate
[3] Compound Annual Growth Rate

3.4 Impacts to households

We calculate net benefit to household expenditures from the Climate Protection Act as the difference between the per capita rebate and increases in cost of energy expenditure by U.S. households. In other words, this term refers to the rebate minus the direct cost of climate policy; to calculate the net benefit to consumer welfare, one would need to include indirect costs, which we do not estimate here. The specified rebate level in the Climate Protection Act is 60% of revenues. For additional context, the figures in this section also include calculations of the net impact to household energy expenditures for lower (50%) and higher (70%) rebate levels.

We begin by discussing the cost impacts. NEMS-Stanford projects that the policy would cost the average American household $245 in the first year, ramping up to about $396 in 2023. The total for the first ten years of the policy is $3,360 (or $336 per year on average), mostly due to expenditure increases on gasoline and electricity (see Figure 7).

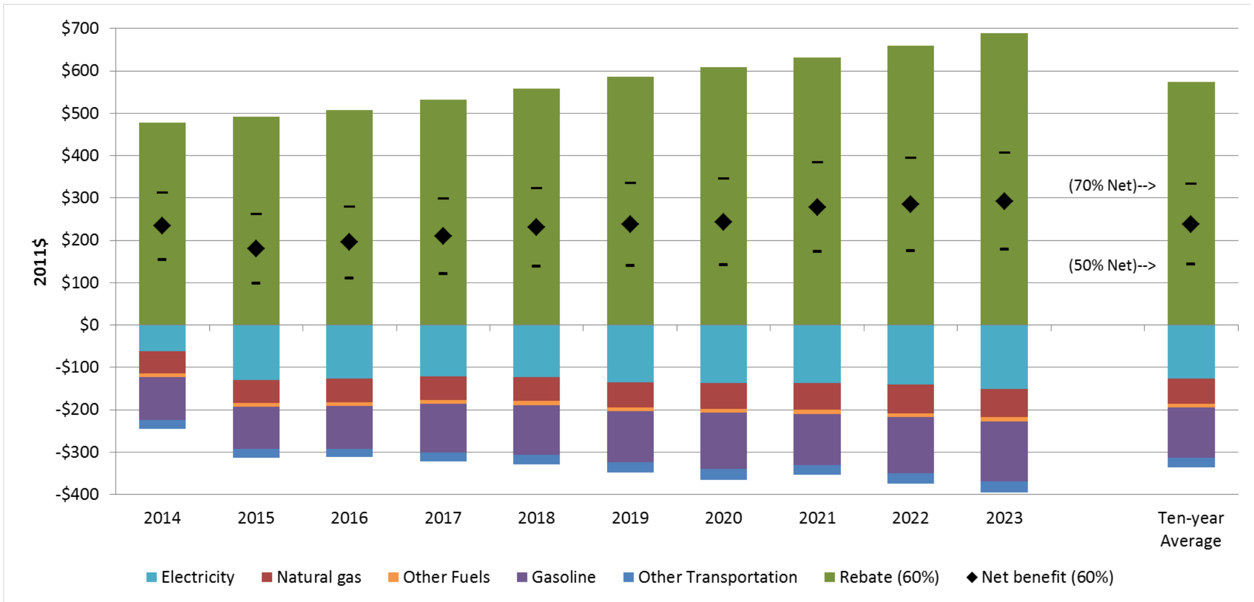


Figure 7: Annual household rebates and direct costs for the average American household with a 60% rebate

Next, we discuss rebates. Rebating 60% of total carbon fee revenue would return $191 to each U.S. resident in 2014, increasing to $275 by 2023. The amount returned to each household depends on the number of people per household (PPH). According to 2011 CEX data, the average American household had 2.5 members. Thus, the average household rebate would begin at $478 in 2014, growing to $688 in 2023. A total of $5,744 would be rebated to the average household over the first ten years of the policy, for an average of $574 per year.

Our analysis indicates that the Climate Protection Act would provide the average American household with a net benefit to household energy expenditures in each of the years studied here. The average yearly impacts are shown in the last bar of Figure 7. Over the first ten years of the policy, the average household would experience a net reduction in direct energy expenditures of $238 per year. The average benefit ratio is 1.71:1, with the average American household receiving $1.71 rebate for every $1.00 spent on increased direct costs for energy-related products and services. Again, however, we stress that these results include only the direct cost impacts from the policy, and not the indirect costs, such as increases in the costs of non-energy goods and services. Numerical ten-year average results are summarized at the end of this section in Table 7.

