Research Paper No. 0912201

Clean Energy and Climate Policy for U.S. Growth and Job Creation

An Economic Assessment of the American Clean Energy and Security Act and the Clean Energy Jobs and American Power Act

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Research Papers on Energy, Resources, and Economic Sustainability

This report is part of a series of research studies into alternative energy and resource pathways for the global economy. In addition to disseminating original research findings, these studies are intended to contribute to public awareness about environment-economy linkages and sustainable growth.

For this economic assessment project, we express thanks to the Energy Foundation and the National Resources Defense Council, who recognized the importance of strengthening the basis of evidence to support a national climate policy dialog. Thanks are also due for outstanding research assistance by the following:

Drew Behnke, Alex Cheng, Billie Chow, Melissa Chung, Joanna Copley, Elliot Deal , Sam Heft-Neal, Shelley Jiang, Adrian Li, Tom Lueker, Jennifer Ly, Adrian Li, Vanessa Reed, Mehmet Seflek, and Rainah Watson.

Pete Altman, Morrow Cater, Laurie Johnson, Dan Lashof, Michael Oko, Marcus Schneider, Theo Spencer, Sophie Turrell, and Jacqueline Wong offered helpful comments, while the authors retain responsibility for errors and omissions. We have also benefitted from the research insights of too many colleagues to list by name here, all of whose dedication is advancing our understanding of climate change and the challenges it presents. Opinions expressed here remain those of the authors, as do residual expository and interpretive errors, and should not be attributed to their affiliated institutions.

Executive Summary

Climate change is the greatest challenge facing humanity in the 21st century. Without determined global action to reduce atmospheric concentrations of greenhouse gas emissions over the next four decades, scientific evidence suggests that carbon-intensive patterns of economic growth run a high risk of dangerously altering the earth's climate system.

As a leader in energy technology development and the largest contributor to the current stock of greenhouse gases in the earth's atmosphere, the United States has an essential leadership role to play in international efforts to mitigate climate change. Exemplifying this leadership, in March the U.S. House of Representatives introduced the American Clean Energy Security Act (ACES), a detailed federal plan to reduce greenhouse gas emissions, and passed the act in June 2009.

Federal climate policy will have different implications for different states and should ultimately be designed to account for and address these differences. The U.S. is a complex patchwork of diverse state and local economies that reflect disparities in geography, climate, population, resources, and historical development paths. These physical and historical differences contribute to a broad spectrum of energy and carbon intensities across states and are important factors in determining the state-level economic impacts of a federal climate policy.

This analysis provides a state-by-state assessment of the economic implications of this kind of comprehensive federal climate policy, focusing on an interpretation of ACES.

This assessment was conducted using the Environmental Assessment in General Equilibrium (EAGLE) model, a new state-of-the-art forecasting model that projects the longer-term economic impacts of climate legislation on each of the 50 states and on the U.S. economy as a whole. EAGLE details economic interactions within and between each of the 50 states to assess the impacts of combining a limit on greenhouse gas (GHG) emissions with complementary energy efficiency and renewable energy policies.

Three overarching conclusions follow from the EAGLE analysis, described in Table 1.

Table 1: Main Findings

1. All 50 states can gain economically from strong federal energy and climate policy, despite the diversity of their economies and energy sources. Though states may differ on the supply side, they all have significant opportunities to grow their economies on the demand side by promoting energy efficiency.
2. Contrary to what is commonly assumed, comprehensive federal climate policy does not benefit the coasts at the expense of the heartland states. In fact, heartland states will gain more by reducing imported fossil fuel dependence because they are generally spending a higher proportion of their income on fossil fuels, which have a low employment, high price risk supply chain.
3. By 2020, the country as a whole can gain 918,000 to 1.9 million jobs and household income can grow by $488 to $1,176 under comprehensive federal energy and climate policy. By aggressively promoting efficiency on the demand side, alternative energy policies can be combined with a cap on GHG emissions to yield net economic growth and job creation.

A federal climate policy package could promote state-level economic growth by adopting three climate strategies in unison: GHG mitigation via market-oriented restrictions on total GHG emissions; energy efficiency; and renewable energy development and deployment. An important finding of this research is that more carbon dependent economies have more to gain from climate action.

Aggregate Results

Federal climate policy will have far-reaching effects on state economies and on the U.S. economy as a whole. Tables 2 and 3 summarize the aggregate growth effects of adopting a national policy package like ACES by state,. Measured as percentage variations in employment and real gross state product (GSP), these results show changes in employment and aggregate real value added (wages, salaries, and profits) in 2020 as compared to a baseline (is the baseline the projections for 2020 without ACES? Specify.). The “moderate” and “high” columns in Tables 2 and 3 refer to moderate and high levels (not sure that “level” is the right word to describe a policy...how about moderately ambitious and highly ambitious instead of moderate and high levels?) of energy efficiency policies, one conforming to ACES standards and the other more aggressive.

Table 2: Job Growth by 2020

	Thousands		Percent	
State	Moderate	High	Moderate	High
United States	918	1,894	.4	.9
Alabama	21	39	.7	1.3
Alaska	1	9	.2	1.7
Arizona	9	24	.2	.6
Arkansas	10	25	.5	1.3
California	120	226	.5	.9
Colorado	11	30	.3	.8
Connecticut	11	16	.4	.6
Delaware	3	7	.5	1.2
Florida	47	78	.4	.6
Georgia	40	70	.6	1.1
Hawaii	4	10	.4	1.0
Idaho	7	14	.6	1.3
Illinois	37	68	.4	.7
Indiana	22	45	.5	1.0
Iowa	14	27	.6	1.1
Kansas	7	22	.3	1.0
Kentucky	10	30	.3	1.0
Louisiana	-6	22	-.2	.7
Maine	6	12	.6	1.2
Maryland	34	71	.8	1.7
Massachusetts	22	40	.4	.8
Michigan	42	37	.6	.6
Minnesota	19	38	.5	.9
Mississippi	8	19	.4	1.0
Missouri	18	29	.4	.7
Montana	5	13	.7	1.8
Nebraska	12	38	.8	2.6
Nevada	9	17	.4	.9
New Hampshire	5	7	.5	.7
New Jersey	13	11	.2	.2
New Mexico	5	15	.4	1.2
New York	77	126	.6	1.0
North Carolina	17	65	.3	1.0
North Dakota	4	11	.7	1.8
Ohio	35	61	.4	.7
Oklahoma	-2	20	-.1	.8
Oregon	13	26	.5	1.0
Pennsylvania	46	78	.5	.9
Rhode Island	5	8	.7	1.1
South Carolina	21	36	.7	1.2
South Dakota	5	10	.8	1.5
Tennessee	2	20	.0	.5
Texas	44	165	.3	1.0
Utah	8	21	.4	1.1
Vermont	4	8	.9	1.5
Virginia	25	50	.4	.9
Washington	1	13	.0	.3
West Virginia	10	31	.9	2.8
Wisconsin	20	28	.5	.7
Wyoming	6	20	1.3	4.5

Table 3: Real 2020 Household Income and GSP

	Income (2008$)		GSP Percent	
State	Moderate	High	Moderate	High
United States	488	1,176	.2	.7
Alabama	547	1,261	.4	.9
Alaska	1,165	5,801	-.1	2.6
Arizona	53	283	.0	.2
Arkansas	457	1,230	.4	1.1
California	735	1,477	.4	.7
Colorado	425	1,138	.0	.4
Connecticut	717	1,011	.3	.4
Delaware	398	1,416	.2	.9
Florida	303	615	.3	.6
Georgia	702	1,362	.4	.9
Hawaii	610	1,464	.3	.8
Idaho	431	1,149	.3	1.0
Illinois	508	1,137	.2	.6
Indiana	476	1,219	.3	.8
Iowa	686	1,501	.5	1.2
Kansas	229	1,182	.1	.7
Kentucky	267	1,133	.2	.9
Louisiana	-219	1,582	-.4	1.0
Maine	550	1,317	.5	1.1
Maryland	1,022	2,172	.6	1.2
Massachusetts	738	1,356	.3	.7
Michigan	667	750	.4	.5
Minnesota	579	1,240	.3	.8
Mississippi	289	889	.2	.8
Missouri	446	892	.3	.7
Montana	599	1,736	.4	1.4
Nebraska	927	4,120	.6	2.7
Nevada	471	1,025	.3	.7
New Hampshire	573	726	.3	.4
New Jersey	196	-92	.1	-.1
New Mexico	516	1,309	.0	.7
New York	902	1,580	.4	.7
North Carolina	230	1,159	.2	.9
North Dakota	1,048	2,683	.5	1.5
Ohio	452	992	.3	.7
Oklahoma	47	986	-.6	-.1
Oregon	399	941	.3	.7
Pennsylvania	637	1,092	.4	.7
Rhode Island	700	1,172	.5	.8
South Carolina	650	1,259	.5	1.0
South Dakota	784	1,602	.6	1.2
Tennessee	-129	406	-.1	.3
Texas	442	1,814	.0	.8
Utah	523	1,435	.2	.8
Vermont	816	1,535	.6	1.2
Virginia	554	1,325	.3	.7
Washington	-195	105	-.1	.1
West Virginia	684	2,737	.5	2.5
Wisconsin	513	749	.3	.6
Wyoming	4,884	9,862	1.2	4.0

The results are variegated, but a few salient findings deserve emphasis. First, implementing the right combination of a cap and trade system and complementary measures to promote lower carbon technologies can result in net economic stimulus. When market-oriented GHG mitigation is combined with energy efficiency and supply side energy policies, the result can be a potent catalyst for economic growth in many states. Second, adverse impacts are limited, even in cases where growth is less than robust. Energy efficiency is an important driver of this result. By saving enterprises and households money, complementary energy efficiency policies create state-level multiplier effects that counterbalance the potential burdens of adjusting to federal climate policy. Energy efficiency savings are largely spent on domestic and in-state goods and services with higher employment intensity than the more import dependent, less employment intensive fossil fuel supply chain.

To fully appreciate the economic effects of climate policy, we must recognize the importance of complementary policies that improve efficiency and yield a low carbon, higher growth economic future. Markets alone may not identify the climate change externality and markets for carbon may not provide adequate incentives for innovation and efficiency. Overcoming hurdles that limit technology development, diffusion, and adoption will require a portfolio of well-designed demand- and supply-side policies that complement a national cap and trade system.

Policies Assessed

A comprehensive national climate policy is the product of complex, detailed negotiations among heterogeneous economic interests. The policy that is ultimately agreed upon will likely look much different than the proposal that it evolved from. This analysis aims to provide overall guidance by considering only the most salient components of a U.S. federal climate initiative. To improve visibility for public and private stakeholders regarding the economic impacts of a federal climate policy like ACES, the EAGLE model assesses a package consisting of five generic policy types:

- GHG Emission Reductions
- Transportation
- Electricity Generation
- Residential and Commercial Energy Efficiency
- Sequestration and Offsets

EAGLE is an economic forecasting model. To estimate engineering-based patterns of adjustment in energy and other mitigation technologies, we draw on results from the MARKAL (energy systems) model of the U.S. We use these MARKAL results as inputs to EAGLE in the final four policy categories.

GHG Emission Reductions include market-based measures to restrict total atmospheric emissions of greenhouse gases. In this analysis, we do not consider detailed design characteristics for such a mechanism, but only impose a national limit on total emissions and assume that a mechanism of trading pollution rights leads to a market premium that provides incentives for energy conservation and investments in more efficient technology. **Transportation** includes changes in the energy requirements and fuel mix of the light duty vehicle (LDV) and heavy duty vehicle (HDV) fleets. Transportation adjustments include shifts in the fuel and fuel economy composition of the LDV and HDV fleets.

Electricity Generation under a carbon cap will experience changes in the composition of electricity generation resources, including shifts toward low or zero carbon energy sources such as coal-fired generation with offsetting carbon capture and storage (CCS).

Residential and Commercial Energy Efficiency includes energy efficiency requirements for residential and commercial buildings, appliances, and electronics that use electricity, natural gas, and petroleum products. . The MARKAL results also include the introduction of solar water heaters on a larger scale (how much larger?).

Sequestration and Offsets include terrestrial carbon sequestration and landfill gas projects. Sequestration and offsets include four major categories: agricultural (mostly soil carbon sequestration), livestock (mostly manure management), forestry (mostly changes in forest management), and landfills (landfill gas capture and generation). We do not include international offsets in this analysis.

Data Sources

Economic Data

The primary economic data resource used to calibrate the EAGLE model is IMPLAN, a nationally consistent collection of economic data that details patterns of supply, demand, and resource use for over 500 sectors of the economy in each of the 50 states. Based on a 20 year data management initiative begun by the US Forest Service, IMPLAN offers the most up-to-date, detailed data on the economic structure of the U.S. economy.

Emissions Data

Data from the Environmental Protection Agency (EPA) and Energy Information Administration (EIA) were used to calculate a state-by-state, sectoral GHG emissions inventory for the EAGLE model. Basic GHG emissions inventories are not yet available at a state level, much less at a sectoral level, in the U.S. In constructing an emissions inventory for the model we use a number of data sources and assumptions, as described in the model documentation. To our knowledge, these estimates represent the first state-by-state, detailed sectoral emissions inventory for the U.S.

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1. Introduction

Climate change is the greatest challenge facing humanity in the 21st century. Without determined and dramatic action to reduce atmospheric concentrations of greenhouse gas emissions over the next four decades, scientific evidence suggests that carbon-intensive patterns of economic growth run a high risk of dangerously altering the earth's climate system.[1]

As a leader in energy technology development and the largest contributor to the current stock of greenhouse gases in the earth's atmosphere, the United States has an essential leadership role to play in international efforts to mitigate climate change. Exemplifying this leadership, in March the U.S. House of Representatives introduced the American Clean Energy Security Act (ACES), a detailed federal plan to reduce greenhouse gas emissions, and passed the act in June 2009.

Federal climate policy will have different implications for different states and should ultimately be designed to account for and address these differences. The U.S. is a complex patchwork of diverse state and local economies that reflect disparities in geography, climate, population, resources, and historical development paths. These physical and historical differences contribute to a broad spectrum of energy and carbon intensities among statesand are important factors in determining the state-level economic impacts of a federal climate policy.

This analysis provides a state-by-state assessment of the economic implications of a comprehensive federal climate policy, focusing on an interpretation of ACES. The assessment was conducted using the Environmental Assessment in GeneraL Equilibrium (EAGLE) model, a new state-of-the-art forecasting model that projects the longer-term economic impacts of climate legislation on each of the 50 states and on the U.S. economy as a whole. EAGLE details economic

[1] This conclusion has been affirmed by the National Academy of Science, the top U.S. scientific advisory body. See National Academy of Sciences, *Understanding and Responding to Climate Change*, 2008.

interactions within and between each of the 50 states and examines the impacts of combining a limit on greenhouse gas (GHG) emissions with complementary energy efficiency and renewable energy policies.

The report is divided into seven sections:

1) *Summary of Results* provides a brief overview of key results.
2) *Federal Climate Policy: An Overview* describes the main components of the American Clean Energy and Security Act.
3) *States under a Federal Climate Policy: The Importance of Managing Diversity* examines the implications of differences in energy and carbon use and intensity among states for federal climate policy design.
4) *Detailed Discussion of Results* provides a more detailed elucidation of key findings and their implications for federal climate policy design.
5) *Documentation of Complementary Policy Inputs* describes the policy inputs used by the EAGLE model.
6) *Overview of Economic Forecasting Model* outlines the main features of the EAGLE model.
7) *Frontiers in Technology and Policy* explores the dynamics of technology and policy innovations under a federal climate policy, focusing on three technology and policy areas.

A more detailed documentation of both the EAGLE model itself and the GHG emissions inventory for the model accompany this report.

2. Summary of Results

We highlight three main findings in this report:

1) All 50 states can gain economically from strong federal energy and climate policy, despite the diversity of their economies and energy sources. Although states may differ on the supply side, they all have significant opportunities to grow their economies on the demand side by promoting energy efficiency.

2) Contrary to what is commonly assumed, comprehensive federal climate policy does not benefit the coasts at the expense of the heartland states. In fact, heartland states will gain more by reducing imported fossil fuel dependence because they are generally spending a higher proportion of their income on fossil fuels, which have a low employment, high price risk supply chain. Demand side policies are more important for more carbon-dependent states because these states tend to have higher energy expenditure as a share of income.
3) By 2020 the country as a whole can gain 918,000 to 1.9 million jobs and household income can grow by $488 to $1,176under comprehensive federal energy and climate policy. By aggressively promoting efficiency on the demand side, alternative energy policies can be combined with a cap on GHG emissions to yield net economic growth and job creation.

3. U.S. Federal Climate Policy: An Overview

U.S. federal climate policy has converged around the creation of a national cap and trade (C&T) system, with a substantial program of research, development and demonstration (RD&D) and a number of mandatory alternative energy, energy efficiency, and other measures to complement the GHG emission reductions achieved through the C&T system. A detailed plan to implement this system was introduced in March of 2009 by Representatives Henry Waxman and Ed Markey through the American Clean Energy and Security Act (ACES), which was passed in June 2009.

In September 2009, Senators John Kerry and Barbara Boxer introduced a Senate version of climate legislation, the Clean Energy Jobs and American Power Act (CEJAPA). Because CEJAPA is a recent bill and many of the specifics remain under discussion, the focus in this analysis is on ACES.

This section provides an overview of ACES in the context of the magnitude and sources of current U.S. GHG emissions. Since both the data inputs and GHG emission constraints used in this analysis are based on an interpretation of ACES, an explanation of the features of the bill is important for understanding our results.

Overview of the American Clean Energy and Security Act (ACES)

ACES is an extensive and complex bill, and many of its provisions are outside of the scope of this study. The data inputs and model constraints used in this analysis are based on an interpretation of key components of the bill.

ACES includes four major provisions that are relevant for this study:

- A cap and trade system (Title III) with a cap that steadily declines over time and a system to allocate allowances.
- A requirement that electric utilities meet 20% of their sales through renewable energy by 2020, with utilities able to meet a certain portion of this obligation (25%) with efficiency (Title I).
- Aggressive energy efficiency standards for new buildings, appliances, and vehicles (Title II).
- A substantial program (in the hundreds of billions of dollars) to support RD&D in clean energy and energy efficient technologies, funded in part through CO_2e allowances (Title IV).

The ACES cap is designed to be comprehensive, covering 84% of U.S. GHG emissions by 2016.[2] Regulated entities must hold one allowance to emit one metric CO_2e ton of any GHG included under the cap. Allowance obligations can be met by reducing emissions, through allowances saved ("banked") from a previous period, by purchasing allowances, by purchasing international offsets, or by using allowances from countries that have comparable systems. ACES places a ceiling on international offsets, but grants the EPA administrator the flexibility to adjust that ceiling.

The ACES cap has two primary targets: economy-wide GHG emissions must be reduced by 17% from 2005 levels by 2020 and by 83% by 2050. Two intermediary targets require a 6% reduction from 2005 GHG emissions levels by 2012 and a 42% reduction from 2005 levels by 2030. The CEJAPA has proposed a more aggressive 2020 target of 20%, but has adopted the same 2050 target.

Figure 2. GHG Emission Reduction Targets under ACES

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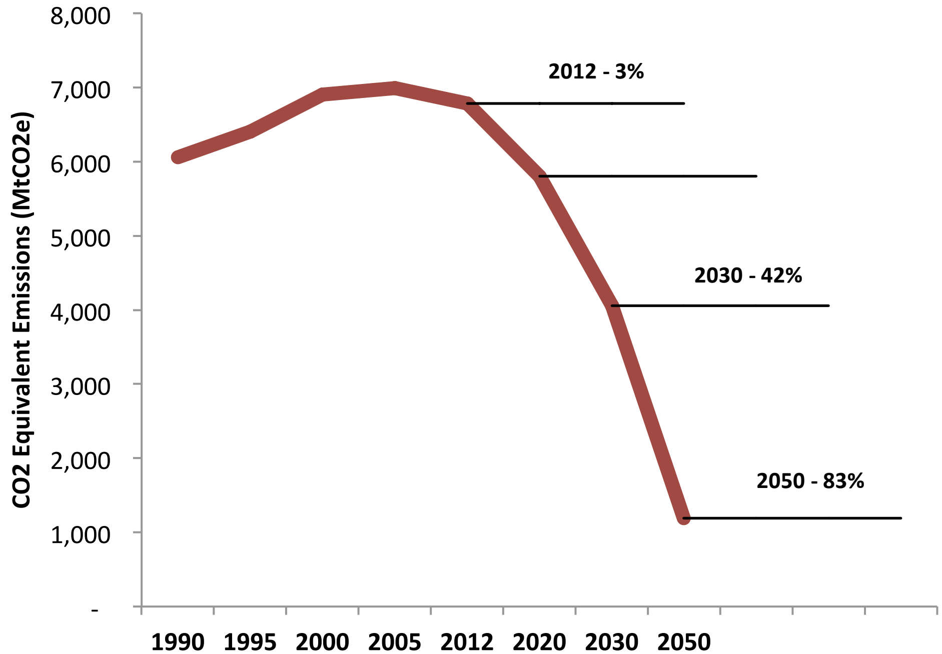
[2] ACES covers seven primary greenhouse gases (CO_2, CH_4, N_2O, HFCs, PCFs, SF_6, and NF_3), but does not cover the entire spectrum of gases and aerosols with known positive radiative forcing potential. These gases and aerosols, including carbon monoxide and black carbon, are either regulated separately or are not yet included under the ACES cap.



Source: GHG emissions data are from EPA, "Inventory of U.S. Greenhouse Gas Emissions and Sinks, 1980-2007," April 2009.

ACES in the Context of U.S. Greenhouse Gas Emissions

Gross U.S. GHG emissions totaled an estimated 6,993 $MtCO_2e$ in 2005.[3] Reducing these emissions by 17% by 2020 would require a 1,189 $MtCO_2e$ reduction from 2005 emission levels, but the exact level of required abatement will depend on the magnitude and carbon intensity of baseline growth. Higher and more carbon-intensive economic growth will require higher levels of absolute GHG emission reductions.

[3] This estimate includes five of the seven gases regulated under ACES (NF_3 is not included, and HFCs are included under a separate agreement). Data are from EPA, "Inventory of U.S. Greenhouse Gas Emissions and Sinks, 1980-2007," April 2009.

As Figure 2 suggests, ACES requires faster GHG emission reductions in later years. For instance, ACES would require GHG emissions to fall nearly twice as fast from 2030-2050 (3.9% per year) than from 2020-2030 (2.2% per year) (Table 1). Through this design, ACES allows for an adjustment period in which households, business, and government adapt to a new policy environment and in which large-scale investments in research, development and demonstration (RD&D) increase the scope and reduce the costs of new technologies.