3.4.1 Household impacts by income

Household energy expenditures vary significantly by income in the United States. Lower income households typically spend a smaller amount on energy, but a larger fraction of their total income. Thus, a carbon fee without a rebate is likely to have regressive impacts. By rebating a fixed portion of carbon fee revenues back to households on a per capita basis, however, these distributional consequences can be mitigated—and even reversed.

Our analysis indicates that the Climate Protection Act's 60% rebate is sufficient to offset increased energy prices for the lower 80% of U.S. households by income (see Figure 8). The highest quintile of income earners faces net energy expenditure increases under the policy. Their higher expenditures are mostly due to higher overall home energy consumption and air travel expenditures. For U.S. households in the lower three income quintiles, the average annual net benefit to energy expenditures from the Climate Protection Act is approximately $300 for the first 10 years of the program. Net expenditures in the fourth quintile (Q4) would be roughly $200 on average. The fifth quintile (Q5) would have a net cost of about $90, on average, under a 60% rebate; the net direct cost impact to Q5 would be slightly net positive under a 70% rebate.

We note that the difference in the amount rebated to average households in each quintile is a reflection only of differences in the average PPH across incomes. On average, lower income households tend to have fewer residents than higher income households. For example, in 2011, the lowest 20% of U.S. households by income had 1.7 members on average, compared with 3.2 for the highest 20% (See Table 1).