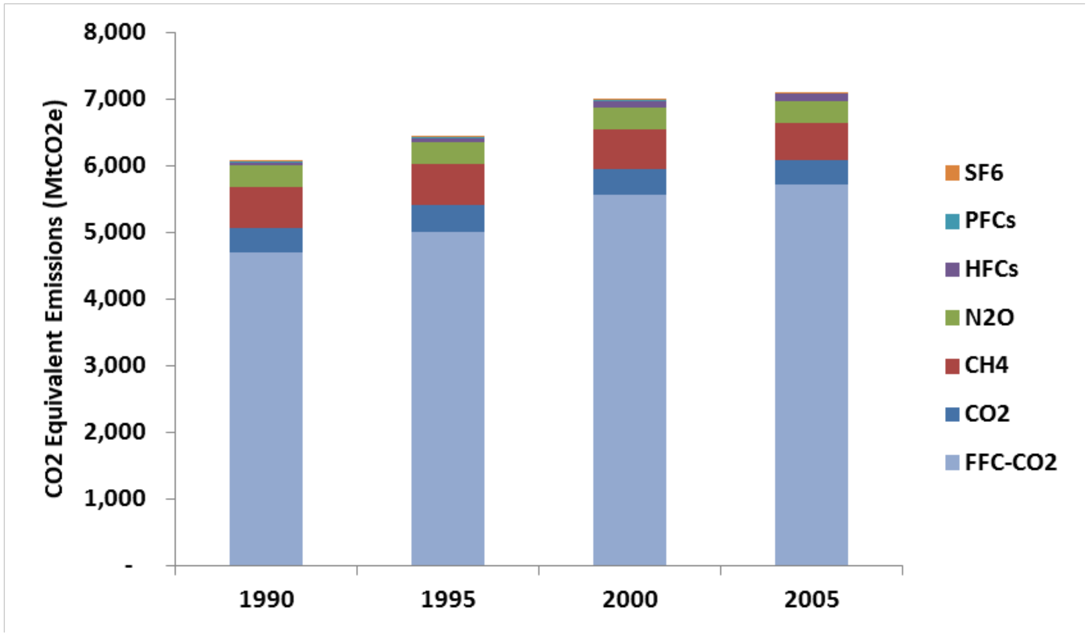
Table 1. ACES Goals and Required Rate of GHG Emission Reductions

End Period	Percent Reduction from 2005 levels	Required Annual Average Reduction from 2005 levels
2012	3%	-0.004
2020	17%	-0.012
2030	42%	-0.022
2050	83%	-0.039

Sources: Interim targets are reported by John Larsen, Alexia Kelly, and Robert Heilmayr, "WRI Summary of H.R. 2454, the American Clean Energy and Security Act (Waxman-Markey)," July 31, 2009.

U.S. GHG emissions are and have historically been dominated by fossil fuel combustion (Figure 3), which accounted for 80% of total GHG emissions in 2005. Under the ACES cap, reducing GHG emissions by 17% by 2020 will require significant changes in the way that the U.S. produces and consumes energy over the next decade. Reducing emissions by 83% by 2050 will require a more fundamental transformation of the U.S. energy system over the next four decades.

Figure 3. U.S. Greenhouse Gas Emissions, 1990-2005 (FFC = Fossil Fuel Combustion)

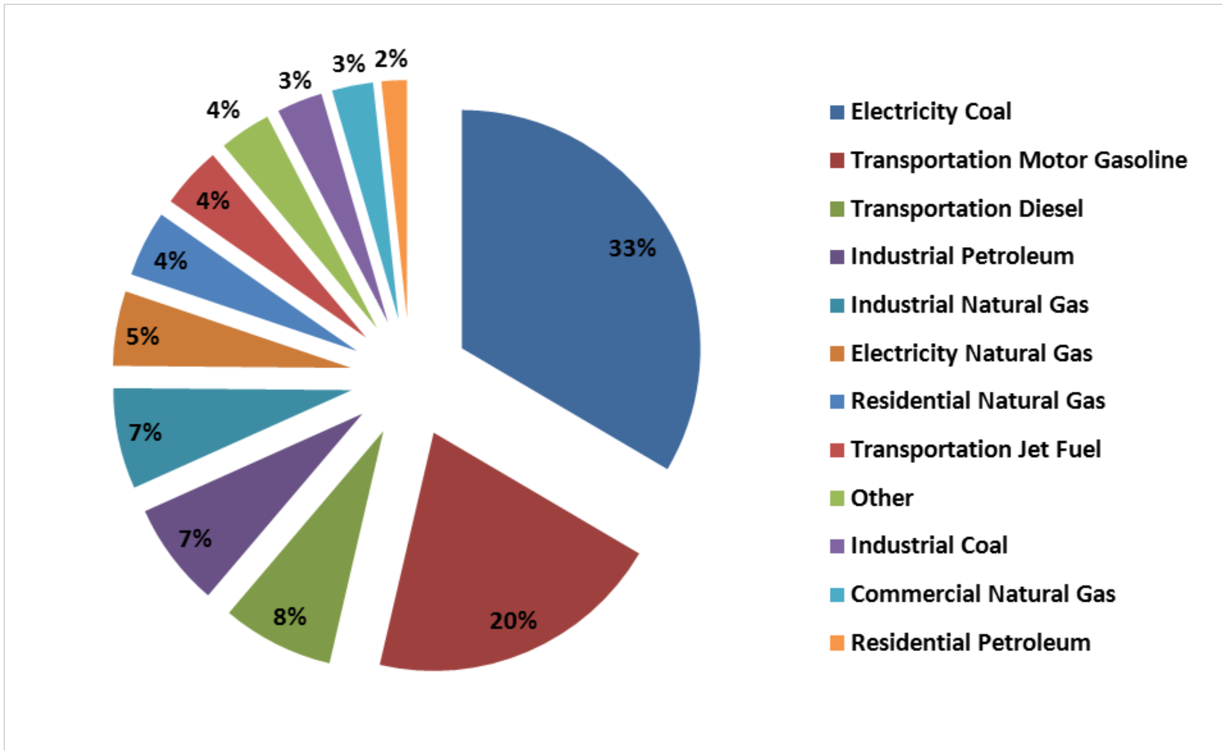


Source: EPA, "Inventory of U.S. Greenhouse Gas Emissions and Sinks, 1980-2007," April 2009.

Within the category "CO_2 from fossil fuel combustion" (FFC-CO2 in Figure 3), emission sources are diffuse, with two exceptions. The two largest emission sources — coal-fired electricity generation (33%) and motor gasoline (20%) — accounted for 53% of energy-related CO_2 emissions in 2005 (Figure 4). The next largest sources of energy-related GHG emissions each accounted for less than 10% of total energy-related GHG emissions. This combination of concentration and diffuseness is important in policy design. To strike a balance between focus and inclusion, ACES includes both specific measures that target the electricity and transportation sectors as well as a comprehensive emissions cap.

As Figure 4 suggests, because of the high concentration of energy-related CO_2 emissions in coal-fired electricity generation and transportation gasoline use, a limited set of policies could in principle achieve the bulk of GHG emission reductions in the near term, particularly if transaction costs under a C&T system are high. Both the cost-effectiveness and the political acceptability of a more focused policy approach will depend on differences in energy use and GHG emissions profiles among states, a topic to which we turn next.

Figure 4. U.S. Emissions from Fossil Fuel Combustion, 2005



Source: Data are from the EIA website, http://www.eia.doe.gov/environment.html.

4. States under a Federal Climate Policy: The Importance of Managing Diversity

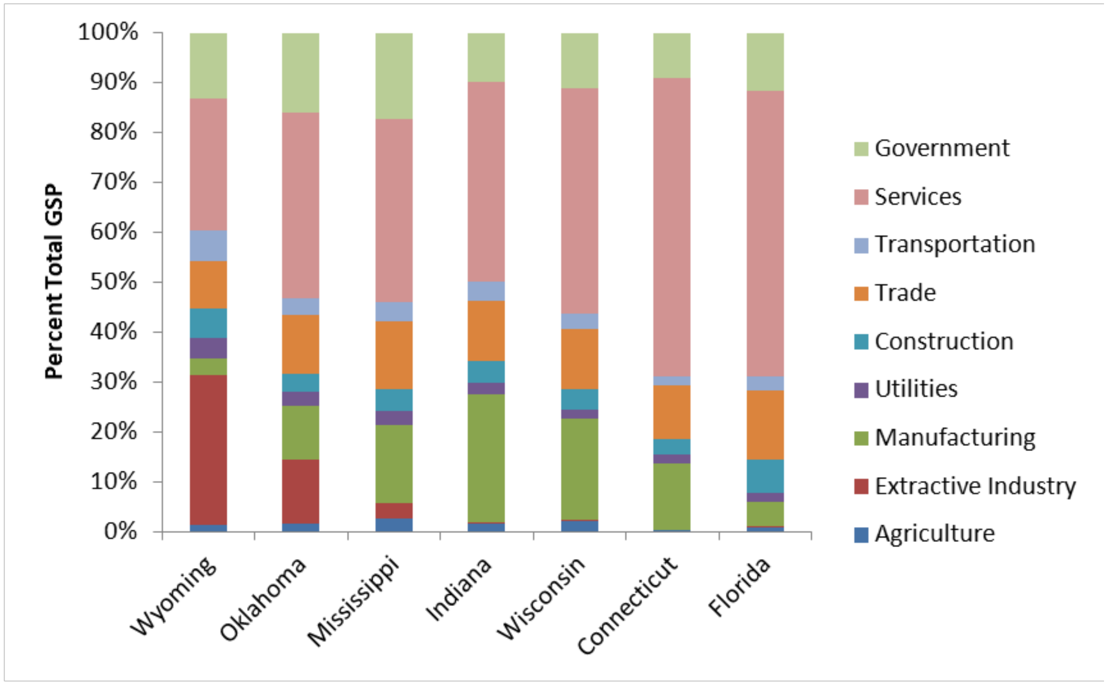
While analyses of U.S. climate policy have focused on the national level, the economic implications of a national policy on individual states are likely to be highly uneven. The design of a national policy should account for important differences among states and should strive to reduce disproportionately negative economic and social impacts on individual states or groups of states. This section provides an overview of the diversity in economic activity, energy sources and use patterns, CO_2 emissions, and energy policies among states. Understanding this state-level diversity sheds light on the local impacts of a federal climate policy.

Diversity in Economic Structure and Sectoral Energy Use

The U.S. is a patchwork of diverse state economies that reflect different geography, climate, resource endowments, and historical development paths. Differences in economic activity and structure lead to a range of sectoral energy use profiles among states, with industry dominating energy use in some states and residential users dominating in others. Additionally, as we discuss in the following sections, diversity in economic structure contributes to differences in energy and carbon intensity among states.

At an aggregate level, the most significant differences among state economies are in the shares of extractive industries, manufacturing, and services as a share of gross state product (GSP). More than 30% of Wyoming's GSP in 2007, for instance, was generated by coal, natural gas, and oil extraction, whereas manufacturing (3%) and services (26%) played smaller roles (26% is relatively close to 30%; it might not fit into the same category of "much smaller" as the 3% number). Indiana had the highest GSP share of manufacturing (26%) in the U.S. in 2007, a moderately large services industry (40%), and negligible resource extraction (0%). At the other end of the spectrum, services dominated the Florida economy (57%) in 2007, whereas manufacturing (5%) and extractive industries (0%) were not major activities. Figure 5 shows aggregate sectoral GSP shares for seven states that illustrates the spectrum of economic activity among states.

Figure 5. Differences in Economic Structure among Seven Representative States, 2007

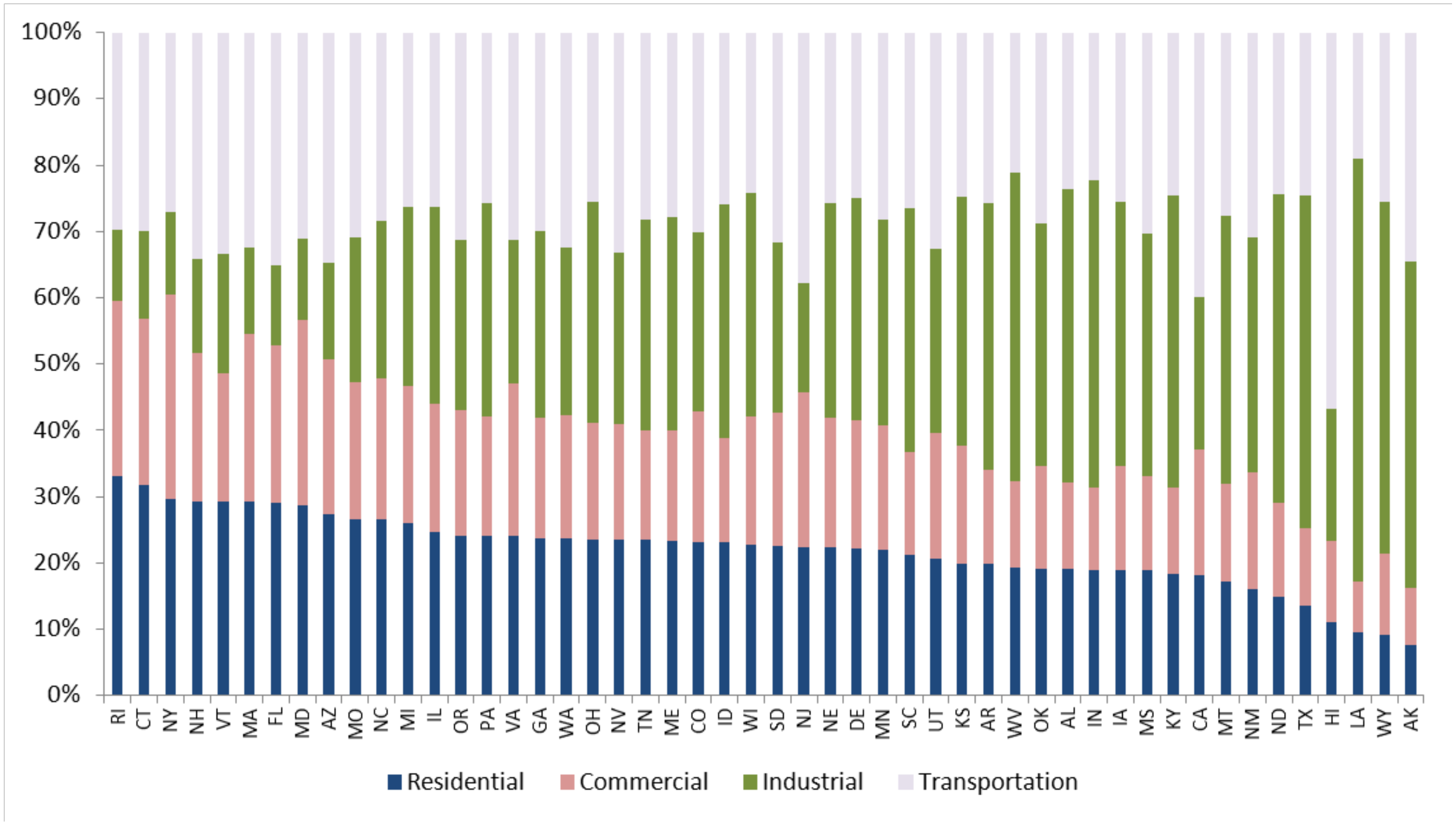


Source: Data are from BEA website, http://bea.gov/regional/index.htm#gsp.

Differences in economic structure lead to pronounced differences in energy use by sector among states. States that tend to have higher shares of commercial energy use also tend to have higher shares of residential energy use and lower shares of industrial energy use (

Figure 6). Alternatively, in states where shares of residential and commercial energy use are lower, shares of industrial energy use tend to be significantly higher. Industry accounts for 64% and residential/commercial accounts for [18]% of total energy use in Louisiana, for instance, while only 11% of total energy use is attributed to industry in Rhode Island and [ ]% to residential/commerical. In general, there is greater variation in shares of commercial and industrial energy use among states, whereas shares of residential and transportation energy use among states are more uniform.

Figure 6. End-Use Energy Consumption by Sector by State, 2007



Notes and Source: States are organized along the x-axis from highest to lowest shares of residential energy consumption. Data are from EIA website, http://www.eia.doe.gov/emeu/states/hf.jsp?incfile=sep_sum/plain_html/sum_btu_1.html.

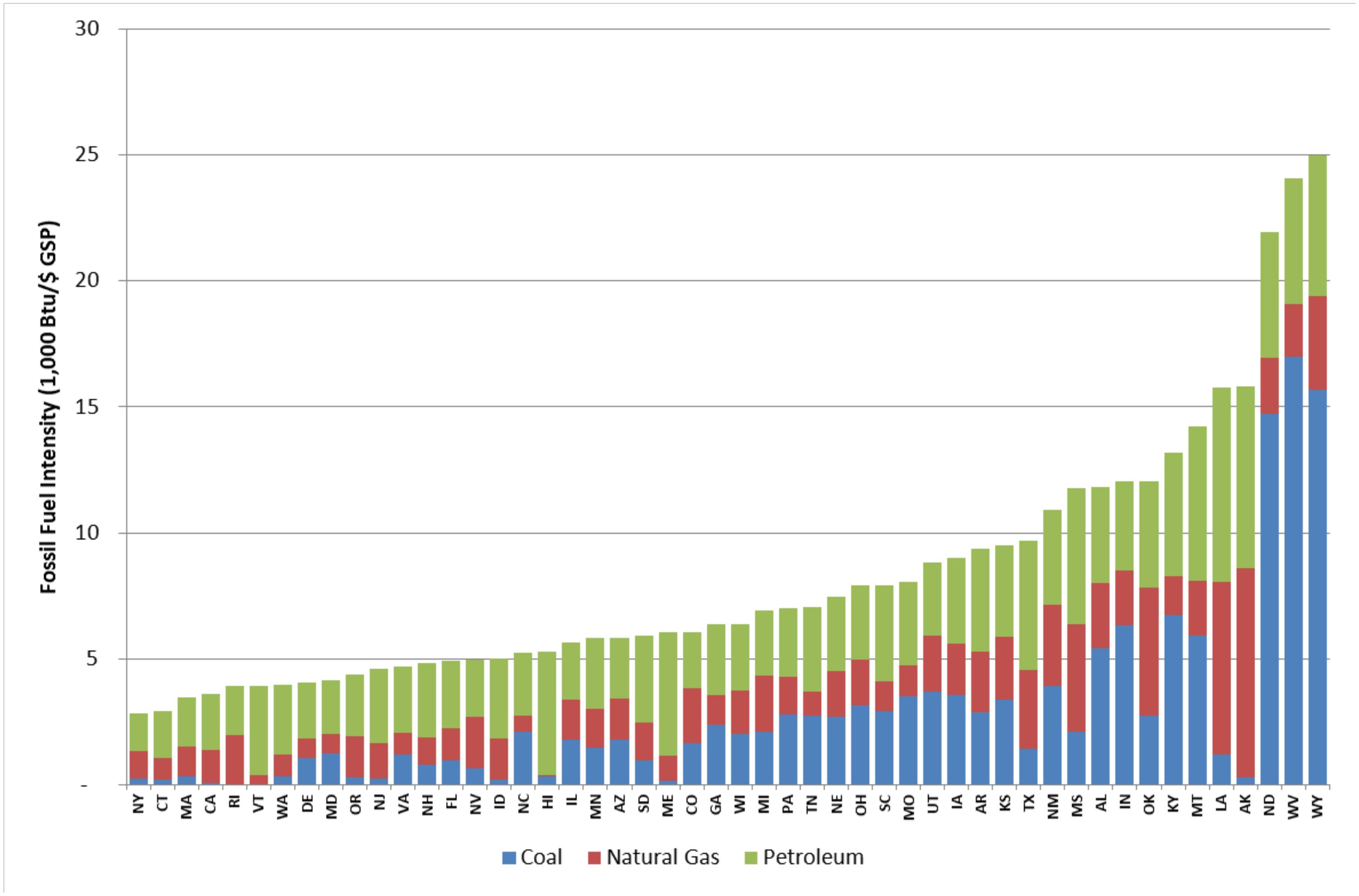
These differences in economic structure and sectoral energy use will play an important role in how states adjust to the requirements of a federal climate policy. For instance, the economic impact on states that are more dependent on fossil fuel extraction will depend on the feasibility and cost-effectiveness of carbon capture and storage (CCS), the timing of shifts to alternative energy sources, and the effects of a range of energy and climate policies on fossil fuel prices. Manufacturing is typically more energy intensive than services, and states where manufacturing is a larger share of GSP will have to give greater consideration to managing the impacts of a federal climate policy on retail energy prices.

Diversity in Energy Sources and Energy Use

States differ considerably both in their energy sources and in their fossil fuel intensities. Four states (Indiana, North Dakota, West Virginia, Wyoming) rely on coal for more than 50% of in-state energy use.[4] Nine states (California, Delaware, Hawaii, Maine, Massachusetts, New Jersey, South Dakota, Texas, Vermont) rely on petroleum for more than half of all in-state energy use. Only one state (Alaska) is more than 50% reliant on natural gas for in-state energy use. The lack of significant concentration suggests the diversity in energy sources both within and among states. **Error! Not a valid bookmark self-reference.** also illustrates the skewed distribution of total energy use among states. The three largest energy users — Texas (12%), California (8%), and Florida (5%) — accounted for roughly one quarter of total U.S. energy consumption in 2007. The 10 smallest energy using states (Vermont, Rhode Island, South Dakota, Delaware, New Hampshire, Hawaii, North Dakota, Maine, Montana, and Wyoming) accounted for only 3.6% of total U.S. energy consumption in 2007. These dramatic differences in state energy use are shaped by a variety of factors, most notably state population.

Figure 8. State Fossil Fuel Intensity by Fuel, 2007

[4] We define in-state energy use here to be primary energy converted in-state. In other words, net electricity imports are not included in this total. We also omit "Other" from this total, as Other accounts for less than 1% of in-state energy use.



Sources: Energy data are from the EIA website. Economic data are from BEA website, http://bea.gov/regional/index.htm#gsp.

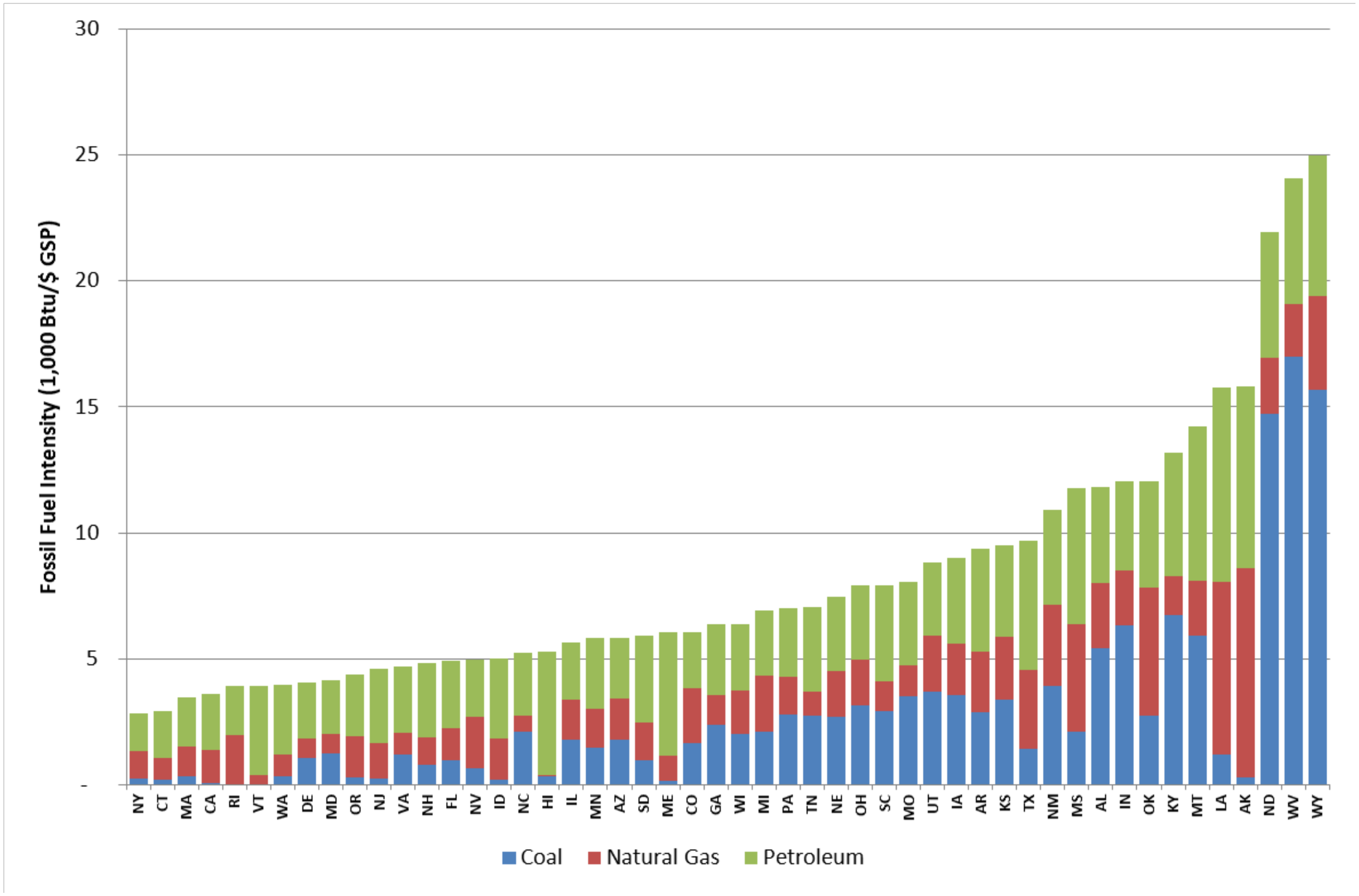
shows the considerable range in fossil fuel intensity (in 1,000 Btu per dollar of GSP) among states. At the two ends of the spectrum, Wyoming (25,000 Btu/$) has a fossil fuel intensity nearly nine times higher than that of New York (2,800 Btu/$). Variation in coal intensity among states is much larger than variation in either natural gas or petroleum intensity, as coastal states tend to be significantly less coal dependent than inland states. Petroleum intensity is relatively consistent across states.

Figure 7 shows the shares of in-state energy use by state.

Error! Not a valid bookmark self-reference. also illustrates the skewed distribution of total energy use among states. The three largest energy users — Texas (12%), California (8%), and Florida (5%) — accounted for roughly one quarter of total U.S. energy consumption in 2007.[5] The 10 smallest energy using states (Vermont, Rhode Island, South Dakota, Delaware, New Hampshire, Hawaii, North Dakota, Maine, Montana, and Wyoming) accounted for only 3.6% of total U.S. energy consumption in 2007. These dramatic differences in state energy use are shaped by a variety of factors, most notably state population.

Figure 8. State Fossil Fuel Intensity by Fuel, 2007

[5] Because these statistics reflect energy use (including electricity imports) the ranking here is different than what might be suggested in Figure 6.



Sources: Energy data are from the EIA website. Economic data are from BEA website, http://bea.gov/regional/index.htm#gsp.

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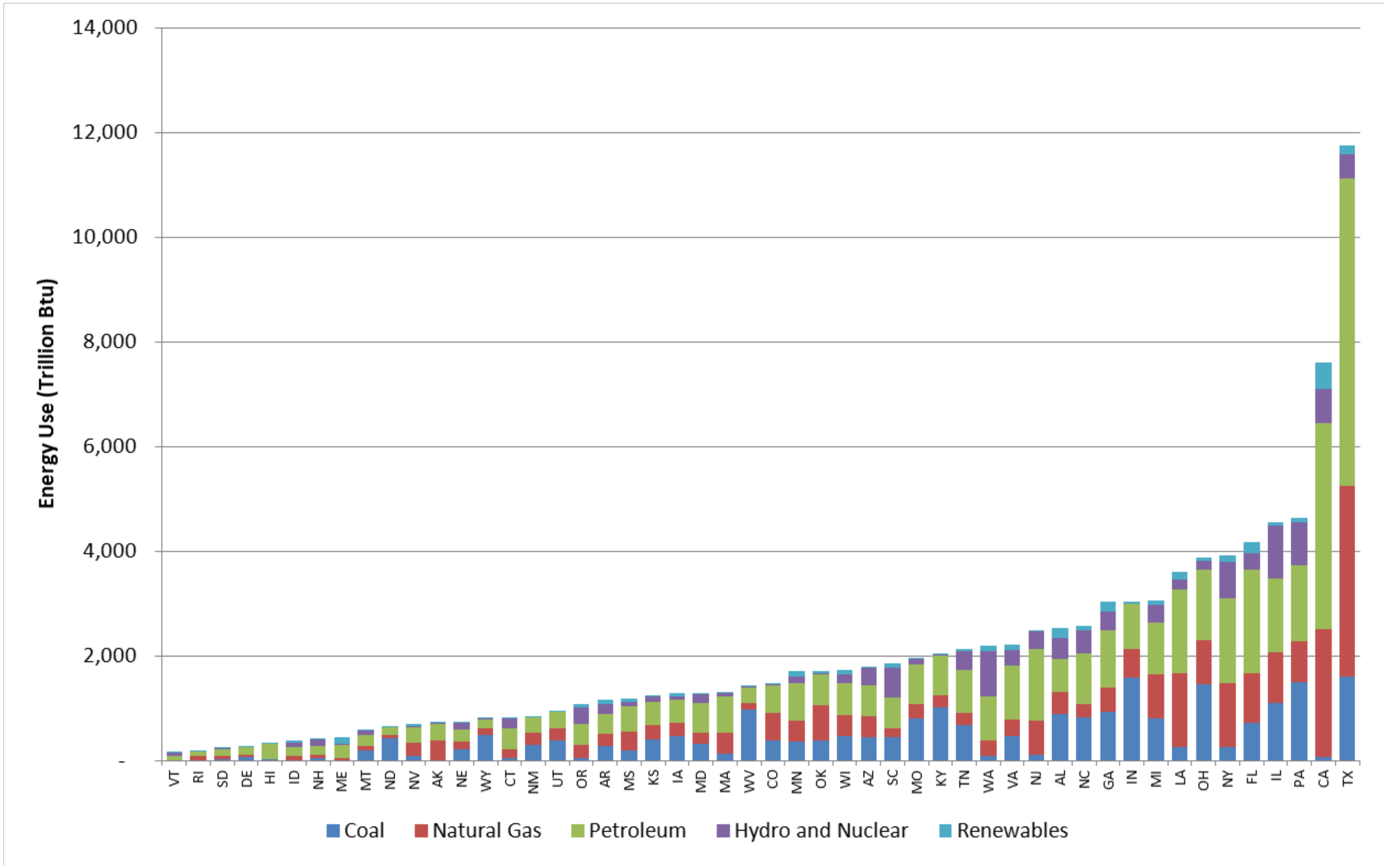
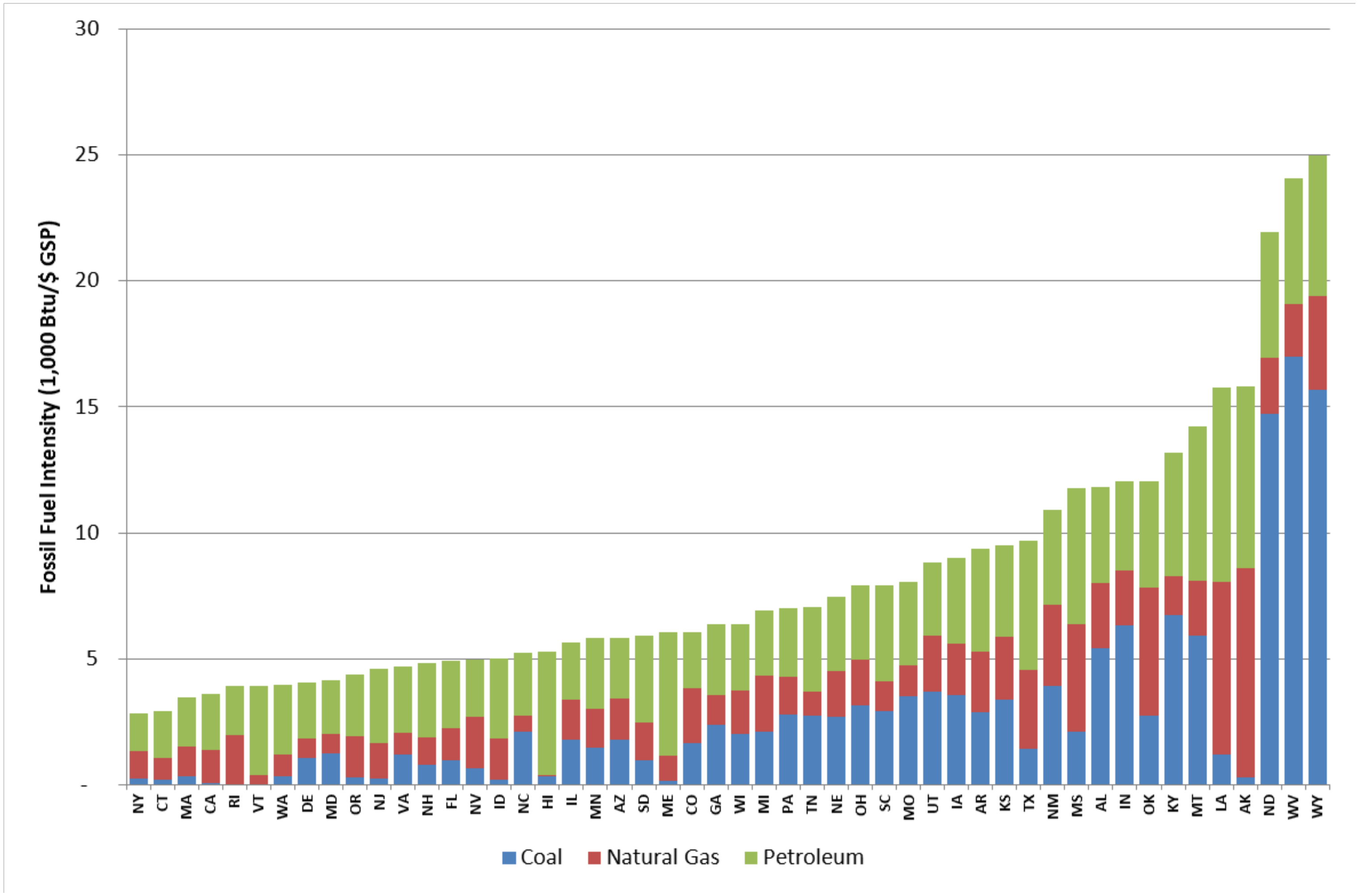
Figure 7. In-State Energy Use by Source and State, 2007



Notes and Source: In-state energy use refers to energy converted in-state, which does not include net electricity imports. All data are from the EIA website,

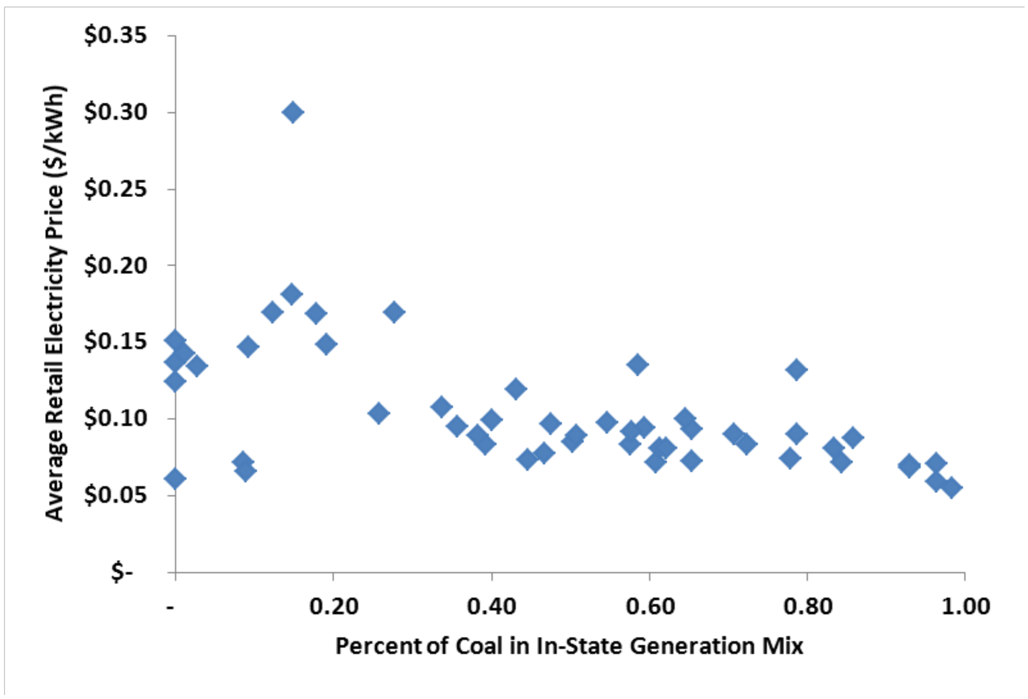
Figure 8. State Fossil Fuel Intensity by Fuel, 2007



Sources: Energy data are from the EIA website. Economic data are from BEA website, http://bea.gov/regional/index.htm#gsp.

In the context of climate policy, the most defining difference in energy use among is in the degree of reliance on coal. Depreciated nuclear facilities aside, coal is by significant margin the cheapest baseload resource for generating electricity. As Fi illustrates, states that have higher shares of coal in their generation mix generally lower average retail electricity prices. This central fact about coal — that it is the cheapest source of energy but has the highest carbon intensity among conventior energy sources — has salient implications for particular states' economic exposur changes in carbon prices. A \$20/tCO_2 across the board carbon tax imposed on Wyoming's 2005 CO_2 emissions, for instance, would induce tax payments equival 4.8% of Wyoming's 2005 GSP. The same tax applied to Vermont would induce payments equivalent to 0.6% of Vermont's 2005 GSP.[6]

Figure 9. Average Electricity Retail Prices by State as a Function of the Perc Coal in In-State Generation



Sources and Notes: All data are from the EIA website. Average prices here refle average across all customers in the state. Percent coal in in-state generation mix not account for electricity imports.

On the demand side, residential energy use is relatively consistent acro regions on a normalized basisFor instance, regional variation in vehicle m

---

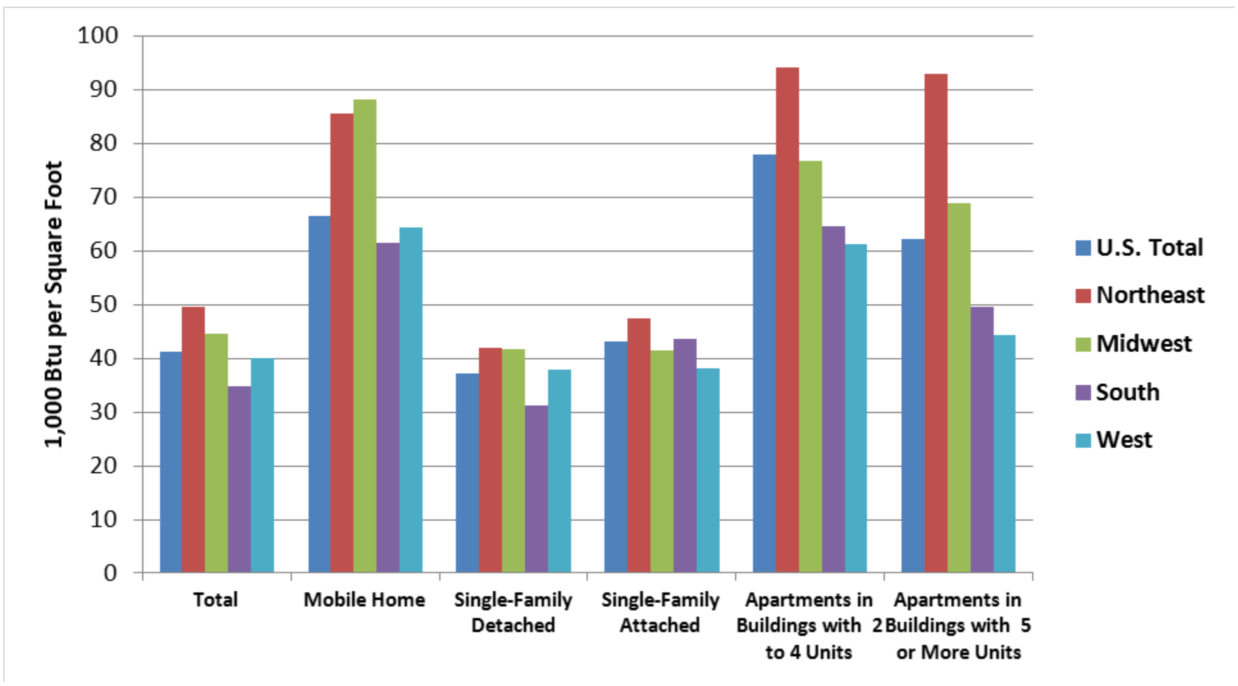
[6] Wyoming emitted 63 million metric tons of CO_2 equivalent in 2005, which, at \$20/tCO_2, amounts \$1.3 billion tax exposure, or 4.8% of the state's \$26.4 billion GSP in 2005. CO_2e emissions data he not include all GHG emissions. GHG data are from the EIA website, http://www.eia.doe.gov/environment.html. State GSP data are from the BEA website, http://bea.gov/regional/index.htm#gsp.

traveled (VMT) per vehicle is small. Average VMT across the U.S. was 11,974 VMT/vehicle in 2002, with a high of 12,538 VMT/vehicle (5% above the U.S. average) in the West South Central region and a low of 11,311 VMT/vehicle (6% below the U.S. average) in the Mountain region.[7] Variation in weather-adjusted, home energy use per square foot is also relatively small for single family homes, but appears to be somewhat larger for apartment buildings and mobile homes (

Figure 10). If not adjusted for weather or home size, variation in household use is significantly larger among regions, suggesting the role that differences in climate and socioeconomic conditions play in shaping energy use.

[few sentences on demand side commercial use?]

Figure 10. Weather-Adjusted Home Energy Use Per Square Foot by U.S. Census Region, 2005



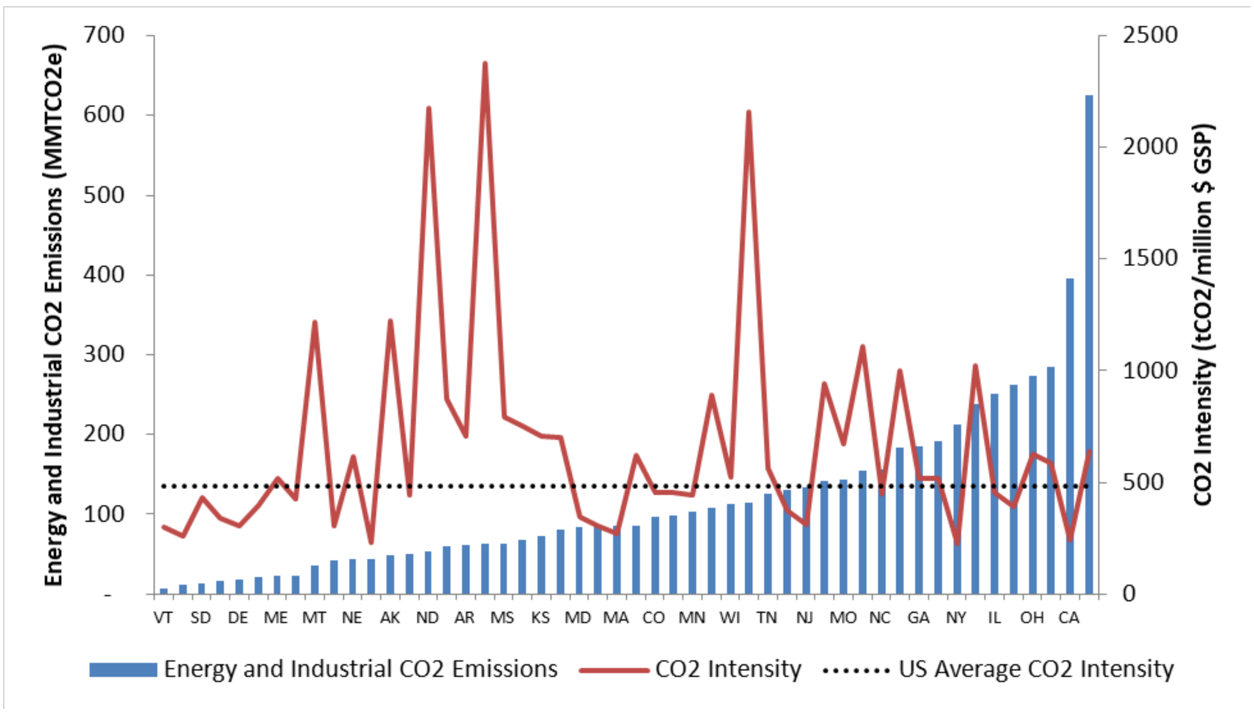
Source: Data are from the EIA's Residential Energy Consumption Survey (RECS), online at: http://www.eia.doe.gov/emeu/efficiency/recs_tables_list.htm.

[7] VMT data and data on vehicle stock are from the EIA website, online at: http://www.eia.doe.gov/emeu/consumption/index.html.

Diversity in Magnitude and Intensity of GHG Emissions

CO_2 emissions are tied to energy use in general, but coal intensity has a particularly dramatic effect on state-level CO_2 intensity.[8] Each of the three major spikes in Figure 11 corresponds to a state where coal is more than 50% of in-state energy conversion (North Dakota, West Virginia, and Wyoming). The second tier of spikes generally includes states that have more diverse energy sources but energy-intensive economies, such as Arkansas, Montana, and Louisiana. In all, 27 states have CO_2 intensities that are higher than the U.S. average.

Figure 11. State Energy and Industrial CO2 Emissions, State CO2 Intensity, and U.S. Average CO2 Intensity, 2005



Source: CO_2 emissions data are from the EIA website, http://www.eia.doe.gov/environment.html. Economic data are from the BEA website.