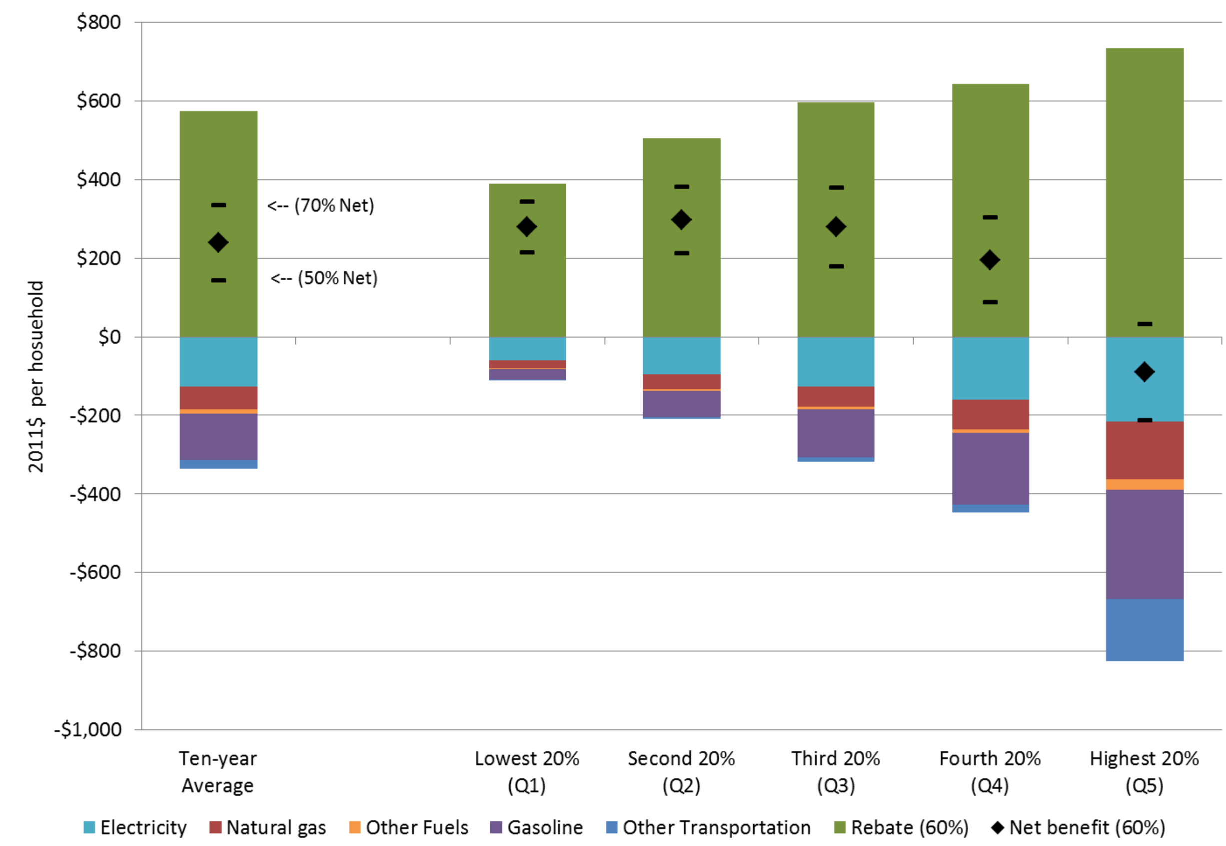


Figure 8: Average rebates and direct costs over ten years (2014-2023) by income quintile

In addition to reporting expenditures by income quintiles, the CEX data also include data across specific income levels. Applying our analysis to these categories shows that average households with less than $120,000 (HH1–HH11) in total annual income would experience net benefits to energy expenditures under the Climate Protection Act of between $93 and $304 per year over the first ten years of the program, depending on household income level (see Figure 9). These income segments represent 88% of all U.S. households. Households with total annual incomes less than $50,000 (HH1–HH7) can expect an average annual net benefit to energy expenditures of approximately $200 per year during the first ten years. Households making between $100,000 and $120,000 (HH11) should expect minimal net direct costs from the Climate Protection Act.

In general, only households with total annual incomes above $120,000 (12% of all households) should expect net increases in energy expenditures due to the direct cost of the fee-and-dividend policy. Costs would fall most heavily on households with total annual incomes above $150,000 (wealthiest 7% of all households). Because the wealthiest Americans consume the most energy, due primarily to larger homes and frequent air travel, the carbon rebate does not fully offset the increased direct costs these households would face under the Climate Protection Act.

Under the Climate Protection Act's 60% rebate level, the threshold for net positive impacts to average household energy expenditures falls between HH10 and HH11 (encompassing 88% of households). Increasing the dividend percentage shifts this threshold to the right (to include more households), while decreasing the rebate percentage shifts the threshold to the left (to include fewer households). Under a 70% rebate, average households earning less than $140,000 (HH1–HH12, 93% of households) would experience net benefits to energy expenditures. Under a 50% rebate, average households earning less than $100,000 (HH1–HH10, 82% of households) would experience net benefits to energy expenditures.