Here we make a distinction between CO_2 emissions (net CO_2 emitted) and energy intensity (the quantity of energy required per unit output or activity). Because of their large populations and economies, Texas (10%) and California (7%) together account for

---

[8] Coal leads to much higher CO_2 emissions per unit energy (94.6 tCO_2/TJ, for bituminous coal) than natural gas (56.1 tCO_2/TJ), gasoline (69.3 tCO_2/TJ), or diesel (74.1 tCO_2/TJ). Emissions factors are from *2006 IPCC Guidelines for National Greenhouse Gas Inventories*, online at: http://www.ipcc-nggip.iges.or.jp/public/2006gl/vol2.html.

17% of U.S. energy and industrial CO_2 emissions, despite the fact that both are under or just slightly above the U.S. average level for CO_2 intensity. Alternatively, the three most CO_2 intensive states (Wyoming, West Virginia, and North Dakota, in that order) account for just under 4% of total U.S. energy and industrial CO_2 emissions.[9]

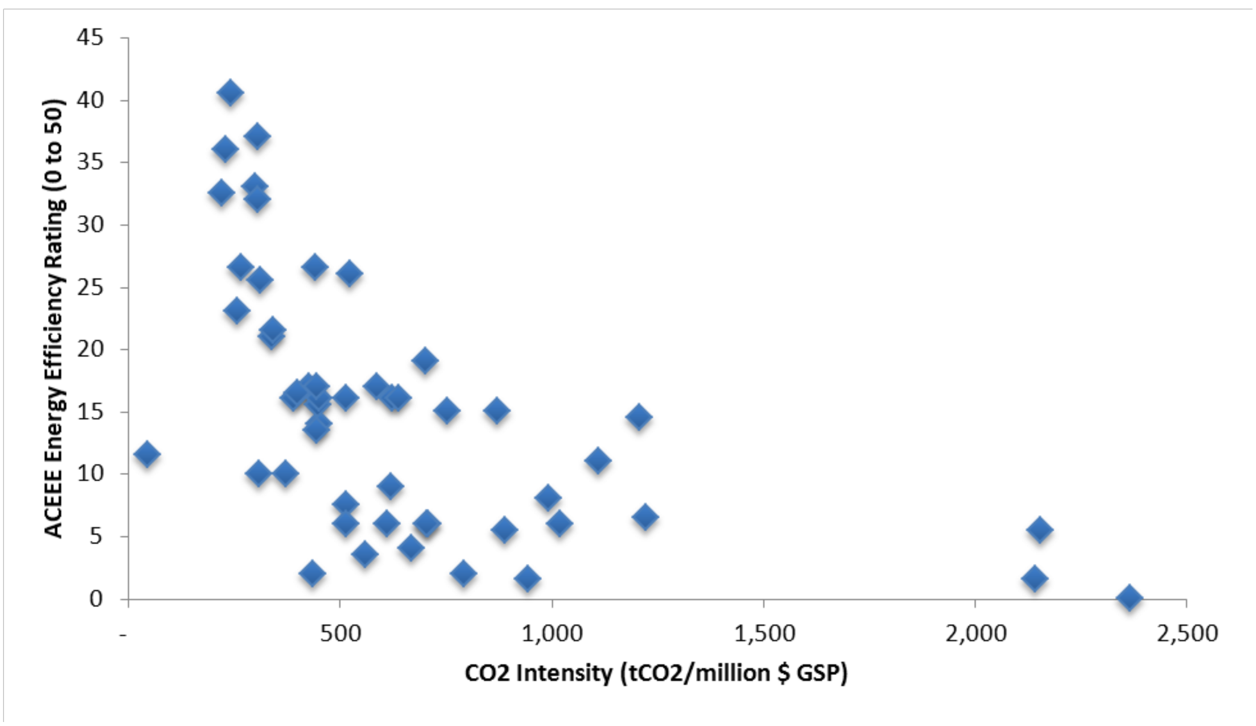
Diversity in Energy Policies

A final important difference among states, and one that is less amenable to modeling, is their historical commitment to energy efficiency and alternative energy programs. States that have historically run extensive mandatory energy policies are arguably better positioned to implement the large-scale complementary energy programs that would accompany a federal climate policy. As

Figure 12 illustrates, states with higher CO_2 intensities are less likely to have achieved a high score in the American Council for an Energy Efficient Economy's (ACEEE's) energy efficiency scorecard. Given the aforementioned relationship among coal, carbon intensity, and electricity prices, this relationship is not surprising. States with lower electricity prices (that tend to have higher coal use and thus higher CO_2 intensity) have had less incentive to invest in energy efficiency. This relationship does, however, suggest a possible facilitating role for federal government agencies in targeting both funds and technical assistance to states with lower ACEEE scores.

[9] Data here are from the same source as in Figure 11.

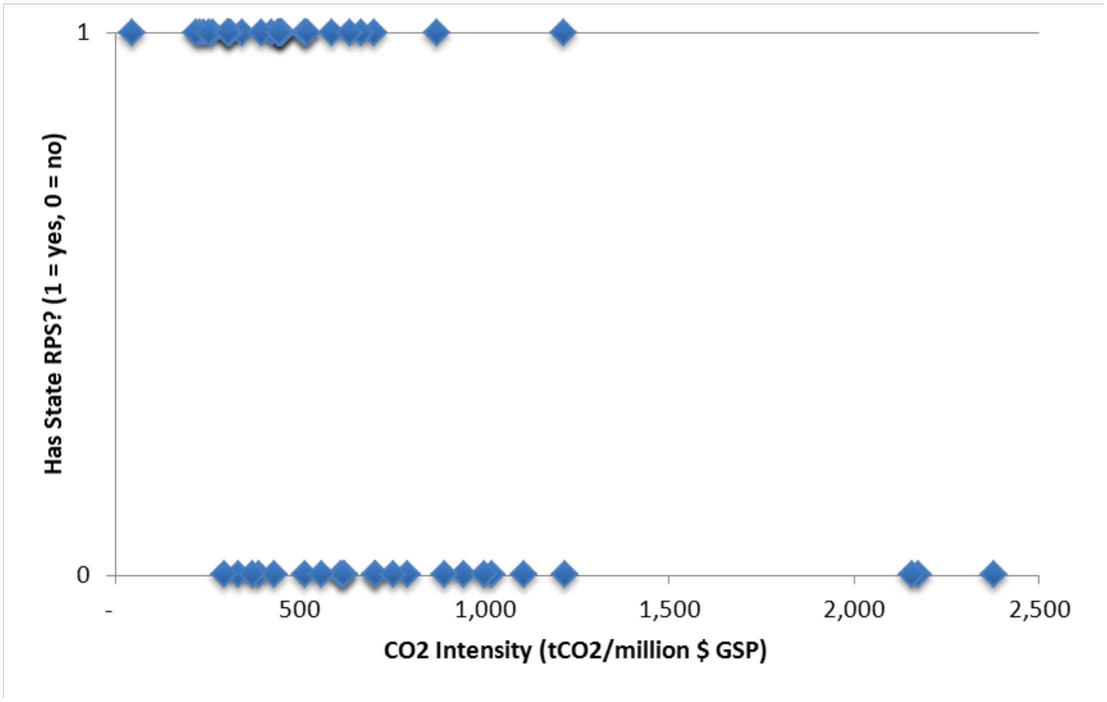
Figure 12. State ACEEE Energy Efficiency Rating as a Function of 2005 State CO_2 Intensity



Sources: ACEEE energy efficiency rating is from ACEEE, "The 2008 State Energy Efficiency Scorecard", http://www.aceee.org/pubs/e086_es.pdf. CO_2 data are from the Energy Information Administration (EIA) website, GSP data are from the Bureau of Economic Analysis (BEA) website.

Figure 13 shows that states with more CO_2 intensive economies are less likely to have adopted a state renewable portfolio standard (RPS). An RPS sets a mandate for either a level of renewable generation capacity or a percentage of total state generation or electricity sales that must come from renewable sources. Because of the significant amount of planning built into RPS processes to ensure adequate transmission, to match transmission and renewable resources, and to address potential intermittency problems, states that have run RPS programs will be better placed to manage the integration of renewable energy into existing energy systems.

Figure 13. State RPS as a Function of State CO_2 Intensity (1 = has RPS, 0 = does not have RPS)



Sources: CO_2 emissions data are 2005 data from the EIA website, http://www.eia.doe.gov/environment.html, GSP data are from the BEA website, RPS data are from the U.S. Department of Energy EERE website and reflect programs as of 2009, http://apps1.eere.energy.gov/states/maps/renewable_portfolio_states.cfm.

5. Detailed Discussion of Results

Federal climate policy will lead to significant economic adjustments, both at a state and national level. Aggregate growth effects from the EAGLE model are summarized by state in Table 2 and

Table 3. Measured as percentage variations in employment and real gross state product (GSP), the results show changes in employment and aggregate real value added (wages, salaries, and profits) in 2020, compared to a baseline [explain what the specific baseline is here).

The “moderate” and “high” columns in Table 2 and

Table 3 refer to moderate and high levels (see earlier comment...how about moderately and highly ambitious instead of moderate and high levels of policies?) of energy efficiency policies, one conforming to ACES standards and the other more aggressive. In the more aggressive scenario, we assume that energy efficiency increases by an additional 1% per year, approximating efficiency gains in the California economy over the last 30 years.

As Table 2 and

Table 3 **show, many states could achieve net gains in employment and income over a business as usual scenario through the implementation of a well-designed federal climate policy. Even in states that do experience a net loss in employment and/or income vis-à-vis business as usual, losses are relatively minor and would most likely be lost in the uncertainty surrounding GSP growth. It is important to keep in mind that the forecasts in Table 2 and**

Table 3 are vis-à-vis a baseline, so that all states still experience positive growth relative to the base year (2010).

Energy efficiency is an important driver of the results in Table 2 and

Table 3. To the extent that it generates net savings to businesses and households, energy efficiency produces local multiplier effects. Energy savings are largely spent on in-state and domestic services, which are substantially more labor intensive than the energy sector. Workers in the services industry spend this additional income on goods and services, and so on. Differences in employment and income in Table 2 and

Table 3 occur, in part, because average wages are lower in the services sector.

A second important driver results from the shift of capital and labor out of the fossil fuel supply chain and into more employment intensive industries, both in manufacturing and services. Wyoming is a prime example of this effect. As noted previously, the extractive industries account for a large portion of Wyoming's GSP, and these industries are negatively impacted by the implementation of an ACES-like policy. However, the shift of resources out of extractive industries and into more employment-intensive and broadly linked sectors provides a stimulus to the Wyoming economy, which, combined with demand-side efficiency gains, outweighs the contraction in the extractive sectors. These kinds of sectoral adjustments can be facilitated or hindered by policy.

Table 2: Job Growth by 2020

State	Thousands		Percent	
	Moderate	High	Moderate	High
United States	918	1,894	.4	.9
Alabama	21	39	.7	1.3
Alaska	1	9	.2	1.7
Arizona	9	24	.2	.6
Arkansas	10	25	.5	1.3
California	120	226	.5	.9
Colorado	11	30	.3	.8
Connecticut	11	16	.4	.6
Delaware	3	7	.5	1.2
Florida	47	78	.4	.6
Georgia	40	70	.6	1.1
Hawaii	4	10	.4	1.0
Idaho	7	14	.6	1.3
Illinois	37	68	.4	.7
Indiana	22	45	.5	1.0
Iowa	14	27	.6	1.1
Kansas	7	22	.3	1.0
Kentucky	10	30	.3	1.0
Louisiana	-6	22	-.2	.7
Maine	6	12	.6	1.2
Maryland	34	71	.8	1.7
Massachusetts	22	40	.4	.8
Michigan	42	37	.6	.6
Minnesota	19	38	.5	.9
Mississippi	8	19	.4	1.0
Missouri	18	29	.4	.7
Montana	5	13	.7	1.8
Nebraska	12	38	.8	2.6
Nevada	9	17	.4	.9
New Hampshire	5	7	.5	.7
New Jersey	13	11	.2	.2
New Mexico	5	15	.4	1.2
New York	77	126	.6	1.0
North Carolina	17	65	.3	1.0
North Dakota	4	11	.7	1.8
Ohio	35	61	.4	.7
Oklahoma	-2	20	-.1	.8
Oregon	13	26	.5	1.0
Pennsylvania	46	78	.5	.9
Rhode Island	5	8	.7	1.1
South Carolina	21	36	.7	1.2
South Dakota	5	10	.8	1.5
Tennessee	2	20	.0	.5
Texas	44	165	.3	1.0
Utah	8	21	.4	1.1
Vermont	4	8	.9	1.5
Virginia	25	50	.4	.9
Washington	1	13	.0	.3
West Virginia	10	31	.9	2.8
Wisconsin	20	28	.5	.7
Wyoming	6	20	1.3	4.5

Table 3: Real 2020 Household Income and GSP

State	Income (2008$)		GSP Percent	
	Moderate	High	Moderate	High
United States	488	1,176	.2	.7
Alabama	547	1,261	.4	.9
Alaska	1,165	5,801	-.1	2.6
Arizona	53	283	.0	.2
Arkansas	457	1,230	.4	1.1
California	735	1,477	.4	.7
Colorado	425	1,138	.0	.4
Connecticut	717	1,011	.3	.4
Delaware	398	1,416	.2	.9
Florida	303	615	.3	.6
Georgia	702	1,362	.4	.9
Hawaii	610	1,464	.3	.8
Idaho	431	1,149	.3	1.0
Illinois	508	1,137	.2	.6
Indiana	476	1,219	.3	.8
Iowa	686	1,501	.5	1.2
Kansas	229	1,182	.1	.7
Kentucky	267	1,133	.2	.9
Louisiana	-219	1,582	-.4	1.0
Maine	550	1,317	.5	1.1
Maryland	1,022	2,172	.6	1.2
Massachusetts	738	1,356	.3	.7
Michigan	667	750	.4	.5
Minnesota	579	1,240	.3	.8
Mississippi	289	889	.2	.8
Missouri	446	892	.3	.7
Montana	599	1,736	.4	1.4
Nebraska	927	4,120	.6	2.7
Nevada	471	1,025	.3	.7
New Hampshire	573	726	.3	.4
New Jersey	196	-92	.1	-.1
New Mexico	516	1,309	.0	.7
New York	902	1,580	.4	.7
North Carolina	230	1,159	.2	.9
North Dakota	1,048	2,683	.5	1.5
Ohio	452	992	.3	.7
Oklahoma	47	986	-.6	-.1
Oregon	399	941	.3	.7
Pennsylvania	637	1,092	.4	.7
Rhode Island	700	1,172	.5	.8
South Carolina	650	1,259	.5	1.0
South Dakota	784	1,602	.6	1.2
Tennessee	-129	406	-.1	.3
Texas	442	1,814	.0	.8
Utah	523	1,435	.2	.8
Vermont	816	1,535	.6	1.2
Virginia	554	1,325	.3	.7
Washington	-195	105	-.1	.1
West Virginia	684	2,737	.5	2.5
Wisconsin	513	749	.3	.6
Wyoming	4,884	9,862	1.2	4.0

An important finding of this study is that the most carbon intensive states are not necessarily the ones most negatively impacted by federal climate policy. In part this result is driven by the fact that, as noted above, carbon intensive states tend to be coal dependent states where a history of cheap energy prices has led to high levels of energy consumption. Rising fossil fuel prices put these states at risk because energy expenditure's share of income increases disproportionately vis-à-vis other states, and energy efficiency investments reduce these more carbon intensive states' exposure to higher fossil fuel prices. Proportional reductions in energy consumption in these states thus have greater effects than in states where energy consumption is already low.

Complementary policies at the municipal, regional, and state level that encourage energy efficiency and proactively facilitate sectoral adjustment can significantly cushion the impact of rising energy prices that will likely accompany federal climate policy and can promote net growth in employment and income.

6. Documentation of Complementary Policy Inputs

A significant portion of the greenhouse gas (GHG) emission reductions achieved under ACES will result from regulatory policies — or policies that complement the cap and trade (C&T) system — that force shifts in energy technology portfolios. To capture the importance of mandatory shifts in technology that will result from ACES, the EAGLE model incorporates results from a separate model of the U.S. energy system and uses those results as exogenous inputs. This energy system model, a MARKAL model, was supported by the Natural Resources Defense Council (NRDC) as part of an effort to model the effects of federal climate policy on the U.S. national energy system from 2000 to 2050. EAGLE uses a subset of MARKAL results as policy-dependent inputs, allocating national-level results from MARKAL across the 50 states.

As exogenous inputs, the MARKAL results can be interpreted as the benefits and costs associated with specific regulatory policies. For instance, the shift toward more renewable sources of energy in MARKAL is typically accompanied by higher capital (i.e., $/kW) costs, higher or lower operational (i.e., $/kWh) costs, a reduction in fuel use (e.g., coal), and a reduction in GHG emissions (e.g., CO_2, CH_4, and N_2O in the case of coal) relative to a business as usual baseline. We treat this shift as an exogenous policy regime change — akin to a renewable portfolio standard (RPS) — in EAGLE, with concomitant changes in capital costs, intermediate inputs, real fuel consumption, and GHG emissions for corresponding sectors.

This section describes the MARKAL results used in this study, how national results were allocated across states, and how state-level results were incorporated into the EAGLE model.

Description of MARKAL Results

The EAGLE model uses four categories of results from MARKAL:

- **Transportation** includes changes in the energy requirements and fuel mix of the light duty vehicle (LDV) and heavy duty vehicle (HDV) fleets.
- **Electric Power Generation** includes changes in the composition of the mix of electricity generation resources.
- **Residential and Commercial Energy Efficiency** includes changes in the energy requirements of residential and commercial buildings, appliances, and electronics.
- **Sequestration and other Offsets** include terrestrial carbon sequestration and landfill gas projects.

For reasons described below we do not include industrial policies in this mix, although policies and programs that promote energy efficiency, and to a lesser extent fuel switching and process improvements, will play an important role in shaping the economic response to federal climate policy.

For each of the four policy categories above, the subsections below provide an overview of the MARKAL results used in this analysis, focusing on the four specific inputs integrated into the EAGLE model:

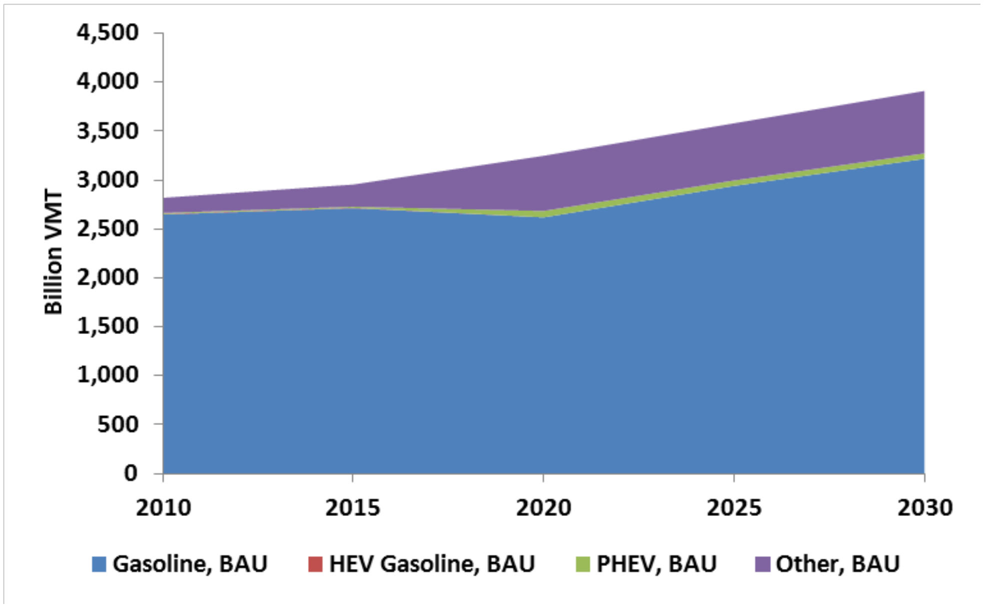
- Capital costs;
- Variable costs;
- Real fuel consumption; and
- GHG emissions.

Changes in the above four variables under an ACES-like C&T system (Policy Case) are measured relative to business as usual projections (BAU Case) in MARKAL. The MARKAL results presented below cover the 2010-2030 time frame. To adjust these to 2020 for use in the EAGLE model we assume that changes in the above four variables are smooth over time. The below subsections describe changes in these variables for five aggregate regions: the Midwest, Northeast, Plains, South, and West.

Transportation

Transportation includes shifts in the composition of technologies powering the light duty vehicle (LDV) and heavy duty vehicle (HDV) fleets. In the MARKAL BAU Case, the majority of LDV fuel use (82% of total VMT) is met with gasoline, with a small but significant amount of ethanol (9% of VMT) in the fuel mix by 2030. HDV fuel use in the BAU Case is predominantly diesel (93% of VMT).

Figure 14. Composition of LDV Technologies, BAU Case

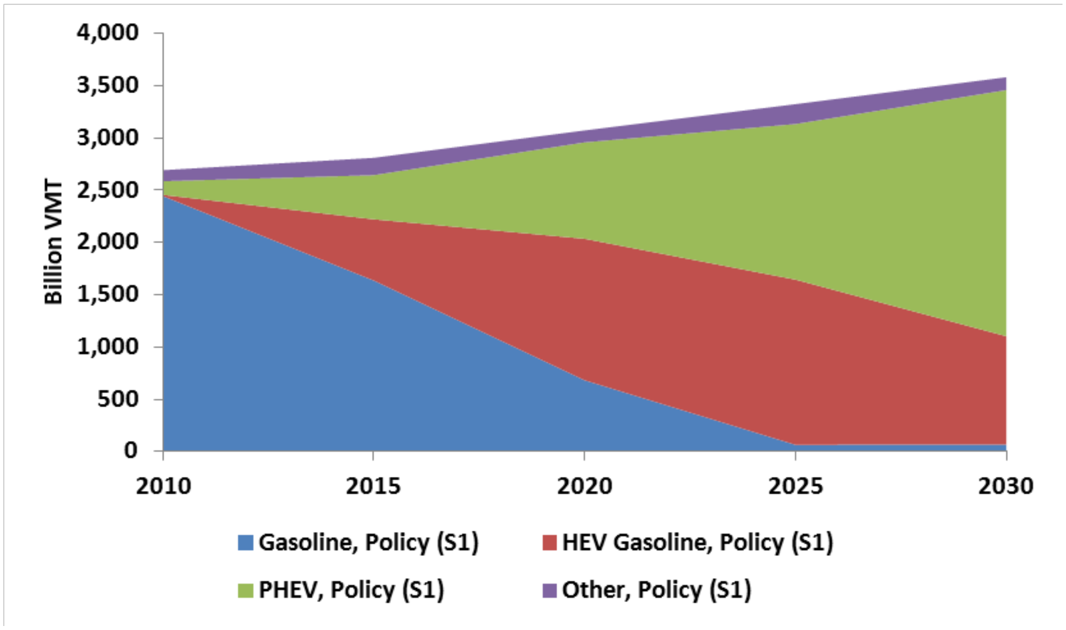


In the MARKAL Policy Case, the primary shift is toward greater adoption and use of hybrid electric vehicles (HEVs) and ultimately plug-in hybrid electric vehicles (PHEVs) (

Figure 15), which account for the majority of VMT by 2025. We also examined a second scenario, where greater constraints were placed on the adoption of PHEVs and instead the dominant shift is from conventional gasoline vehicles to HEVs. In terms of the variables of interest here (cost, fuel, emissions), differences between these scenarios were relatively small. We ultimately used cost, fuel, and emissions estimates based on the compositional changes represented in

Figure 15.

Figure 15. Composition of LDV Technologies, Policy Case



For HDVs, we consider only cost, fuel, and GHG emission changes from heavy trucks in the MARKAL results, as no other changes in HDVs occurred. In the Policy Case, the primary shift in heavy trucks is toward more efficient vehicles, with a much smaller shift toward biodiesel. By 2030, roughly one-third of all heavy truck VMT in the Policy Case is accounted for by high efficiency vehicles.

Table 4. Total Change in Transportation Costs, Fuel Consumption, and Emissions Relative to BAU, 2010-2030

	Vehicle Costs	Annual Costs	Petroleum Consumption	Electricity Consumption	CO_2 Emissions
LDVs	34%	4%	-34%	4,567%	-30%
HDVs	23%	2%	-7%	0%	-13%

Notes: Petroleum consumption is shorthand for refined product consumption and includes primarily gasoline and diesel. Ethanol does not play a major role in the LDV results. CO_2 emissions do not include emissions from electricity generation. Differences between changes in energy consumption and CO_2 emissions are the result of changes in the fuel mix. For instance, in the HDV case an increase in FTL biodiesel with CCS relative to BAU biodiesel use reduces the emission factor for biodiesel.

Table 4 shows the impact of the technology shifts described above on unit vehicle costs, annual costs, petroleum consumption, electricity consumption, and CO_2 emissions, with costs shown as the percentage increase over the BAU Case. The shift to more efficient vehicles leads to higher vehicle and annual costs

and a decline in petroleum consumption and CO_2 emissions, with differences between the latter two dependent on changes in the fuel mix (i.e., the “Other” in

Figure 14 and

Figure 15). The huge relative increase in electricity consumption for transportation is the result of its having started from a very small base. We assume that regional variation in LDV and HDV policies is uniform across states, with differences in vehicle use reflected in the state social accounting matrices (SAMs) rather than in the MARKAL inputs.

As the difference in VMT between

Figure 15 and

Figure 14 suggests, MARKAL includes significant price-induced changes in VMT that reduce demand for transportation energy over time. Including these changes as inputs in a CGE[define acronym] modeling framework would lead to a double counting of price effects. To control for price-induced shifts in consumption in MARKAL,[10] we normalize cost, fuel consumption, and GHG emissions by VMT and calculate changes in per unit terms.[11]

Electric Power Generation

Electricity generation includes shifts toward low or zero carbon energy sources, including coal-fired generation with offsetting carbon capture and storage (CCS). In the MARKAL BAU Case (Figure 3), shares of electricity generation remain largely unchanged, with coal and natural gas continuing to provide more than 65% of U.S. electricity generation (

Figure 16). A small (9%) amount of biomass and wind generation begins to gain share from nuclear power by 2030.

Figure 16. Electricity Generation Mix, BAU Case

[10] More generally, we control for price-induced changes in MARKAL using simple decomposition techniques that isolate total changes in unit cost, energy use, and GHG emissions from changes induced by changes in consumption. For instance, to decompose the role that consumption (Q) plays in shaping total cost (C), from the identity $C = \frac{C}{Q} \times Q$ we get $\Delta C = \left[\Delta\left(\frac{C}{Q}\right) \times Q_{BAU}\right] + \left[\left(\frac{C}{Q}\right)_{POL} \times \Delta Q\right]$, where the first term is the change in costs due to a change in unit costs, and the second term is the change in costs due to a change in consumption (BAU here is the BAU Case; POL is the Policy Case). From this, the percentage change in costs attributable to the change in unit costs is $\frac{\Delta C}{C_{BAU}} = \frac{C_{POL}}{Q_{POL}} / \frac{C_{BAU}}{Q_{BAU}} - 1$.

[11] Vehicle investment and annual costs, fuel use, and CO_2 emissions are calculated differently to reflect differences in timing and volatility. The change in vehicle investment (VI) is calculated as the change in cumulative investment divided by the sum of inter-period changes in VMT, or $\frac{\Delta VI}{VI_{BAU}} = \frac{\sum_t VI_{POL}}{\sum_t \Delta VMT_{POL}} / \frac{\sum_t VI_{BAU}}{\sum_t \Delta VMT_{BAU}} - 1$, where VI is vehicle investment summed over all periods t and ΔVMT is the inter-period change in VMT. Inter-period changes in investment and VMT are relatively volatile in the MARKAL results, and this approach allows us to more accurately reflect differences between the two over the 2010-2030 period. Cumulative vehicle investments are undiscounted, as the timing of investments in MARKAL are difficult to reconcile with economic activity in the CGE. Changes in annual costs are normalized by 2030 VMT, or $\frac{\Delta AC}{AC_{BAU}} = \frac{AC_{POL,2030}}{VMT_{POL,2030}} / \frac{AC_{BAU,2030}}{VMT_{BAU,2030}} - 1$, where AC is total annual costs, VMT is total VMT, and the subscripts denote the year of the two variables. Percentage changes in unit fuel consumption and CO_2 emissions are also calculated using this approach.

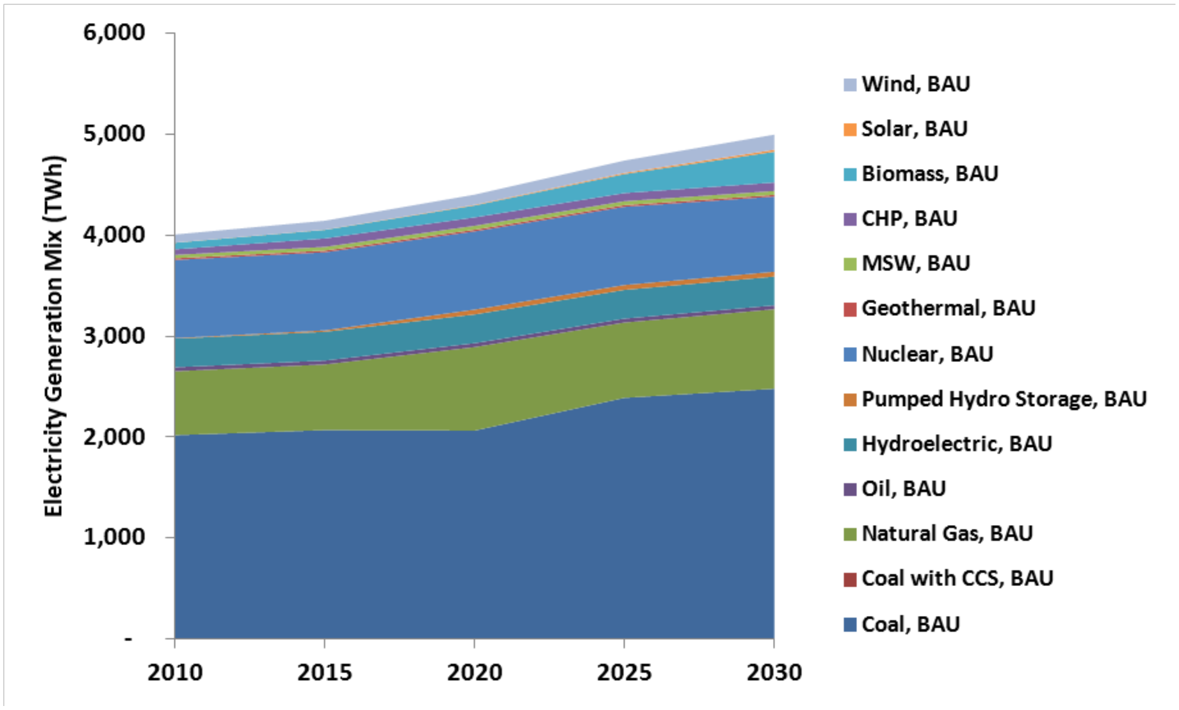
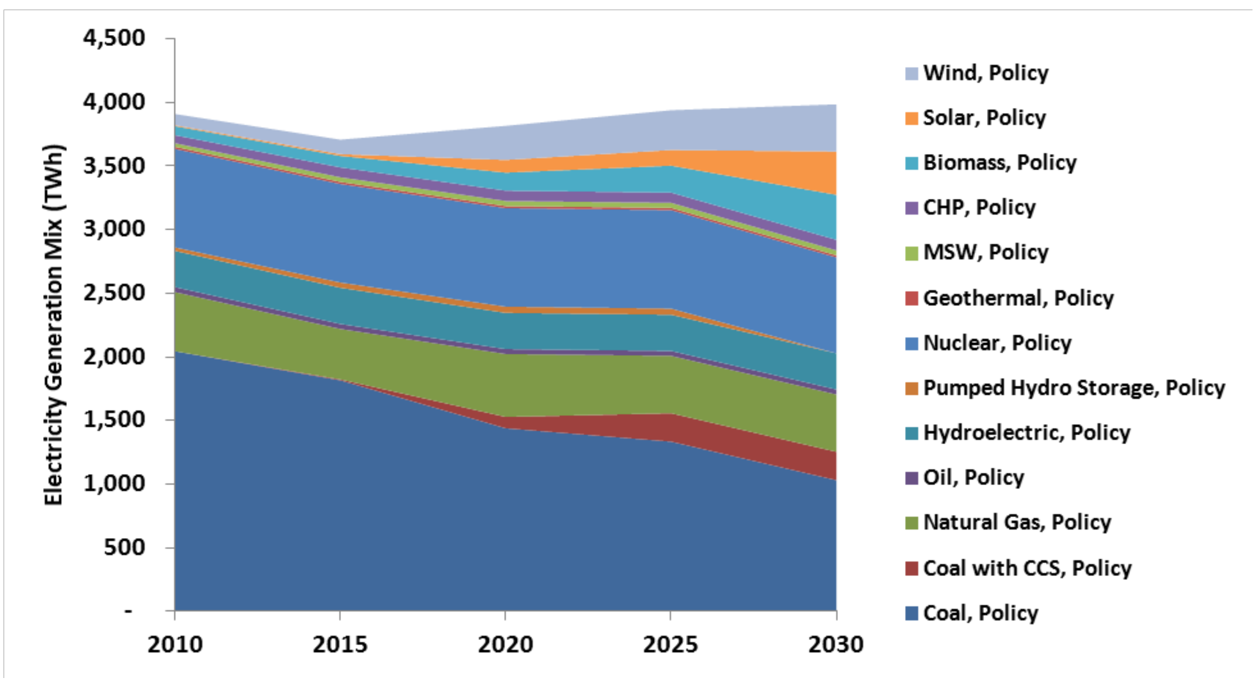


Figure 17. Electricity Generation Mix, Policy Case



Two main resource shifts occur in the MARKAL Policy Case (Figure 4). First, with a significant ramp up in generating capacity over the 2010-2030 period, biomass, solar, and wind power account for 27% of total national generation by 2030. Second, a small but significant amount of coal with CCS (6% of generation by 2030) begins to come online. These two shifts displace conventional coal and natural gas generation, with the majority of CO_2 emission reductions coming from reductions in conventional coal-fired generation (

Figure 17).

As

Figure 17 shows, efficiency gains — from both technology improvements and conservation — lead to a significant decrease in electricity demand in the MARKAL Policy Case. Efficiency gains from technology improvements are included in a separate set of efficiency policies (See *Residential and Commercial Efficiency*, below); conservation is price-induced and would lead to double counting in MARKAL. To isolate the effects of changes in generation mix on changes in per unit capital costs, annual (variable) costs, real fuel consumption, and GHG emissions, we use a decomposition approach similar to that described in *Transportation*, above.[12]

Relative to the BAU Case, the Policy Case results in an increase in capital costs, an increase in annual costs in all regions except for the West,[13] and relatively significant declines in coal and natural gas use (

[12] For the electricity sector, changes are normalized in units of either per capacity (GW) or per generation (MWh). Percentage changes in capital costs are calculated using the total change in cumulative investment divided by total change in cumulative installed capacity, or $\frac{\Delta CC}{CC_{BAU}} = \frac{\sum_t INV_{POL}}{\sum_t TIC_{POL}} / \frac{\sum_t INV_{BAU}}{\sum_t TIC_{BAU}} - 1$, where CC is capital costs, INV is investment, TIC is total installed capacity, and t is measured at five-year intervals between 2010 and 2030. We use cumulative investment and installed capacity to account for the "burstiness" of investment in MARKAL and the fact that any given year may not represent the trajectory of investment. Cumulative investments are undiscounted, as the timing of investments in MARKAL are difficult to reconcile with economic activity in the CGE. Percentage changes in annual costs are calculated using year 2030 total annual costs for the Policy and BAU Cases, divided by 2030 total generation, or $\frac{\Delta AC}{AC_{BAU}} = \frac{AC_{POL,2030}}{GEN_{POL,2030}} / \frac{AC_{BAU,2030}}{GEN_{BAU,2030}} - 1$, where AC is total annual costs, GEN is total generation, and the subscripts denote the year of the two variables. Percentage change in real fuel consumption are calculated as the change in consumption of fuel in 2030 divided by total change in generation, or $\frac{\Delta FC_i}{FC_{i,BAU}} = \frac{FC_{i,POL,2030}}{GEN_{POL,2030}} / \frac{FC_{i,BAU,2030}}{GEN_{BAU,2030}} - 1$, where FC_i is consumption of fuel i (in PJ) and GEN is total generation (in TWh). We use the normalized fuel consumption estimates from the calculation above and aggregate emission factors to calculate the change in GHG emissions between the two scenarios. By using emission factors, we can account for the introduction of CCS by reducing the aggregate emission factor for coal.

[13] The decline in annual costs in the West is simply a function of cost input assumptions, existing generation mix, and the mix of marginal generation. For the West, new generation has lower annual costs than existing generation.

Table 5 and 6). Although reductions in natural gas are uniform across regions, changes in coal fuel use are not uniform because CCS potential is not evenly distributed geographically. . *Methods of State Allocation* describes the state and regional allocation of electricity generation in greater detail.

Table 5. Total Change in Capital and Annual Costs for Electricity Generation Relative to BAU, 2010-2030

Region	Capital Costs ($/GW)	Annual Costs ($/MWh)
Midwest	29%	11%
Northeast	28%	11%
Plains	29%	2%
South	27%	9%
West	40%	-4%

Table 6. Total Change in Electricity Fuel Use and Emissions Relative to BAU, 2010-2030

Region	Coal		Natural Gas		Biomass
	Energy	CO_2 Emissions	Energy	CO_2 Emissions	Energy
Midwest	-42%	-44%	-26%	-26%	15%
Northeast	-44%	-44%	-26%	-26%	15%
Plains	-29%	-44%	-26%	-26%	15%
South	-40%	-44%	-26%	-26%	15%
West	-6%	-44%	-26%	-26%	15%

Notes: Differences between coal energy and CO_2 emissions result from the introduction of coal with CCS, which leads to a lower average emission factor for coal-fired generation. The Northeast region, for instance, has no coal with CCS, while the West region has the largest amount. Changes in oil-fired generation in MARKAL were negligible and are not included in our totals.

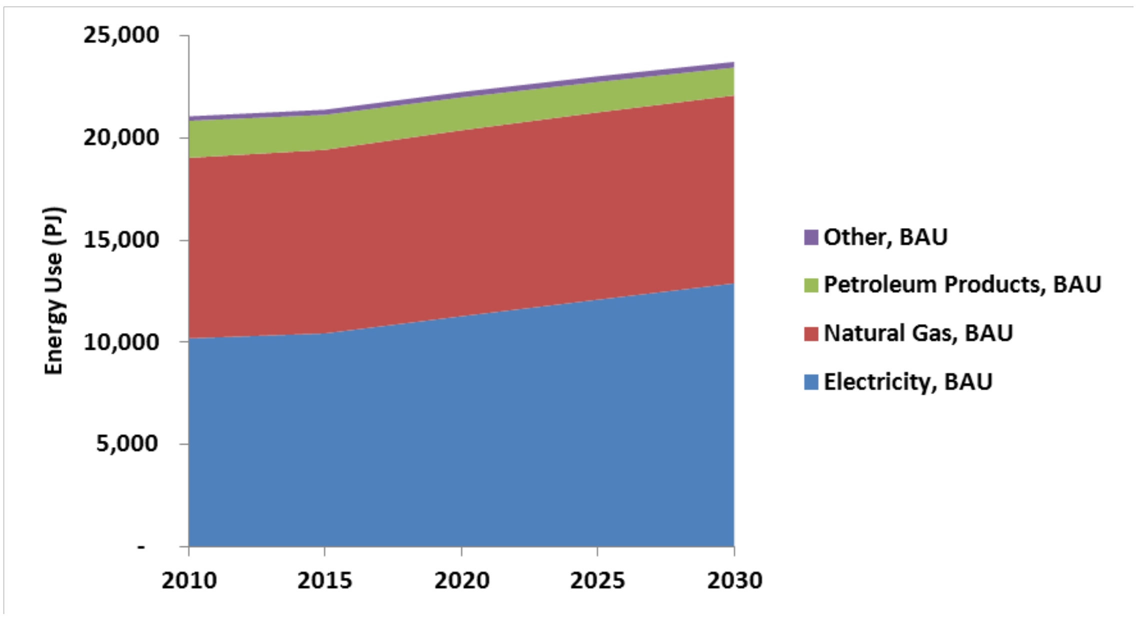
Residential and Commercial Efficiency

Residential and commercial energy efficiency requires improvements in the efficiency of buildings, appliances, and electronics that use electricity, natural gas, and petroleum products. The MARKAL results also include the introduction of solar water heaters on a larger scale.

In the MARKAL BAU Case, residential and commercial energy use increases steadily between 2010 and 2030, with little change in the shares of end use energy carriers (

Figure 18). Muted growth in consumption between 2010 and 2015 reflects the fact that some of the energy efficiency measures that were part of the American Recovery and Reinvestment Act are included in the MARKAL BAU Case.

Figure 18. Residential and Commercial Energy Use, BAU Case



In the Policy Case, residential and commercial energy use falls steadily from 2010 and 2030, reflecting improvements in the efficiency of "stationary" energy using devices and a limited amount of technology substitution (e.g., natural gas furnaces to solar water heaters) to energy sources not included in

Table 7 lists the changes in capital costs, annual costs, energy use, and CO_2 emissions for natural gas and oil use that result from these efficiency improvements. Equipment and annual costs increase for commercial users, but to a much lesser extent for residential users. For both residential and commercial users, energy use and natural gas and oil-related CO_2 emissions decline significantly over 2010-2030.

Figure 19. While the share of electricity and petroleum (heating oil) use holds relatively steady, the share of natural gas falls over time. These efficiency improvements represent a 15% decline in energy use over 2010 Policy Case levels by 2030, and a more than 30% decline over 2030 BAU Case levels.

Table 7 lists the changes in capital costs, annual costs, energy use, and CO_2 emissions for natural gas and oil use that result from these efficiency improvements. Equipment and annual costs increase for commercial users, but to a much lesser extent for residential users. For both residential and commercial users, energy use and natural gas and oil-related CO_2 emissions decline significantly over 2010-2030.

Figure 19. Residential and Commercial Energy Use, Policy Case

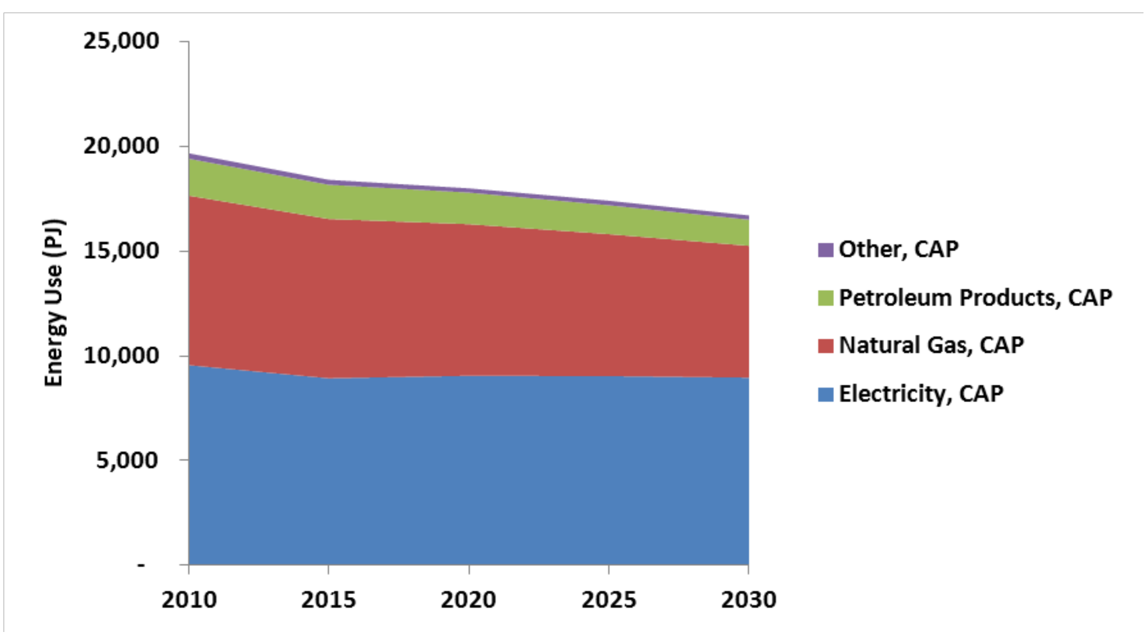


Table 7. Total Change in Residential and Commercial Capital Costs, Annual Costs, Energy Use, and Emissions Relative to BAU, 2010-2030

	Equipment Costs	Annual Costs	Energy Use		Gas and Oil CO_2 Emissions
			Electricity	Gas and Oil	
Residential	3%	n/a	-28%	-31%	-33%
Commercial	31%	25%	-33%	-25%	-25%

Notes: CO_2 emissions here do not include emissions from electricity generation, which are accounted for endogenously in EAGLE. The difference between changes in energy use and emissions in the Residential sector are the result of proportionately larger reductions in oil use relative to natural gas. MARKAL does not include annual (e.g., maintenance) costs for residential buildings, appliances, and electronics.

As with other sectors, the values in

Table 7 are adjusted to reflect changes in unit, rather than total, costs, energy use, and emissions. In MARKAL, price-induced conservation reduces both levels of energy consumption and investments in energy using equipment, and it is important to control for the effects of conservation to ensure that changing costs reflect changing unit costs.[14]

Sequestration and Offsets

Sequestration and offsets include four major categories: agricultural (mostly soil carbon sequestration), livestock (mostly manure management), forestry (mostly changes in forest management), and landfills (landfill gas capture and generation). Table 8 shows the abatement potential for domestic sequestration and offsets, aggregated by region.