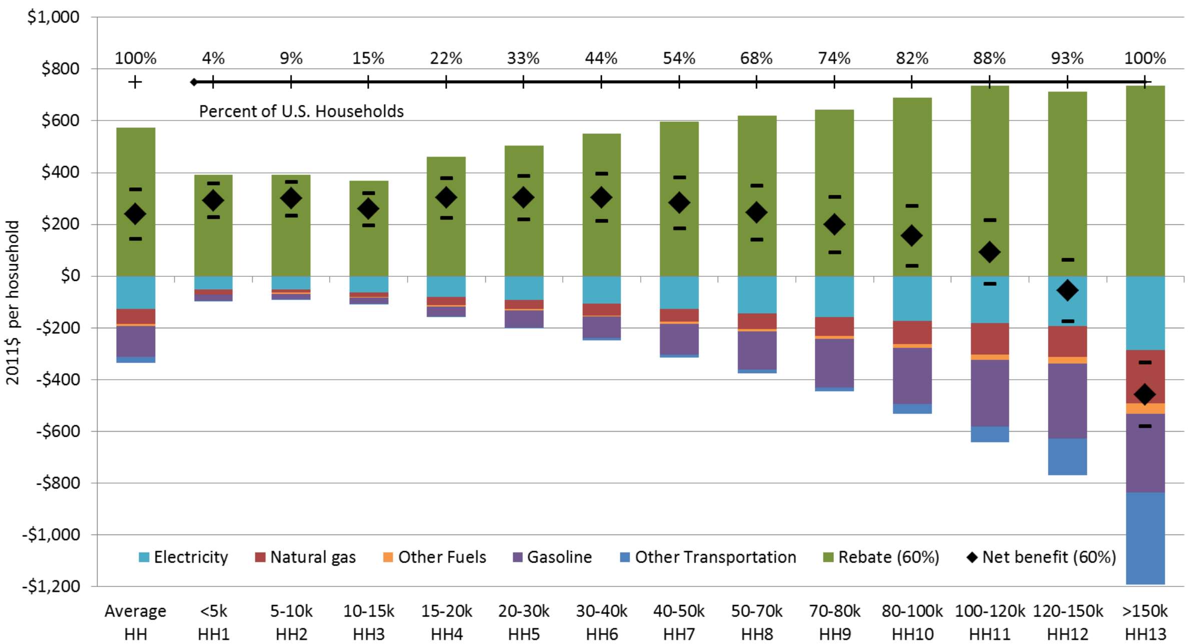


Figure 9: Average rebates and direct costs over ten years (2014-2023) by household income

3.4.2 Household impacts by region

Our analysis also indicates that average households in all areas of the country would experience reductions in net energy expenditures due to the Climate Protection Act, despite different patterns of energy consumption in each of the four Census regions. Figure 10 shows that the per capita rebate is sufficient to more than protect the average household from the direct costs of the Climate Protection Act in all Census regions. The average household in each region would see average annual net benefits to energy expenditures of between $100 and $220, depending on location.

Differences in regional results reflect two factors. First, the current and projected future patterns of energy consumption vary by region. These differences are primarily due to the variation in the carbon intensity of regional electricity fuel mixes and in regional demand for heating and cooling services; both factors help explain the variation in cost impacts to electricity

and natural gas expenditures. Second, dividend benefits vary due to minor regional differences in average household size.

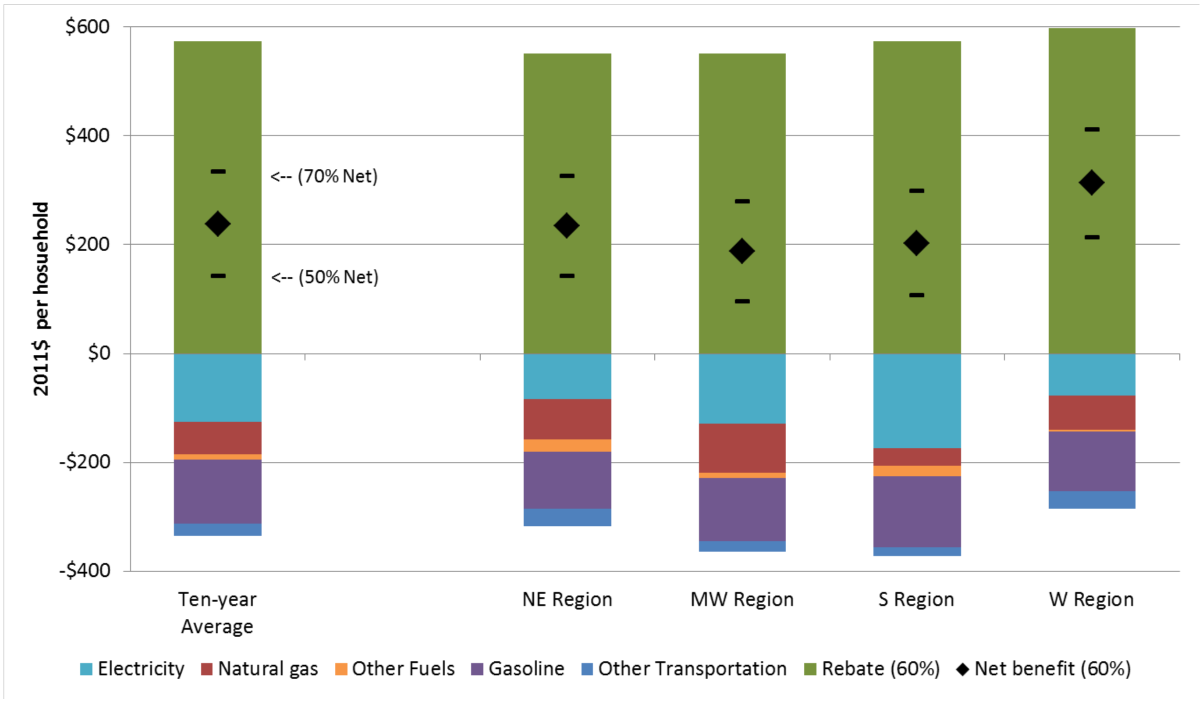


Figure 10: Estimated average rebates and direct costs for average households by region, 2014-2023

Table 7: Summary of average annual rebates and direct costs for each market segment.

Market Segment	Average Anmnual Policy impacts to household market segments[1]										
	Average Direct Costs						Rebate and Net Change			Percent of HH[3]	
	Natural Gas	Electricity	Fuel oil & Other Fuel	Gasoline & Motor Oil	Other Trans.	Total Cost	Rebate (60%)	Net Change	Percent of income[2]	Mkt. Seg.	Cum.
Average Household											
Avg. Consumer Unit	$59.43	$126.03	$9.02	$118.37	$23.01	$335.86	$574.39	$238.53	0.4%	100.0%	-
By Income Quintiles											
Lowest 20% (Q1)	$19.89	$60.39	$2.65	$25.28	$2.86	$111.07	$390.59	$279.52	2.8%	20%	20.0%
Second 20% (Q2)	$38.49	$94.77	$5.18	$65.90	$3.60	$207.95	$505.46	$297.52	1.1%	20%	40.0%
Third 20% (Q3)	$50.20	$127.09	$7.18	$121.88	$11.64	$317.98	$597.37	$279.39	0.6%	20%	60.0%
Fourth 20% (Q4)	$75.06	$159.93	$10.58	$182.32	$19.50	$447.38	$643.32	$195.94	0.3%	20%	80.0%
Highest 20% (Q5)	$146.31	$216.01	$26.69	$278.58	$157.94	$825.54	$735.22	-$90.32	-0.1%	20%	100.0%
By Region											
Northeast (NE)	$0.00	$84.04	$22.68	$105.41	$31.11	$243.24	$551.42	$308.18	0.4%	18.4%	-
Midwest (MW)	$90.20	$129.29	$9.19	$116.15	$19.40	$364.22	$551.42	$187.19	0.3%	22.2%	-
South (S)	$32.46	$173.48	$18.88	$131.59	$15.27	$371.68	$574.39	$202.71	0.4%	36.7%	-
West (W)	$62.07	$78.02	$3.72	$108.65	$32.03	$284.49	$597.37	$312.88	0.5%	22.7%	-
By Household Income											
Less than $5k (HH1)	$19.57	$51.43	$0.88	$22.13	$4.61	$98.62	$390.59	$291.97	N/A[4]	4.1%	4.1%
$5k to <$10k (HH2)	$13.61	$50.41	$3.66	$20.77	$2.13	$90.58	$390.59	$300.01	3.7%	4.5%	8.5%
$10k to <$15k (HH3)	$17.67	$62.99	$2.77	$23.07	$2.59	$109.08	$367.61	$258.53	2.0%	6.7%	15.2%
$15k to <$20k (HH4)	$33.64	$79.05	$4.67	$37.13	$2.71	$157.21	$459.51	$302.31	1.7%	6.3%	21.5%
$20k to <$30k (HH5)	$35.37	$91.88	$6.38	$65.24	$3.05	$201.92	$505.46	$303.55	1.2%	11.8%	33.4%
$30k to <$40k (HH6)	$46.37	$105.51	$3.44	$84.79	$6.87	$246.98	$551.42	$304.43	0.9%	10.9%	44.3%
$40k to <$50k (HH7)	$48.65	$127.81	$7.38	$120.52	$10.17	$314.53	$597.37	$282.84	0.6%	9.3%	53.5%
$50k to <$70k (HH8)	$61.43	$143.04	$9.14	$147.23	$14.45	$375.29	$620.34	$245.05	0.4%	14.2%	67.8%
$70k to <$80k (HH9)	$71.91	$159.33	$10.46	$187.90	$15.75	$445.35	$643.32	$197.97	0.3%	6.0%	73.8%
$80k to <$100k (HH10)	$91.80	$171.92	$12.80	$219.09	$37.64	$533.25	$689.27	$156.02	0.2%	8.6%	82.3%
$100k to <$120k (HH11)	$122.50	$181.99	$19.03	$258.18	$60.39	$642.09	$735.22	$93.13	0.1%	5.8%	88.1%
$120k to <$150k (HH12)	$120.48	$192.79	$26.10	$289.22	$140.02	$768.61	$712.25	-$56.36	0.0%	5.0%	93.1%
$150k and more (HH13)	$204.45	$286.89	$40.11	$305.75	$355.02	$1,192.23	$735.22	-$457.01	-0.2%	6.9%	100.0%