Table 8. Annual Abatement Potential for Sequestration and Offsets by Region, Year 2030

Region	Abatement Potential ($MMTCO_2$)

[14] For both residential and commercial efficiency, the percentage change in investment is calculated using the total change in cumulative investment divided by total change in cumulative energy use, or $\frac{\Delta INV}{INV_{BAU}} = \frac{\sum_t INV_{POL}}{\sum_t EN_{POL}} / \frac{\sum_t INV_{BAU}}{\sum_t EN_{BAU}} - 1$, where INV is investment and EN is energy use. The percentage change in annual costs for commercial users is calculated using year 2030 total annual costs for the Policy and BAU Cases, divided by 2030 total energy use, or $\frac{\Delta AC}{AC_{BAU}} = \frac{AC_{POL,2030}}{EN_{POL,2030}} / \frac{AC_{BAU,2030}}{EN_{BAU,2030}} - 1$, where AC is total annual costs, EN is energy use, and the subscripts denote the year of the two variables. Percentage changes in unit energy consumption and CO_2 emissions are also calculated using this approach.

	Agriculture	Livestock	Forestry	Landfill	Total
Midwest	4	15	16	20	55
Northeast	1	3	12	7	26
Plains	3	13	7	25	61
South	2	9	30	24	72
West	3	13	58	25	137
TOTALS	12	4	236	100	351

Abatement costs for sequestration and offsets are not appreciably different among states or regions. National abatement costs are shown in Table 9.

Table 9. National Abatement Costs for Sequestration and Offsets, 2030

Sector	Abatement Cost ($/t$CO_2$)
Agriculture	$14.93
Livestock	$14.72
Forestry	$10.55
Landfill	$11.89
AVERAGE	$11.51

In addition to these modeled results, we also include a 15% productivity enhancement in the oil and gas sector resulting from improvements in enhanced oil recovery.

Methods of State Allocation

MARKAL results can be separated into those that are expected to be more uniform across states and those that are more state or region dependent. For instance, the U.S. vehicle market is relatively homogeneous, so differences in vehicle technologies between states are expected to be relatively small. Alternatively, because different states have different access to energy resources and distribution is constrained (by transmission lines, in this case), states will face significantly different cost curves as they look to decarbonize their electricity generation.

For Transportation and Residential and Commercial Efficiency, we assume that technologies are uniform across states and that the percentage changes in cost, energy use, and emissions that result from regulatory policies are the same across states. Differences in purchase and use behavior for transportation and residential and commercial energy use come from differences among states as outlined by their respective social accounting matrices (SAMs). Alternatively, both Electricity Generation and Sequestration and Offsets are constrained by resource endowments and access.

To capture this state-level heterogeneity in EAGLE, we allocate the MARKAL results for both across states.

To allocate national MARKAL results for electricity generation across states we first allocate these results across an expanded set of the North American Electricity Reliability Corporation (NERC) regions[15] and Hawaii and Alaska using regional shares of national generation from a NEMS modeling run supported by NRDC. This has the desired effect of creating regional clusters of generation resources. Seven regions (MAPP, ERCOT, CA, NWP, SERC, MAIN, and NE) account for 92% of wind generation, for instance. Seventy-three percent of CCS capacity is in five regions, with the Northwest (NWP) and Southwest (RA) regions (both part of "West" in

Table 5 and

Table 7) accounting for more than 40%.

The expanded set of NERC regions does not map neatly onto states. We allocate states to these regions on the basis of national census data, where each state comprises a percentage of one or more regions. In this way, national results are mapped onto states through a two-stage process in which results are first allocated to regions and then to states, and percentage changes in cost, fuel use, and emissions variables for states are a weighted average of regional results.

Sequestration and offset potential was similarly regionalized based on USDA state-level data on agricultural output and McKinsey regional estimates for forest management, afforestation, agricultural soil N_2O, and soil carbon sequestration.

Methods of CGE Integration

We integrate results from MARKAL into the EAGLE model by adjusting its underlying economic database, or social accounting matrix (SAM), to incorporate the changes in energy and other technologies implied by the MARKAL results. By changing SAM entries (i.e., a column representing an expenditure, and a row representing a marketed output), we make adjustments to the intermediate and final demand portions of the SAM at a sectoral level. For example, if household consumption of electricity decreases

[15] The regions used include ECAR, ERCOT, MAAC, MAIN, MAPP, NY, NE, FL, SERC, SPP, NWP, RA, and CA.

through efficiency measures (as in Table 7), we adjust the household column's expenditure on the electricity row.

Because it is a constrained optimization model, MARKAL tends to produce "bursty" results.I Investment patterns in adjacent periods may be completely different. This volatility can significantly affect the mechanics of CGE models, and to provide more stability for EAGLE we linearize the MARKAL results so that they are smooth over time. Because the terminal period in this analysis is 2020, we use linearized values for 2020 from the MARKAL results as EAGLE inputs, as noted above,.

7. Overview of the Economic Forecasting Model

The EAGLE model is a national, multi-state/region,[16] multi-sector, dynamic applied general equilibrium model. It is currently implemented in the GAMS[17] programming language and the model specification is virtually free of references to specific dimensions (state/region, sector, or time). The model is accompanied by an aggregation facility, which is used to aggregate the extensive IMPLAN dataset to a more tractable scale for simulation purposes. The output of the aggregation facility is the primary input for the model. The remainder of this section outlines briefly the main characteristics of supply and demand and the dynamics, the policy instruments, and the GHG emissions inventory of the model.

General Model Components

General model components include: Production, consumption and closure, trade, and prices. The approach to each of these taken in the EAGLE model is described below.

Production

All sectors are assumed to operate under constant returns to scale and cost optimization. Production in each sector is modeled by a series of nested constant elasticity of substitution (CES) production functions, which are intended to represent the different substitution and complementarity relations across inputs in each sector. These inputs include intermediate inputs that generate the underlying input/output table, as well as factor inputs representing value added.

The model includes adjustment rigidities. An important feature is the distinction between old and new capital goods. In addition, capital is assumed to be partially mobile, reflecting differences in the marketability of capital goods across sectors.[18]

Once the optimal combination of inputs is determined, sectoral output prices are calculated assuming competitive supply (zero-profit) conditions in all markets. A fixed markup has been introduced in the model so that the impacts of greater competitiveness may be assessed.

[16] In its primary form, EAGLE disaggregates all 50 US states, but for individual assessments, these may be aggregated.
[17] See www.gams.com.
[18] For simplicity, it is assumed that old capital goods supplied in second-hand markets and new capital goods are homogeneous. This formulation makes it possible to introduce downward rigidities in the adjustment of capital without increasing excessively the value of the equilibrium price to be determined by the model (see Fullerton, 1983).

Consumption and the Closure Rule

All income generated by economic activity is assumed to be distributed to consumers. A single representative consumer allocates optimally his/her disposable income among consumer goods and saving. The consumption/saving decision is completely static: saving is treated as a "good" and its amount is determined simultaneously with the demands for the other goods, the price of saving being set arbitrarily equal to the average price of consumer goods.[19]

Government collects income taxes, indirect taxes on intermediate and final consumption, production taxes, tariffs, and export taxes/subsidies. Aggregate government expenditures are linked to changes in real GDP. The real government deficit is exogenous. Closure therefore implies that some fiscal instrument is endogenous in order to achieve a given government deficit. The standard fiscal closure rule is that the marginal income tax rate adjusts to maintain a given government fiscal stance. For example, a reduction or elimination of tariff rates is compensated by an increase in household direct taxation, *ceteris paribus*.

Each state/region runs a current-account surplus (deficit), which is fixed (in terms of the model numéraire). The counterpart of these imbalances is a net inflow (outflow) of capital, which is added to (subtracted from) the domestic flow of saving. In each period, the model equates gross investment to net saving (equal to the sum of saving by households, the net budget position of the government and foreign capital inflows). This particular closure rule implies that investment is driven by saving.

Trade

The trade block of the EAGLE model is based on two market perspectives: domestic (DOM) and international trade between the state's/region's economy and the rest of the world (ROW). Because complete data on US interstate bilateral trade do not exist, we follow a convention established by Rutherford (2002), assuming all states export to and import from a single domestic market. The basic assumption in EAGLE is that imports originating in different regions are imperfect substitutes. Therefore in each region, total import demand for each good is allocated across two representative partners (DOM and ROW) according to the relationship between their export prices. This specification of imports—commonly referred to as the Armington[20] specification—implies that each state/region faces a downward-sloping demand curve for its exports. The Armington specification is implemented using two constant-elasticity-of-subsitution (CES) nests. At

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[19] The demand system used in EAGLE is a version of the Extended Linear Expenditure System (ELES), which was first developed by Lluch (1973). The formulation of the ELES used in EAGLE is based on atemporal maximization—see Howe (1975). In this formulation, the marginal propensity to save out of supernumerary income is constant and independent of the rate of reproduction of capital.

[20] See Armington (1969).

the top nest, domestic agents choose the optimal combination of the domestic good and an aggregate import good consistent with the agent's preference function. At the second nest, agents optimally allocate demand for the aggregate import good across the two trading partners (DOM and ROW).[21]

The bilateral supply of exports is specified in parallel fashion using a nesting of constant-elasticity-of-transformation (CET) functions. At the top nest, domestic suppliers optimally allocate aggregate supply across the intra-state/regional market and the aggregate export market. At the second nest, aggregate export supply is optimally allocated across the two representative trading regions (DOM and ROW) as a function of relative prices.

Trade measures are specific to states/regions, although in practice they will differ only at the national level, including both export and import taxes/subsidies. Trade and transport margins are also included. Therefore world prices reflect the difference between FOB and CIF pricing.

Prices

The EAGLE model is fully homogeneous in prices; only relative prices are solved for. The price of a single good, or of a basket of goods, is arbitrarily chosen as the anchor to the price system. The price (index) of manufacturing exports has been chosen as the numéraire, and is set to 1 in the base year and all subsequent years. From the point of view of the model specification this has an impact on the evaluation of international investment flows. They are evaluated with respect to the price of the numéraire good. Therefore, one way to interpret the foreign investment flows is as the quantity of foreign saving which will buy the average bundle of manufacturing exports.

Dynamic Features and Calibration

The EAGLE model has a simple recursive dynamic structure as agents are assumed to be myopic and to base their decisions on static expectations about prices and quantities. Dynamics in EAGLE originate from three sources: (i) accumulation of productive capital; (ii) the putty/semi-putty specification of technology; and (iii) productivity changes.[22]

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[21] The GTAP data set allows each agent of the economy to be an Armington agent, i.e. each column of demand in the input/output matrix is disaggregated by domestic and import demand. (The allocation of imports across regions can only be done at the national level). For the sake of space and computing time, the standard model specification adds up Armington demand across domestic agents and the Armington decomposition between domestic and aggregate import demand is done at the national level, not at the individual agent level.

[22] Unlike some previous versions of the model, this version of the model does not have a resource depletion module for fossil fuels.

Capital Accumulation

In the aggregate, the basic capital accumulation function equates the current capital stock to the depreciated stock inherited from the previous period plus gross investment. However, at the sectoral level, the specific accumulation functions may differ because the demand for (old and new) capital can be less than the depreciated stock of old capital. In this case, the sector contracts over time by releasing old capital goods. Consequently, in each period, the new capital vintage available to expanding industries is equal to the sum of disinvested capital in contracting industries plus total saving generated by the economy, consistent with the closure rule of the model.

The Putty/Semi-putty Specification

The substitution possibilities among production factors are assumed to be higher with the new than with the old capital vintages—technology has a putty/semi-putty specification. Hence, when a shock to relative prices occurs (e.g. tariff removal), the demands for production factors adjust gradually to the long-run optimum because the substitution effects are delayed over time. The adjustment path depends on the values of the short-run elasticities of substitution and the replacement rate of capital. As the replacement rate determines the pace at which new vintages are installed, a larger volume of new investment means a greater possibility of achieving the long-run total amount of substitution among production factors.

Dynamic calibration

The model is calibrated on exogenous growth rates of population, GDP per capita, and an autonomous energy efficiency improvement in energy use (known as the AEEI factor). There are various alternatives for calibrating the key growth parameters in the baseline scenario. The model does need some unique instrument per state/region to achieve a desired per capita GDP growth. The current strategy has three components. First, agricultural productivity is fixed in the baseline using results from recent empirical studies (footnote for particular studies). Second, productivity in manufacturing and services is divided into three components. The first component is a uniform shifter. This component is in essence the instrument used to achieve the given per capita GDP growth target. The second component is a sectoral shifter which permits constant deviations across sectors, for example imposing manufacturing productivity some 2 percent higher than in services. The third component is a shifter determined by sectoral openness. This latter shifter is sensitive to the sectoral export/output ratio. The degree of sensitivity is measured by an elasticity.[23]

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[23] An alternative strategy is to calibrate the dynamics in each region by imposing the assumption of a **balanced growth** path. This implies that capital/labor ratio (in efficiency units) is held constant.

GHG Emissions Inventory

The EAGLE model is calibrated to a state-by-state, sectoral greenhouse gas (GHG) emissions inventory estimated by the authors for this purpose. Basic GHG emissions inventories are not yet available at a state level,[24] much less at a sectoral level, in the U.S. In constructing an emissions inventory for the model we use a number of data sources and assumptions, which are detailed in the full model documentation. To our knowledge, this is the first state-by-state, detailed sectoral emissions inventory for the U.S.

Data Sources

The U.S. Energy Information Administration (EIA) maintains detailed data on fossil fuel CO_2 emissions, with CO_2 emissions estimated from both national and state-level fossil fuel use data. The U.S. Environmental Protection Agency (EPA) maintains a more comprehensive national inventory that covers all GHG emissions, but lacks detail at a state and sectoral level. In building the CO_2 portion of the EAGLE GHG inventory we make use of both EIA and EPA data. The non-CO_2 portion relies exclusively on EPA estimates.

Sectoral Allocation of GHG Emissions

The EAGLE GHG emissions inventory is based on the structure of the social accounting matrix (SAM) that underpins the computable general equilbrium (CGE) model. Reflecting this structure, the inventory is composed of a series of 1 x (n + k) vectors, where n is the number of economic sectors (e.g., "Electricity"), k is the number of institutions (e.g., "Household 1"), and the row vector sectors are sources of GHG emissions (e.g., "Coal").

We allocate CO_2 emissions among sectors and institutions based on the point of actual emissions. In a SAM framework, this is equivalent to column sectors "consuming" CO_2 emissions as inputs from the source row sectors. This means, for instance, that CO_2 emissions from generating electricity from coal are allocated to the Electricity sector entry of the Coal sector row vector. Alternatively, CO_2 emissions from gasoline consumption, which occur at the point of actual energy use, are allocated to households' and industry's consumption of petroleum products.

For CH_4 and N_2O, the majority of emissions occur at the point of production rather than the point of use. To account for this, for most CH_4 and N_2O sources we allocate emissions on the basis of sector output rather than sector inputs.

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[24] See the EPA's State Greenhouse Gas Inventories, http://www.epa.gov/climatechange/emissions/state_ghginventories.html.

8. Frontiers in Technology and Policy

Technological advances will have a significant bearing on the benefits and costs of ACES compliance. Moreover, how technologies are developed and deployed will ultimately determine their cost-effectiveness, which underscores the importance of policy in fostering and guiding shifts in technology. Innovations relevant to ACES will thus span a wide range of discoveries, processes, and activities, from the development of new materials for solar photovoltaic modules to the design and implementation of programs that encourage adoption of energy efficient appliances.

A wide range of technology and policy innovations might be expected under ACES. The following three sections focus on three technology-policy issues of interest to this report:

- *Energy Efficiency in the U.S.: Potential, Cost, and Barriers* examines the potential for energy efficiency as a cost-effective energy source;
- *A Low Carbon Fuel Standard: An Effective Strategy to Promote Biofuels and GHG Reduction?* examines the design and implementation of a low carbon fuel standard (LCFS); and
- *American Clean Energy Security (ACES) Act Forestry Provisions and Implications* examines the opportunities and challenges to optimal use of forests as a carbon resource under ACES.

Energy efficiency plays a central role in the EAGLE results, both as a means to offset the higher cost of energy under ACES, and as a structural shift to more labor-intensive expenditure patterns. By most accounts, energy efficiency potential in the U.S. is vast, though important financial, institutional, and cultural barriers have kept the implementation of energy efficiency far below its potential. This first section reviews recent studies that estimate the U.S. energy efficiency resource, focusing on both potential and cost.

As described in the model documentation, shifts in transportation fuels are not a significant driver of EAGLE model results. Innovations in both fuels and policies could make transportation fuels a much more significant source of emission reductions, however. In particular, an LCFS that stimulates innovation in low carbon (direct and indirect), low cost biofuels could mean substantial reductions in U.S. gasoline consumption and associated GHG emissions. This second section examines key issues in the design of an LCFS.

U.S. forests will play an important role under ACES, both as a source of renewable energy and as a sink for atmospheric carbon. Forest biomass could provide a significant feedstock for electricity generation or ethanol production, and expanding forest acreage or improvements in forest management could increase the amount of carbon sequestered in the U.S. The final section provides an overview of how forest resources are currently included in ACES, the role forests might play in a national climate program, and the challenges for regulating forest inclusion in a cap and trade system.

Energy Efficiency in the U.S.: Potential, Cost, and Barriers

There is significant potential for improving energy efficiency in the U.S., to such an extent that energy efficiency has been called "our country's largest energy source" (Nadel, 2006). In the context of climate policy, energy efficiency may provide a low cost option for reducing GHG emissions. While there is a consensus that energy efficiency can be improved, there is debate over how much energy can be saved and at what cost.

This section provides an overview of six major recent studies on energy efficiency by McKinsey and Company, Lawrence Berkeley National Lab (LBNL), the National Academy of Engineering (NAE), the National Research Council (NRC), the American Council for an Energy Efficient Economy (ACEEE), and the Electric Power Research Institute (EPRI). For each study, we examine estimates of physical potential, costs, net savings, and other benefits. In addition, we discuss barriers to energy efficiency and ways that these barriers might be overcome.

McKinsey and Company

In 2009, McKinsey and Company published an extensive summary on potential non-transportation energy efficiency improvements. The report estimates that end-use energy consumption by 2020 might be reduced by 9.1 quadrillion Btus (quads), or about 23 percent of the business-as-usual (BAU) demand projected by the EIA (Granade et al., 2009).

McKinsey's primary assumptions were a price of zero for carbon, industrial retail rates for the value of energy (a slightly conservative value), a 7 percent discount rate, and defining net present value (NPV)-positive "to include direct energy, operating, and maintenance cost savings over the equipment's useful life, net of equipment and installation costs, regardless of who invests in the efficiency measure or receives the benefits."

McKinsey estimates that with energy efficiency measures, the residential sector may save 3.16 of the estimated 11.4 quads demanded by 2020. Within the residential sector, McKinsey looks at "electrical devices and small appliances," as well as "lighting and major appliances." By 2020, these two categories have the potential for an annual energy savings of 0.59 and 0.3 quads, respectively, valued at $11 billion and $6 billion.

The present values (PVs) of the upfront investment of the small and large appliance category are $3 billion and $11 billion, and the PV of energy savings is $65 billion and $42 billion.

The present value of upfront investments for overall energy efficiency in the residential sector is $229 billion. The PV of energy savings for these measures is $395 billion. The annual energy savings by 2020 is estimated at $41 billion. The commercial sector can save up to 2.29 quads by 2020, down from 8.01 quads of estimated demand. This savings would come at an investment of $125 billion (PV of savings of $290) and an annual energy savings by 2020 of $37 billion.

By 2020, industrial activities are predicted to consume 51 percent of baseline end-use energy. BAU industrial energy use in 2020 is predicted to be 20.5 quads, with a 3.65-quad saving potential. The PV of upfront investment for industrial activities is $113 billion, with a PV of energy savings of $442 billion. The annual energy savings by 2020 is estimated at $47 billion.

In total, McKinsey found a gross energy savings of over $1.2 trillion, with a present value initial upfront gross investment of $520 billion, not including program costs. Energy efficiency investments would create 600,000 to 900,000 jobs between 2009 and 2020. McKinsey estimates that between 500,000 and 750,000 of these jobs would be either direct, indirect, or induced jobs from the labor-intensive investments, and another 100,000 or more ongoing jobs would result from the regulation and upkeep of these investments.

Lawrence Berkeley National Lab

US Building-Sector Energy Efficiency Potential, a Lawrence Berkeley National Laboratory (LBNL) report, estimated that at a rate of 2.7¢/ kW (with all values in 2007 dollars) about one-third of electricity use could be saved from the 2030 projection (Brown et al., 2008). A similar proportion of natural gas could be saved at a cost of between 2.5 and 6.9 dollars per million Btu. This would result in an annual energy savings of almost $170 billion by 2030, requiring an estimated cumulative investment of $440 billion between 2010 and 2030. LBNL used a 7 percent discount rate when calculating which technologies were cost-effective. Of the estimated 1,896 TWh and 5.47 quads demanded by the residential sector in 2030, 567 TWh and 1.51 quads could be saved. In the commercial sector, 705 of the estimated 2,062 TWh and 1.51 of an estimated 4.36 quads could be saved.

National Academy of Engineering

In a 2009 report, the National Academy of Engineering (NAE) noted that other countries at similar income levels use much less energy per capita than in the U.S. (Lave, 2009).

Japan, Denmark, France and Germany each have per-capita energy use rates of around one-half of America's. Energy efficiency is believed to account for one half of this difference, and the other is believed to result from other factors such as lifestyle. While the United States is markedly different from the other countries in terms of climate, size, transportation infrastructure, and demographics, the comparisons suggest that energy use in the U.S. could be greatly reduced with energy efficiency and reduced even further with lifestyle changes.

The report cites an estimate by the Intergovernmental Working Group on Energy-Efficient and Clean Energy Technologies that by 2020, energy use could be reduced by 16.6 percent of 2000 energy use. When adapted to current EIA projections, this equates to a 5.7 quad savings, with an additional 2 quad potential increase if combined heat and power are implemented. These estimates only include technologies considered cost-effective, or in this case those with an internal rate of return of at least 10 percent.

The NAE used the same efficiency supply curves generated by the LBNL report, but suggested that because the curves address different components of buildings individually, they underestimate the potential savings gained from an integrated approach. The report gives the example that "switching from incandescent lamps to CFLs not only reduces energy use for lighting, but also reduces the air conditioning load in commercial buildings, allowing for downsizing of equipment and reducing the amount of energy required to cool the building."

National Research Council

As part of their ongoing *America's Energy Future* project, the National Research Council's (NRC's) report *Technology and Transformation* addresses potential gains in energy efficiency. The NRC found that a timely initiation of technology in the transportation, industrial, and buildings sectors could reduce annual energy use by 15-17 quads (15 percent) under the EIA's BAU 2020 prediction. The reduction could be as large as 32-35 quads (30 percent) by 2030 (NRC, 2009).

The NRC found the greatest proportionate potential for savings was in the buildings sector, or approximately 840 TWh of electricity per year by 2020. This more than compensates for the EIA's projected increase in electricity demand of about 500 TWh. By 2030, the savings could grow to 1,300 TWh per year, once again surpassing the estimated demand increase of 900 TWh. The NRC estimates that an annual 2.4 quad savings of natural gas would be possible by 2020, rising to 3 quads by 2030.