Notes: [1] Based on ten-year average results
[2] Based on average after-tax income from CEX for each market segment
[3] First column is percent for each market segment, the second is cumulative, ordered from lowest income segment
[4] Income for HH1 is negative, so expressing the net policy impacts to expenditures as a % of income is not logical

4. Discussion

The most important caveat to our distributional analysis is that we examine only the direct policy costs and lump sum rebates under a prospective climate policy. Our analysis does not incorporate the losses to GDP projected by NEMS-Stanford, nor does it include any other measure of indirect costs or benefits. As explained below, GDP losses are likely overstated. Nevertheless, our analysis excludes other indirect costs that households would face, including

changes in the cost of goods and services due to the increased cost of embodied energy throughout the economy.

We chose to focus exclusively on household energy expenditures because these could be mapped to corresponding NEMS outputs. By linking energy expenditures to an energy-economy model with microeconomic and macroeconomic effects, we are able to more accurately estimate the changes to energy expenditures. Indeed, we aim to contribute to climate policy discussions by offering a dynamic method to study the direct costs of climate policy. In order to assess the full impact on consumer welfare, however, these direct costs must be augmented by reliable estimates of indirect costs.

We note that indirect cost estimates generally suffer from the challenge of projecting how the mixture of general goods and services in the economy would respond to a price on carbon. Depending on the household income level in question, other researchers estimate that average indirect costs could range from an additional 50% to 100% of the direct costs (e.g., Hassett et al., 2009; Mathur and Morris, 2014). Due to the complexity of the calculations, however, most assessments of indirect costs are made using static assumptions about household consumption of goods and services. As a result, they do not account for dynamic effects—including, most importantly, the likelihood that consumers and firms would change their consumption patterns in response to higher energy costs. Studies that assume no change in consumption are likely to overestimate indirect costs, though of course including some estimate of indirect cost is necessary to assessing the full effect of climate policy on consumer welfare.

One can combine direct and indirect costs to yield an estimate of total policy costs, but this must be done carefully. If indirect costs for average households are well approximated by Mathur and Morris (2014), then our results suggest that the average change in consumer welfare

from the Climate Protection Act could range between a net benefit of $70 a year to a net cost of $97 per year for the average household (for indirect costs of an additional 50% and 100% of direct costs, respectively). We caution readers that it is inappropriate to apply average indirect costs when extrapolating across household income levels, however, as Mathur and Morris report a strong correlation between household income and indirect costs.

Furthermore, our projected impacts to GDP are very likely overstated for two reasons. First, the impacts of policies aimed at reducing energy-related carbon emissions that are funded by the Climate Protection Act (§§103, 201) are not included. Second, no attempt is made to account for the welfare impacts of changed environmental externalities under the policy. We neglect both global climate benefits and national public health benefits. On the climate benefits, the U.S. government's social cost of carbon (Interagency Working Group, 2013) estimates the total global externality impacts from carbon pollution. But climate benefits are often much smaller than improvements in U.S. public health and healthcare costs associated with reduced air pollution. Prominent economists recently concluded that air pollution damages from some industries, such as coal-fired power plants, are greater than the amount those industries contribute to GDP (Muller et al., 2011). This finding is particularly important here, as our results show that the Climate Protection Act would reduce emissions primarily by switching from coal-fired electricity generation to natural gas-fired and renewable generation. Thus, our results include the costs of choosing cleaner energy, but not the tangible benefits to the global environment or to public health in the United States that come from reducing our consumption of high-polluting coal power. As a final example of the importance of health impacts, we note that EPA's cost-benefit analysis of its forthcoming Clean Air Act § 111(d) regulations shows that

expected health benefits alone were more than sufficient to justify the costs of the regulations (EPA, 2014a: Tables 18-21).