In the residential sector, a cumulative investment of $440 billion in existing technology between 2010 and 2030 could produce an annual savings of $170 billion in reduced energy costs. The cumulative investment includes the full costs of new "add-on" capital investments (attic insulation) as well as incremental costs of energy-efficient over standard technology (a high-efficiency air conditioning system), but does not take into account any program costs associated with motivating, supporting, or requiring any improvements. Only measures achievable at a lower than current cost per energy unit (NRC used 10.7¢/KWh and 9.7¢/KWh for the residential and commercial sectors) were included in the estimate.

Opportunities also exist for industry and transportation: by 2020, the industrial sector could shave 4.9-7.7 quads of annual demand from the EIA estimate (a 14-22 percent decrease). While the EIA already predicts a 30 percent decrease in 2020 fuel consumption from 2008, the NRC estimates that further adoption and exploration of technology could save an additional 1.4 million barrels a day by 2020. By 2035, 5.6 million barrels might be saved per day.

American Council for an Energy-Efficient Economy

A 2009 report by the American Council for an Energy Efficient Economy (ACEEE) examines the potential energy efficiency gains from ACES (Gold et al., 2009). The ACEEE then expands upon the act to demonstrate how even greater efficiency and thus greater savings can be achieved. ACEEE evaluates buildings (including industrial) and transportation. In this report, it is not the total realizable potential savings through energy efficiency that is being examined but an estimate of the possible savings gained through ACES, with some small additions to further explore potential efficiency. ACEEE estimates that, by 2020, a net annual consumer savings of $283 billion could be realized, growing to $832 billion by 2030. This savings would greatly outweigh the projected increase in energy prices and costs that come with managing the cap and trade system.

By 2020, ACEEE estimates that ACES will achieve a 4.9-quad reduction to projected national energy consumption, rising to 7.66 quads by 2030. With their recommended improvements to ACES, these numbers could rise to over 7 quads and nearly 16 quads by 2020 and 2030. These numbers represent a 7.5 and 14.5 percent respective reduction from 2020 and 2030 projected energy demand. ACEEE estimates that with their slight modifications to ACES' energy efficiency provisions, 569,200 jobs could be created by 2020; by 2030, this number could rise to 1,380,700.

Electric Power Research Institute

The Electric Power Research Institute (EPRI) estimates electricity consumption from 2008 to 2030 to grow at an annual rate of 1.07% for a total increase of 26%, or 4,696 TWh (Siddiqui, 2009). EPRI's January 2009 report, *Assessment of Achievable Potential from Energy Efficiency and Demand Response Programs in the U.S. (2010-2030)*, estimates that energy efficiency programs can trim this annual growth rate to 0.83%. Under optimal conditions, this rate could be further decreased to 0.68% per year. For the year 2030, this equates to a reduction of between 236 billion to 382 TWh. EPRI estimates these gains to come at a total gross cost of between $25-63 billion by 2030.

Overcoming Barriers

Nearly all of the available literature recommends that more funds be invested into research, development, and applications of energy efficient technologies and that stricter regulations, such as for fuel economy in automobiles, be set. Many studies also provide specific strategies for improving energy efficiency. The American Physical Society (APS) recommends that a 20 percent reduction in vehicle weight (by using high-strength steel, aluminum, and composite materials) could result in a 14 percent fuel economy gain while simultaneously decreasing vehicle fatalities and injuries (APS, 2008).

The McKinsey study suggests both mandatory and voluntary appliance standards, noting that between 1990 and 2000 these standards were responsible for consumer savings of about $50 billion (Granade et al., 2009). The study also notes the importance of "systematic, periodic reviews," to ensure that the standards remain current. Monetary incentives and rebates also are suggested as effective ways to motivate energy-efficient choices.

The NAE suggests that more demanding environmental regulations could also have a positive impact on efficiency. Because emissions often consist of wasted raw materials and fuel, regulating emissions could improve efficiency in the use of these inputs (Lave, 2009). The NAE report also notes that durable goods such as furnaces and air conditioners are an important part of energy efficiency calculations. Since they are replaced infrequently, it is extremely important that they are replaced with energy-efficient models when the time eventually comes.

A Low Carbon Fuel Standard: An Effective Strategy to Promote Biofuels and GHG Reduction?[25]

The transportation sector is the source of about 33% of the greenhouse gas (GHG) emissions in the US, with gasoline use accounting for the largest proportion of these emissions. A range of options exist for abating GHG emissions from the transportation sector. These include reducing demand for vehicle miles travelled (VMT), increasing the efficiency of vehicles, and reducing the GHG intensity of fuels with existing fuels and vehicle technology. In other words, these abatement strategies involve reduction in fuel consumption with existing vehicle and fuel technology; technological innovation that leads to more fuel efficient vehicles or electric/hybrid vehicles; and reductions in the

[25] This section was authored by Madhu Khanna.

GHG intensity of fuels that can be used with conventional vehicles. This last item can be achieved through blending low carbon biofuels with gasoline and biodiesel with diesel. Currently available biofuels are primarily from corn in the US and sugarcane in Brazil. Technologies for next generation biofuels from cellulosic feedstocks, such as perennial grasses and crop residues, are currently being developed for commercial production. The various options for biofuels differ considerably in their lifecycle GHG emissions and in their current and anticipated costs of production.

GHG emissions are a global public problem, and so far there are no market incentives to adopt costly abatement methods in the absence of regulations or policy incentives that encourage consumers and producers to internalize this externality. Potential policies to achieve reductions in GHG emissions include performance standards for vehicles and/or fuels, such as the Corporate Average Fuel Economy (CAFE) Standards and the Low Carbon Fuel Standard (LCFS), carbon tax or cap-and-trade policy that provides market-based incentives for abatement through carbon pricing, and policies that encourage specific technologies, such as the Renewable Fuel Standard (RFS) that mandates blending biofuels with gasoline and offers biofuel tax credits to lower the costs of biofuels for consumers. California has implemented an LCFS requiring a 10% reduction in GHG intensity of the statewide mix of transportation fuels by 2020 relative to the level in 2010. Other states in the US are also considering an LCFS, including 11 Northeastern and Mid-Atlantic States and several Midwestern states.

An LCFS at the national level was included in the March 31 draft of the Waxman-Markey climate change bill but was subsequently dropped. ACES includes an Open Fuel Standard that may require manufacturers of automobiles to produce a minimum percentage of ‘fuel choice enabling vehicles,’ defined as light duty vehicles that can run on E-85, biodiesel or M85 (85% methanol). The bill also establishes a cap-and-trade program and specifies mandatory emissions limits that decrease over time, requiring a 17% reduction in GHG emissions by 2020 and an 83% reduction by 2050 relative to 2005 levels. Power plants, fossil fuel producers and other capped sectors would need to obtain and submit emissions allowances each year. The cap-and-trade program would cover 87% of the GHG emissions in the US and exclude bioenergy production from renewable biomass, agriculture, forestry and other land management activities. ACES provides incentives to these sectors to reduce their carbon emissions by allowing them to get credits for reducing emissions and then sell them as carbon offsets to the capped sectors. Carbon offsets could be generated, for example, through methane capture at livestock operations, or through sequestration of carbon in soils or vegetation with conservation tillage and afforestation. A number of other initiatives would also encourage the use of bioenergy and store carbon, including the Efficiency and Renewable Energy Standard that would require utilities to derive 6% of energy production from renewable sources by 2012 and 20% by 2021.

This section discusses the design of an LCFS policy, challenges in its implementation, and its environmental- and cost-effectiveness as compared to a cap-and-trade policy that would result in an explicit price on carbon. The extent to which an LCFS encourages fuel conservation and overall reduction in GHG emissions from the transportation sector depends on its design and other policies that accompany it. Such a performance standard could be defined in several ways: by measuring GHG emissions per unit of historical fuel energy; GHG emissions per mile; or GHG emissions per unit of motive (at-the-wheel) energy. It could also be accompanied by technology-based policies, such as biofuel tax credits and the Renewable Fuel Standard (RFS), or by more broad-based policies such as a carbon cap-and-trade applied to the energy-intensive sectors. The alternative definitions of the LCFS and the policies accompanying it have implications for the environmental- and cost-effectiveness of the policy, based on accompanying changes in land use and on their effects on food and fuel prices.

1. Design of an LCFS

The LCFS is a performance standard that seeks to reduce the GHG emissions per unit of fuel energy over a period of time compared to an established baseline. Reduction in emissions could be achieved by blending low carbon fuels, such as ethanol, with gasoline or switching to flex-fuel vehicles or vehicles powered by natural gas, hydrogen-based fuel cells or electricity. An LCFS is neutral to vehicle and fuel technology and seeks to encourage the use of fuels that have lower carbon content than gasoline and the use of vehicles powered by those fuels. Its implementation is based on the lifecycle GHG emissions from various fuels that determine their GHG intensity relative to gasoline.

The GHG emissions of a fuel include those in the form of carbon dioxide (CO_2), methane, nitrous oxide and other GHG contributors. These are all converted to a carbon potential based on their ability to contribute to global warming. The carbon intensity of fuel is expressed in grams of CO_2 equivalent per megajoule (gCO_2e/MJ). The GHG intensity of a fuel is based on an estimation of these emissions generated over the life cycle of the fuel from well-to-wheels and includes production, transportation and combustion in the vehicle. The GHG intensity of biofuels depends on the feedstock used to produce the fuel, the method of production of that feedstock (the efficiency of the conversion process), and on the means of transporting the biofuel from the refinery to the retail distributors.

The production of crops for biofuels displaces other uses of the land either directly or indirectly. Bioenergy crop production that replaces previous crop production may involve direct land use changes that can lead to changes in carbon emissions and soil carbon sequestration. For example, the production of perennial grasses on cropland previously used to grow corn will lead to GHG savings, since these grasses require less carbon-intensive inputs like fertilizers and sequester more soil carbon than corn. Bioenergy crop production also contributes indirectly to land use change. The use of land for biofuel crops raises the price of agricultural commodities, creating incentives to convert non-agricultural land in the US and other countries into farmland. These indirect land use changes lead to the release of carbon sequestered in soils and vegetation that come from clearing trees, tilling pastures, and cultivating converted land (which uses inputs like fertilizer). While the estimation of emissions due to direct land use changes is more straightforward, those due to indirect land use changes are more complicated and subject to uncertainty. It requires the use of simulation models that forecast the implications of biofuel production on crop prices, non-cropland acreage and carbon stocks on that acreage. GHG emissions due to indirect land use changes have been shown to be potentially large enough to offset a part or all of the GHG emissions reduced directly by using biofuels to displace gasoline (Searchinger et al., 2008). There is also considerable controversy about the validity of including emissions due to indirect land use changes in the life-cycle GHG intensity of biofuels.

The LCFS in California measures GHG emissions intensity based on the emissions per unit of energy in the fuel used and on the fuel economy of the vehicle. The estimate of emissions intensity controls for differences in the energy economy of the vehicle and thus the difference in the amount of energy required to travel a given distance. Electric vehicles are expected to have higher emissions per unit of energy delivered to the vehicle but lower emissions per mile since they have higher energy economy. The average fuel carbon intensity (AFCI) in gCO_2e/MJ is then calculated as follows:

$$AFCI = \frac{\sum_{i}^{n} E_i C_i}{\sum_{i}^{n} E_i EER_i}$$

where E_i is the energy of fuel i in MJ per gallon; C_i is the carbon intensity of fuel i in gCO_2e/MJ and EER_i is the ratio of the miles driven per unit of energy for an alternative fuel i (vehicle) to the miles driven per unit energy for a conventional fuel vehicle (Yeh et al., 2009).

The LCFS in California requires providers of transportation fuels to comply annually with the standard, to report all fuels sold, and to track the carbon intensity of the fuels with a system of “credits” and “deficits”. Credits are given to fuels with lower carbon intensity than the standard; deficits are given to fuels with higher carbon intensity than the standard. The volume of credits/deficits (in tons of GHG emissions) is determined based on the amount of fuel sold, the carbon intensity of the fuel and the energy economy of vehicle that converts that fuel to useable energy (CARB, 2009). To achieve compliance, the California LCFS does allow firms to trade credits with other fuel providers that have over- or under- achieved their targets as well as to bank credits for the future.

An LCFS creates incentives for each fuel provider to choose the mix of fuels that meets the LCFS at least cost. An LCFS with GHG intensity that matches current energy use acts as a tax on any fuel with a carbon intensity higher than the standard and as a subsidy on any fuel with a carbon intensity lower than the standard. Hence the LCFS gives an implicit subsidy to biofuels and creates stronger incentives to switch to the low carbon fuel than a policy which prices all fuels based on their carbon intensity and imposes an explicit tax on biofuels. The level of GHG intensity at which the LCFS is set determines the magnitude of the implicit tax and the implicit subsidy to high and low carbon fuels, respectively (Holland et al., 2007). The implicit subsidy is higher for fuels with lower carbon intensities relative to the standard. The more stringent the standard, the greater is the tax on relatively high carbon fuel and the smaller is the subsidy on the relatively low carbon fuel. The extent to which an LCFS creates incentives to substitute a low carbon fuel for a high carbon fuel will depend on its emissions intensity relative to the standard (which determines the subsidy rate) and the marginal cost of the fuel.

1.1 Alternative Designs for an LCFS

The LCFS designed by CARB (2009) measures GHG intensity relative to the motive energy delivered by the fuel to the tank or battery that powers the vehicle. This allows for differences in the fuel economy between two vehicles using different drive train technologies to be adjusted for. Other possibilities considered by CARB included GHG intensity measured relative to the energy entering the vehicle (at the tank/plug) as well as GHG intensity per vehicle mile (ITS, 2007). The former would not control for differences in miles generated per megajoule (MJ) of energy among different vehicle types (electric versus gasoline powered) while the latter measure would be extremely information intensive and require determination of the actual on-road fuel economy of each vehicle based on driver behavior and vehicle age. Holland et al. (2009) examine the effectiveness of other types of LCFSs, such as a historical baseline LCFS that ties each firm’s baseline to historical energy production or a rolling average LCFS that uses the average energy production of the preceding five years as the baseline. An LCFS could also be designed to include trading among firms that have different production costs of meeting a given standard. In this case the LCFS will hold for the market but may not hold for each individual firm or for each unit of fuel sold by a firm.

2. Impact of an LCFS on GHG Emissions

An LCFS reduces the GHG intensity of fuel consumed to mandated levels; its impact on overall GHG emissions, however, depends on the effect it has on overall fuel consumption. The latter in turn depends on the effect of the LCFS on fuel price. An LCFS does not have a direct effect on fuel prices (unlike a carbon tax or cap and trade policy); however, it can indirectly affect fuel prices by influencing the demand for fuel. To the extent that an LCFS increases demand for the low carbon fuel and reduces demand for the high carbon fuel, it raises the price of the former and lowers the price of the latter. If the demand and supply curves of the high carbon fuel are relatively flat while those of the low carbon fuel are steep, the implicit tax under an LCFS will lead to a large reduction in the consumption of the high carbon fuel and a small increase in the consumption of the low carbon fuel. In this case the LCFS could lower total fuel consumption and GHG emissions. But if the demand and supply curves of the low carbon fuel are relatively flat, the LCFS could lead to an increase in GHG emissions. Its overall impact on fuel price and on total fuel consumed is, therefore, ambiguous and depends on the design of the LCFS, the stringency of the LCFS and the slopes of the fuel supply curves. Similarly, the extent to which an LCFS creates incentives for other ways to reduce GHG emissions – such as changing vehicle technology, increasing fuel economy or conserving fuel by driving fewer vehicle miles – also depends on the design of the LCFS. Therefore, the environmental- and cost-effectiveness of an LCFS cannot be taken for granted (Holland et al., 2009). The effects of an LCFS defined using alternative metrics to define intensity on GHG emissions are shown in An LCFS using historical energy consumed as the metric would be equivalent to a carbon cap and trade policy (Holland et al., 2009). In this case, unlike the other LCFS strategies, the standard can be met at least partially by reducing output and thus it creates incentives that are identical to those of a carbon cap and trade or carbon tax policy. However, it could create incentives for a forward looking firm to increase its current production levels to make the LCFS in the future less stringent.

While environmentally desirable, an LCFS based on historical energy consumed might be difficult to implement due to disagreements about the appropriate year to use as the baseline. It could also create incentives to overproduce in anticipation of the current year being used as a baseline for the future. Holland et al. (2009) consider the effectiveness of using alternative metrics, such as a rolling average of energy consumption in the preceding five years as a baseline. They show that it is better than using current energy consumption as the baseline since it leads to a higher tax and a lower subsidy than an energy based LCFS, but they find that it is not as effective as a historical energy based LCFS.

The implications of an LCFS for GHG emissions need to be examined both in the national and international context. While an LCFS would create incentives to reduce the GHG intensity of transportation fuels, its potential to stimulate low carbon electricity generation will be limited to the extent to which electricity is used for transportation by electric cars. An LCFS would need to be complemented by other policies that create incentives for other sectors in the economy to reduce their GHG emissions. Unlike a cap-and-trade policy, an LCFS would not allow trading across sectors and would therefore be more costly than a cap-and-trade policy. An LCFS also differs from a cap-and-trade policy in that it creates unambiguous incentives for reducing imports of tar sands. To the extent that this induces a diversion of exports of tar sands to Asia (for example) instead of the US, it has the potential to offset the GHG savings achieved in the US (Difiglio, 2009). A cap-and-trade policy could allow some imports of tar sands if it is cost-effective to do so while encouraging reductions by sources with low costs of abatement, such as coal-based electricity and offsets by soil carbon sequestration in cropland.

Table 100.

Holland et al. (2009) show that an LCFS with current energy as baseline can lead to the perverse effect of increasing carbon emissions while lowering emissions intensity, if the implicit subsidy on the low carbon leads to an increase in the total fuel energy consumed. A fuel-economy LCFS (similar to the type implemented by CARB) suffers from similar limitations as an LCFS based on current energy in its ambiguous impacts on GHG emissions. An LCFS lowers demand for the high carbon fuel (by implicitly taxing it) and could lower fuel prices for consumers. Therefore, unlike a carbon tax, an LCFS could lower GHG emissions while also lowering fuel prices. However, it may not lead to overall fuel conservation since consumption of the low carbon fuel may increase more than the reduction in the consumption of the high carbon fuel.

Economic theory suggests that the least cost way to achieve a given reduction in carbon emissions is to tax all fuels based on their carbon intensity and to set a carbon price per unit emissions. By pricing emissions, a cap-and-trade policy or carbon tax policy creates incentives to use the least cost combination of various strategies to abate GHG emissions from transportation. These strategies include substituting low carbon fuels for gasoline, reducing demand for VMT, increasing vehicle fuel economy and switching to electric cars. A carbon price would create incentives throughout the energy market to switch to low carbon energy sources without choosing technology winners or losers (Fischer and Newell, 2008). If low carbon fuels are very expensive relative to gasoline, such a policy is more likely to induce a reduction in demand for gasoline and conservation than a switch to high cost but low carbon fuel such as cellulosic biofuels. A carbon price also creates incentives to continuously invest in new technologies to lower carbon emissions even beyond those that would be required to meet a performance standard, such as an LCFS. Finally, a carbon cap on all energy intensive sectors of the economy, including the electricity generating sector, would create greater incentives for reducing emissions from more carbon intensive coal than from gasoline, particularly if there exist relatively few low cost opportunities for abatement in the electricity sector.

Holland et al. (2009) show that with trading, an LCFS equates the marginal costs for each fuel across firms with different costs and can become equivalent to trading carbon permits, with choices limited to the quantity of production for the high and low carbon fuels. Then, if the two policies are designed to result in the same price of carbon, they have the same outcome on amounts of the high and low carbon fuels consumed, similar costs of abatement, and similar reductions in GHG emissions. However, trading permits under an LCFS is not similar to a carbon cap-and-trade policy. The latter imposes a quantitative upper bound on GHG emissions that is fixed. Under an LCFS policy, firms have a flexible supply of permits, which they can increase by increasing the production of low carbon fuels. While a carbon cap can be met by simply reducing production of high carbon fuels, an LCFS, even with trading, requires substitution of low carbon fuels for high carbon fuels. Moreover, an LCFS allows for higher emissions in years with higher fuel demand, since it is only regulating emissions intensity and not the overall quantity of emissions.

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Table 100: Comparison of Outcomes of an LCFS with Alternative Metrics Relative to a Carbon-Price Policy

Baseline for LCFS	Mechanism for change	Substitution of low carbon for high carbon fuels	Incentives for fuel conservation	GHG mitigation relative to unregulated level	Incentives to Innovate	Costs of Abatement
Current Fuel Energy Consumption	Tax on fuel with GHG intensity greater than LCFS and subsidy otherwise	Likely to be greater	None	Could be lower or higher	Low if LCFS is not too stringent; high otherwise	Higher
Vehicle Miles Travelled	Tax on fuel with GHG intensity greater than fuel-economy adjusted emissions rate and subsidy otherwise	Likely to be greater	None	Could be lower or higher	Higher incentives to increase vehicle fuel economy than LCFS 1	Higher
Historical-baseline Fuel Energy Consumption	Tax on all carbon-based fuels based on emissions rate	Same	Yes	Lower	Same as carbon price policy	Same
Five- year Rolling Average Baseline	Tax on high carbon fuel and either tax or subsidy otherwise	Outcomes lie in between LCFS with current energy as baseline and LCFS with historical baseline				

3. Cost-effectiveness of an LCFS

An LCFS is likely to be more expensive than a carbon tax or cap and trade policy because it creates incentives for choosing the least cost methods of GHG abatement . These include not only switching to a low carbon fuel but also reducing the consumption of all fuel. Under an LCFS a fuel producer cannot meet the standard by simply reducing its fuel production (except in the case of the historical energy LCFS). It has to choose a low carbon fuel to reduce the GHG intensity of its fuel even if that is the more costly option.

An LCFS that allows trading of permits can lead to lower costs of compliance when firms differ in their production costs (as compared to an LCFS without trading). High production cost firms can now buy carbon permits from low production cost firms; thus trading reduces (or at least cannot increase) production costs. The magnitude of cost savings depends on the extent of heterogeneity in the costs of meeting the LCFS among firms. However, even with trading an LCFS does not allow a firm to generate carbon credits by simply reducing the level of its total output, and so it is likely to result in higher costs of abatement than a cap-and-trade policy. Since the price of carbon under a cap-and-trade policy is equal to the marginal cost of abatement, this implies that the cap-and-trade policy can be expected to result in a lower price of carbon than an LCFS. This is more likely to be the case if low carbon fuels are expensive and have a steep supply curve and if the technological options for lowering GHG intensity are few.