Two additional reasons suggest GDP is overstated, but are less important in this context. First, the projected impacts to GDP are limited by the core assumptions in NEMS. Notably, the model does not fully account for the possibility of induced innovation, which some believe a carbon price on carbon would encourage. Environmental economists have shown that induced innovation in the context of climate policy has the potential to significantly lower compliance costs and increase social welfare (Goulder and Mathai, 2000). We merely note the issue here without assessing whether carbon prices in the range of those imposed by the Climate Protection Act would be sufficient to cause these changes. Second, the structure of the macroeconomic model does not account for any impacts of deficit reduction under the Climate Protection Act on future U.S. debt servicing costs.

Finally, our analysis is based entirely on the structure of NEMS. Any bias that is in the model structure, code, or standard input parameters will be reflected in our results.

5. Conclusions

In this paper, we describe a methodology for dynamically estimating the direct costs of climate policy across U.S. households of different income levels and different regions. Our approach combines output from an independent copy of the federal government's flagship energy-economic model (NEMS-Stanford) with cross-sectional data on household expenditures (CEX). We then apply our methodology to analyze S. 332, the Boxer-Sanders Climate Protection Act of 2013, which would have implemented a fee-and-dividend policy in the U.S.

The Climate Protection Act would have levied a carbon pollution fee on energy-related carbon dioxide (CO_2) emissions, starting in 2014 at $20 per metric ton of CO_2 and rising at 5.6% in nominal terms each year through 2023. We estimate that the bill would have raised $1.3 trillion in carbon revenues over its first ten years. A fixed portion would be rebated to American households on a per capita basis ($774 billion, or 60%). Additional expenditures ($205 billion, or 16%) would be used to assist trade-exposed industries, weatherize low-income households, retrain and compensate displaced workers, increase energy R&D, and support new energy project finance. The remaining revenues ($311 billion, or 24%) would be used to reduce the federal government's deficit.

NEMS-Stanford projects that the policy would have reduced energy-related CO_2 emissions by 4,200 million metric tonnes in the first ten years of the program. These reductions represent an 8.5% decline from baseline emissions in 2010 and a 10.5% decline in 2023. Our projections also indicate that energy-related CO_2 emissions would have fallen 17% below 2005 levels in 2020, putting the United States within reach of its commitment to reduce under the Copenhagen Accord. Finally, we find that the emission reductions from this policy would occur more rapidly than those projected by EPA's analysis of its proposed Clean Air Act § 111(d) regulations.

NEMS-Stanford projects modest impacts to GDP of less than one half of one percent in 2020. These impacts are likely overstated, however, as our modeling framework does not account for environmental externalities, cost containment from complementary policy measures, fiscal stimulus effects, or deficit reductions. We note that the dominant source of emission reductions in the policy scenario comes from switching between coal- and natural gas-fired power plants. Because the environmental externalities from coal power plant production have

been shown to exceed their contribution to GDP, due to the tangible public health costs from air pollution, this suggests that our macroeconomic costs are overstated.

To explore the distributional consequences of the policy across households of different income levels and in different areas of the country, we coupled NEMS-Stanford output with the Bureau of Labor Statistics' 2011 Consumer Expenditure Survey (CEX). By linking the energy-related expenditures in the CEX to corresponding data series projected by NEMS-Stanford, we dynamically estimated the increased energy costs households of different income levels and in different regions of the country would experience under the Climate Protection Act. We included a household-level calculation of the per capita climate dividend to estimate the net impact on household energy expenditures—*i.e.*, the value of the climate dividend minus the policy's direct costs. Based on this analysis, we find that the policy would reduce net energy-related expenditures for average households making less than $120,000 per year (the bottom 88% by income). It would also reduce net energy-related expenditures for the average U.S. household in all regions of the country. A sensitivity analysis shows how these thresholds change if the rebate were increased to 70% of revenue or decreased to 50%.

Overall, these results suggest that a fee-and-dividend policy can be designed to protect a wide range of household income levels from direct energy costs while also using the remaining revenue for deficit reduction or other policy expenditures. Such a policy can also drive relatively rapid emissions reductions that enable the U.S. to meet its obligations under the Copenhagen Accord. In order to fully evaluate the consumer welfare implications of U.S. climate policy, however, our reported direct policy costs should be supplemented with other estimates of indirect policy costs.

Acknowledgments

We thank the following Stanford University groups for their financial support: the Precourt Institute for Energy, Steyer-Taylor Center for Energy Policy and Finance, Energy Modeling Forum, and School of Earth Sciences.

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