The cost-effectiveness of an LCFS should be examined not only relative to a cap-and-trade policy that would apply to the transportation sector but relative to a cap-and-trade policy that includes all the energy producing sectors. Since coal is considerably more carbon intensive than oil, there may be a potential for achieving low cost carbon emission reductions in the electricity sector. The electricity sector is therefore likely to be able to sell permits to the transportation sector and reduce the extent to which reductions in GHG emissions are required to achieve a national GHG emissions cap. Analysis by McCarl et al. (2009) shows that the use of bioenergy for electricity generation would be a more cost-effective strategy for reducing GHG emissions than producing biofuels.

Should a cap-and trade policy of the kind in H.R. 2454 be combined with other mandates like an LCFS, an open fuel standard or renewable electricity standards? Economic theory would say no. In the best case, these standards could be redundant if the cap-and-trade policy achieves the same or more stringent outcome than mandates by the standards. In the worst case, these standards could be binding and lead to inflexibility in finding the most cost-effective options for meeting the cap (Metcalf and Reilly, 2008).

4. Incentives to Innovate with an LCFS

Carbon reduction policies can also differ in the incentives they provide to innovate and develop new, less costly technologies to reduce emissions. These technologies include next-generation biofuels that have lower carbon intensity than those currently available, vehicles that have higher fuel economy, and flex-fuel vehicles that can use varying mixes of low carbon fuels. In the short run with a relatively fixed vehicle fleet, a carbon tax could create incentives to switch to low cost biofuels while achieving the remaining reductions in GHG emissions through conservation. In the long run, a carbon tax would create incentives to develop vehicles with higher fuel economy and lower emissions per mile. A carbon tax would also create incentives for continued innovation and carbon emissions reduction. Under an LCFS, on the other hand, there is no incentive to reduce carbon intensity below the standard.

When low carbon alternatives are initially very expensive, the carbon price needs to be extremely high to induce a switch from gasoline to those fuels. Moreover, the development of low carbon technologies may require substantial upfront research and development, involving numerous uncertainties and risk. Because its effects depend on uncertain market forces, on the business cycles and on the price of fossil fuels, a carbon price that operates through the market to reward low carbon technologies may not be sufficient to provide the assurance of long term demand for those technologies. Biofuel mandates and standards such as the LCFS provide greater assurance of long term demand for low carbon technologies. The market price effects of an LCFS are implicit rather than explicit (i.e., a price at which carbon is traded in a cap-and-trade scenario). It may therefore be less likely that consumers and fuel producers will resist such a policy. If we anticipate that the cost of low carbon alternatives is likely to fall in the future with technological innovation, then learning by doing and economies of scale could provide a rationale for policies that are more technology based rather than price-based. This rationale is further strengthened if the long term goal of the policy is to develop low carbon alternatives, irrespective of their cost-effectiveness in reducing carbon emissions, in order to reduce dependence on current technologies and fossil fuels.

5. Implications of an LCFS for Biofuel Production

Biofuels offer a pragmatic alternative to meeting an LCFS in the near term with existing vehicle technology and fuel distribution infrastructure. The US produced 9 billion gallons of ethanol in 2008, primarily from corn. The share of biofuels in total fuel consumption in the US was about 3%. The share of corn being used for ethanol production in the US increased from 10% to 28% between 2004/2005 and 2007/2008, while the acreage cultivated with corn increased by 15%. (Bange, 2007). Reliance on food-based biofuels has created considerable controversy about its impact on food prices. Recent studies have also prompted skepticism about the extent to which grain-based ethanol can mitigate GHGs (Searchinger et al., 2007) when direct and indirect land use effects are considered. There are also concerns about the negative impacts of expanding corn-based biofuel production on water quality (NRC, 2007; English et al., 2008).

Ethanol can be imported from Brazil, where it is made from sugarcane, at a cost that is about 80% of the cost of producing corn ethanol. Sugarcane ethanol production in Brazil has more than doubled, from about 3 billion gallons in 2001 to over 7 billion gallons in 2007-2008 (Lasco and Khanna, 2009). Of Brazil's total land area of 850 M ha, 55% is forest, 35% is pasture land and 7% is currently under agricultural production. Sugarcane acreage in Brazil accounts for 10% of total cultivated land, 2.5% of the 264 million ha of agricultural land available and 1% of the total land available for agriculture (Fischer et al., 2008; Goldemberg, 2007). There is considerable capacity for expansion of sugarcane acreage to lands currently under pasture. The yield per acre of sugarcane in Brazil is relatively high (77 metric tons per hectare) and can produce about 1700 gallons of ethanol per hectare as compared to about 1100 gallons per hectare of corn ethanol in the US (Table 11). Goldemberg (2007) estimates that a ten-fold expansion of sugarcane production in Brazil would require an additional 30 million hectares of land in Brazil and would supply enough ethanol to replace 10% of the gasoline used in the world.

Recognition of the limits of corn ethanol to make a significant contribution to energy security in the US and to GHG reduction has led to a growing interest in other domestic sources of renewable sources such as cellulosic biofuels. Feedstocks being considered for cellulosic biofuels include crop and wood residues and dedicated energy crops (or perennial grasses) such as switchgrass and miscanthus. These energy crops have been identified as the best choices for low input bioenergy production from herbaceous crops in the U.S. because they can be grown under a wide range of growing conditions, they have high yields, and they are compatible with conventional agricultural production.

Crop residues, such as corn stover and wheat straw, can be used to produce biofuels without diverting any cropland from food or feed production. Corn stover is a by-product of corn that is currently left on the field after the corn is harvested. Corn stover yields are expected to be in the ratio of 1:1 with corn yields. Areas with high corn yields are therefore expected to have high corn stover yields. These are expected to range between 6 t dm per ha (metric tons of dry matter per hectare, with 1kg = 0.001 metric ton) and 9 t dm per ha in the Midwestern United States. The amounts that can be sustainably harvested vary between 40% and 70% depending on the tillage practice (Sheehan et al., 2004). A greater removal of residue can affect soil fertility and lead to soil erosion. It is estimated that if all available corn residue that could be sustainably harvested is used to produce biofuels, it could produce about 7 billion gallons of biofuels per year (USDA, 2005).

Switchgrass is a perennial warm season grass that is a dominant species of the remnant tall grass prairies in the U.S. Field trials have shown significant differences in yields per acre across states and across crop varieties. Average yields range from a low of 9.5 metric tons of dry matter per hectare (t DM/ha) in Kansas to 23 t DM/ha in Alabama (McLaughlin and Kszos, 2005). Yields for switchgrass obtained from crop models range from 12.2 to 22.1 t DM/ha in southern U.S. (Kiniry et al. 2005) and from 10.9 to 16.9 t DM/ha across the Midwestern states (Jain et al., 2009). Switchgrass is typically assumed to have a life of 10 years.

Miscanthus is a perennial rhizomatous grass. A sterile hybrid genotype *Miscanthus x giganteus* has been studied extensively in field trials in several European countries but is non-native to the US. Miscanthus seems to be better adopted to cool weather than switchgrass and has been observed to have a life of 20 years in field trials. Crop productivity models and field trials both indicate that it can have a relatively high yield in the Midwest, more than twice the yield of switchgrass in the Midwest and higher than miscanthus yields observed in Europe (Heaton et al., 2004; Lewandowski et al., 2003). Preliminary estimates suggest that average yields range from 30 to 50 t DM/ha across the Midwestern states. These high yields per acre lead to considerably lower costs of production per ton as compared to switchgrass. Additionally, it results in a greater volume of biofuel per acre of land and thus reduces the amount of land that would need to be diverted from row crops to meet a given level of biofuel production. Miscanthus can produce about twice as much ethanol as corn or switchgrass per unit of land and more than six times as much as corn stover (see The production of biofuels also involves changes in land use, both directly and indirectly. Direct land use change occurs when there is a change from existing land cover to a biofuel crop. This could occur if cropland is converted to perennial grasses or if conservation land is tilled for grain based biofuels. Indirect land use change occurs when the diversion of land for biofuel crops leads to an increase in crop prices which induces people to convert grasslands and forests to cropland. The Energy Independence and Security Act of 2007 specifies that indirect as well as direct GHG emissions are to be included in the life cycle assessment of biofuel emissions that meet the RFS. However, there is considerable uncertainty in measuring indirect land use change and in determining its implications for GHG emissions.

Table 1111). Miscanthus can produce at least 40% more ethanol per acre of land than the combined ethanol production from corn grain and corn stover. More details about the growing patterns of these crops, their input requirements and costs of production can be found in Khanna et al. (2008) and in Jain et al. (2009).

5.1 Potential of Biofuels to reduce GHG Intensity

Estimates of the average lifecycle GHG emissions per megajoule (g CO_2e/MJ) for the five feedstocks are given in The production of biofuels also involves changes in land use, both directly and indirectly. Direct land use change occurs when there is a change from existing land cover to a biofuel crop. This could occur if cropland is converted to perennial grasses or if conservation land is tilled for grain based biofuels. Indirect land use change occurs when the diversion of land for biofuel crops leads to an increase in crop prices which induces people to convert grasslands and forests to cropland. The Energy Independence and Security Act of 2007 specifies that indirect as well as direct GHG emissions are to be included in the life cycle assessment of biofuel emissions that meet the RFS. However, there is considerable uncertainty in measuring indirect land use change and in determining its implications for GHG emissions.

Table 1111. They show that corn ethanol (produced using a corn-soybean rotation and conventional tillage in the Midwest) can reduce GHG emissions by 36% relative to gasoline while sugarcane ethanol in Brazil can reduce emissions by 80%. Cellulosic biofuels have the potential to reduce emissions by about 90% relative to gasoline. These estimates are the above ground estimates of GHG emissions. Perennial grasses as well as the production of corn using conservation tillage also sequesters carbon in the soil. This would increase the direct GHG savings of biofuels relative to gasoline. The estimate for emissions from corn ethanol is close to the 66 gCO_2e/MJ estimated by CARB (2009b) for the Midwest. CARB (2009) estimates that the GHG emissions from corn ethanol range from 47.4 -75.1 g CO2e/MJ, depending on whether a dry mill or a wet mill technology is used and whether coal, natural gas or biomass is used to power the ethanol refinery. Other estimates of the direct life-cycle GHG savings from corn ethanol in the US range from 18% (Farrell et al. 2006) to 51% with natural gas fueled refineries (Liska et al., 2008).Our estimate of the GHG emissions from switchgrass is similar to that obtained by Farrell et al. (2006) (11g CO_2e/MJ) and by Wang et al. (2007) (13 g CO_2e/MJ). Estimates for the life cycle emissions, including the offsets of soil carbon sequestration, from switchgrass field trials in Nebraska and in South and North Dakota by Schmer et al. (2008) range from -5 to 15 gCO_2/MJ. Our estimate for the GHG emissions intensity of sugarcane ethanol is considerably lower than that of CARB (2009), at 27 gCO_2/MJ, but is close to that obtained by Macedo et al. (2008). Our estimates for the GHG emissions from corn stover are somewhat lower than the 13gCO_2e/MJ estimated by Wu et al. (2006a, b) due to that study's assumption of much higher emissions during the biorefinery phase.

The production of biofuels also involves changes in land use, both directly and indirectly. Direct land use change occurs when there is a change from existing land cover to a biofuel crop. This could occur if cropland is converted to perennial grasses or if conservation land is tilled for grain based biofuels. Indirect land use change occurs when the diversion of land for biofuel crops leads to an increase in crop prices which induces people to convert grasslands and forests to cropland. The Energy Independence and Security Act of 2007 specifies that indirect as well as direct GHG emissions are to be included in the life cycle assessment of biofuel emissions that meet the RFS. However, there is considerable uncertainty in measuring indirect land use change and in determining its implications for GHG emissions.

Table 11: Costs and Emissions of Corn Ethanol and Cellulosic Biofuels

9.	10.	11.	12.	13.	14.	Tax/Subsidy per gallon with value of \$100/tCO_2e	
Fuel Type	**Yield**	**Annualized Delivered**	**Ethanol**	**Break-even cost**	**Life cycle GHG**	**LCFS with historical**	**LCFS with**

	(t DM/ ha)	Yield (t DM/ha)	(g/ha)	of production ($ per gallon of gasoline equivalent, (gge))	emissions (gCO2e/ MJ)	baseline (equivalent to a carbon price policy) $/gge[c]	current energy baseline $/gge[c]
Corn	8.3	8.3	1080	2.88	60	-0.48	0.20
Corn Stover	3.7	3.4	298	3.98	8	-0.06	0.61
Miscanthus[a]	41	22.7	1982	3.90	5	-0.04	0.63
Switchgrass[a]	13	9.5	830	5.04	12	-0.10	0.58
Sugarcane[b]	90	77	1714	2.60[d]	18	-0.14	0.53
Gasoline					94	-1.14	-0.11

[a]Peak biomass yield; [b]Average yield over 6 year rotation
[c] Negative sign indicates a tax while positive sign indicates a subsidy; [d] estimated assuming $1=$R2

When GHG emissions from indirect land use changes estimated by Searchinger et al. (2007) are added to the direct emissions estimated by Farrell et al. (2006), the life-cycle GHG emissions from corn ethanol become 195% of those from gasoline. Others estimate indirect land use emissions to be about a third or less of those of Searchinger et al. (2007) (Hochman et al., 2008; CARB, 2009). Even with these lower estimates, the total life-cycle GHG emissions from corn ethanol are larger than those from gasoline except in the case of refineries using natural gas and biomass for fuel and producing the wet form of dried distiller grains (DDGs) used in livestock feed (CARB, 2009).

Estimates of the indirect land use changes and GHG emissions from cellulosic biofuels are relatively few. Cellulosic biofuels that do not divert any cropland from food production (such as corn stover and perennial grasses grown on land not suitable for agricultural production) are not expected to cause any indirect land use changes (CARB, 2009). Perennial grasses grown on cropland do have the potential to cause indirect land use changes. Searchinger et al. (2007) estimates that emissions from indirect land use change caused by switchgrass would be 111 gCO_2/MJ and that switchgrass ethanol would have emissions that are 50% higher than those of gasoline (amortized over a 30 year period). CARB (2009) estimates the land use related emissions from switchgrass-based cellulosic ethanol to be 18 gCO_2/MJ and from sugarcane ethanol to be 46gCO_2/MJ. The EPA (2009)[i] estimate of GHG emissions associated with fuels that will be used to meet the Renewable Fuels standard suggests that land use changes caused by switchgrass production can release significant near-term GHG emissions that will be offset over time with the displacement of petroleum by biofuels. Taking indirect land use change effects into account, they estimate that switchgrass ethanol will result in 124% lower emissions than gasoline over a 30 year period.

The current vehicle technology allows only 10% blending of ethanol with gasoline. Thus a 10% reduction in GHG intensity cannot be achieved by simply blending corn ethanol or any of the cellulosic biofuels. Vehicles that accommodate blends greater than 10% are critical for achieving an LCFS that seeks to reduce GHG intensity by 10% or more.

The production of biofuels also involves changes in land use, both directly and indirectly. Direct land use change occurs when there is a change from existing land cover to a biofuel crop. This could occur if cropland is converted to perennial grasses or if conservation land is tilled for grain based biofuels. Indirect land use change occurs when the diversion of land for biofuel crops leads to an increase in crop prices which induces people to convert grasslands and forests to cropland. The Energy Independence and Security Act of 2007 specifies that indirect as well as direct GHG emissions are to be included in the life cycle assessment of biofuel emissions that meet the RFS. However, there is considerable uncertainty in measuring indirect land use change and in determining its implications for GHG emissions.

Table 11 also provides estimates of the break-even cost of production of biofuels from the different feedstocks at the refinery gate in $ per gallon of gasoline equivalent in 2007 prices under representative conditions. More details about the assumptions underlying these estimates are in Khanna et al. (2009) and Lasco et al. (2009). The cost of cellulosic biofuels is highly dependent on the conversion technology that is developed to produce them and the costs of the feedstock. A commercial technology does not currently exist and hence these costs are based on relatively optimistic projections (Wallace et al., 2005). CARB (2009a) estimates the cost of cellulosic biofuels from corn stover to be $3.19/gge (gallon of gasoline equivalent) assuming that the cost of corn stover is $38 per ton. Our estimates are somewhat higher due to a higher feedstock cost for corn stover in the Midwest (Khanna, 2008). In the case of dedicated energy crops, the cost of the feedstock must also include the opportunity cost of converting land from existing uses. To the extent that this land is cropland, these opportunity costs are the foregone profits from its most profitable crop production. The production of biofuels also involves changes in land use, both directly and indirectly. Direct land use change occurs when there is a change from existing land cover to a biofuel crop. This could occur if cropland is converted to perennial grasses or if conservation land is tilled for grain based biofuels. Indirect land use change occurs when the diversion of land for biofuel crops leads to an increase in crop prices which induces people to convert grasslands and forests to cropland. The Energy Independence and Security Act of 2007 specifies that indirect as well as direct GHG emissions are to be included in the life cycle assessment of biofuel emissions that meet the RFS. However, there is considerable uncertainty in measuring indirect land use change and in determining its implications for GHG emissions.

Table 11 (column 4) shows the minimum wholesale gasoline price that would be needed to make biofuels from each of these feedstocks break even. Costs will be higher once the costs of transportation from refinery to pump and profit margins at the wholesale and retail levels are added in. With gasoline costs less than $3 per gallon there are unlikely to be market incentives to produce biofuels and blend it with gasoline in the absence of any government policy intervention. An exception to this is sugarcane ethanol, which is competitive with gasoline at current market prices. Column 5 shows the addition to the price of biofuels with a carbon price of $100 per ton of CO_2. Whether this price is sufficient to make biofuels from specific feedstocks competitive with gasoline will depend on the price of oil and the actual costs of producing these biofuels in the future. The incentives provided under an LCFS with a carbon value of $100 per ton of CO_2 will depend on how stringent the standard is, since that determines the magnitude of the implicit subsidy and tax. A hypothetical calculation in column 6 shows that this carbon value together with an LCFS that reduces intensity by 10% is unlikely to make biofuels competitive with gasoline. An LCFS is therefore likely to require a higher carbon value to achieve compliance which implies a higher cost of abatement for the transportation sector than $100 per ton of CO_2.

5.3 Incentives for Biofuels with an LCFS Compared to Other Policies

We can use the estimates of the greenhouse gas intensity of alternative biofuels to analyze the incentives provided by an LCFS to consume various low carbon fuels. As discussed above, an LCFS with a historical baseline provides incentives that are identical to those of a carbon tax or cap and trade policy that prices each fuel based on its GHG intensity. Given the GHG intensities of the various biofuels in The production of biofuels also involves changes in land use, both directly and indirectly. Direct land use change occurs when there is a change from existing land cover to a biofuel crop. This could occur if cropland is converted to perennial grasses or if conservation land is tilled for grain based biofuels. Indirect land use change occurs when the diversion of land for biofuel crops leads to an increase in crop prices which induces people to convert grasslands and forests to cropland. The Energy Independence and Security Act of 2007 specifies that indirect as well as direct GHG emissions are to be included in the life cycle assessment of biofuel emissions that meet the RFS. However, there is considerable uncertainty in measuring indirect land use change and in determining its implications for GHG emissions.

Table 11, we can calculate the fuel tax implied by a carbon price of $100 per ton of CO_2e. With a historical baseline LCFS that is equivalent to a carbon price policy, the tax on gasoline would be $1.14 per gge and the tax on miscanthus-based biofuel would be $0.03/gge. In contrast to an LCFS that uses current energy as the baseline, the tax or subsidy depends on the difference in the GHG intensity of the fuel relative to the standard. A standard that seeks to reduce intensity by 10% relative to the baseline with gasoline as the only fuel and a carbon price of $100 per ton of CO_2e implies subsidies per gge that range from $0.20/gge for corn ethanol to $0.63/gge for miscanthus and a tax on gasoline of $0.11/gge. Note that an LCFS does not imply an explicit tax or subsidy for the producers of fuels. Instead, the implicit tax/subsidy is simply a wedge between consumer price and producer price with the burden of the tax/subsidy shared by consumers and producers depending on the slopes of the fuel demand and supply curves (Holland et al. 2009).

The carbon price needed to ensure that the LCFS is met depends on the elasticity of supply for the fuels, the elasticity of demand for fuel and the elasticity of substitution between gasoline and biofuels as well as the technological options available to reduce the GHG intensity of fuel. This price could be quite different from the carbon price that emerges with a cap-and-trade policy. The more elastic are the demand and supply curves, the lower is the fuel price increase needed to induce the required level of increase (decrease) in low (high) carbon fuel consumption to meet the LCFS.

The estimates in The production of biofuels also involves changes in land use, both directly and indirectly. Direct land use change occurs when there is a change from existing land cover to a biofuel crop. This could occur if cropland is converted to perennial grasses or if conservation land is tilled for grain based biofuels. Indirect land use change occurs when the diversion of land for biofuel crops leads to an increase in crop prices which induces people to convert grasslands and forests to cropland. The Energy Independence and Security Act of 2007 specifies that indirect as well as direct GHG emissions are to be included in the life cycle assessment of biofuel emissions that meet the RFS. However, there is considerable uncertainty in measuring indirect land use change and in determining its implications for GHG emissions.

Table 11 can be used to make several inferences. First, for an equivalent carbon price, an LCFS would create much stronger incentives to produce and blend biofuels than a cap-and-trade policy because the LCFS (implicitly) subsidizes biofuels while a cap-and-trade would make them more expensive based on their GHG intensity. Second, the LCFS with the historical baseline taxes all fuels and therefore encourages fuel conservation in addition to fuel switching. The extent to which it induces production of expensive low carbon fuels may be limited because the incentive payment for low carbon cellulosic fuels may not be enough to overcome the cost differential between cellulosic fuels and gasoline. For example, if the wholesale price of gasoline is $2.50/gge and the carbon price is $100/t CO_2e, the after tax price of gasoline would still be lower than the cost of production of cellulosic biofuels. Thus, a much higher carbon price would be needed to make cellulosic biofuels competitive with gasoline at current costs of production. Third, even with the taxes and subsidies implied by the LCFS based on current energy use, cellulosic biofuels are unlikely to be competitive with a carbon price of $100/t$CO_2e$. A doubling of this price is needed to cover the gap in costs of cellulosic biofuels relative to gasoline and to provide an implicit subsidy of about $1.2/gge for cellulosic biofuels. Fourth, the mandatory requirement to meet an LCFS involves a much higher price of carbon than might occur under a cap-and-trade policy; moreover, the implied subsidies for corn ethanol and cellulosic biofuels would lead to significant increases in biofuel production, not only biofuels from cellulosic feedstocks but also corn ethanol. An LCFS has the potential to substantially increase the profitability of biofuel producers at the expense of gasoline producers and fuel consumers.

As compared to a cap-and-trade policy, an LCFS can also be expected to create greater certainty of demand for low carbon biofuels when there is variability in macro-economic conditions. Under a cap-and-trade policy, emissions reduction may be more easily achieved by reducing gasoline consumption during a recession. However, an LCFS would continue to necessitate blending of biofuels even if gasoline demand falls (Rajagopal et al., 2009). Moreover, an LCFS based on full life cycle accounting of GHG emissions will create relatively greater incentives for cellulosic biofuels than for corn ethanol as compared to H.R. 2454, in which agricultural sector GHG emissions are not capped. Although the H.R. 2454 does not cap the emissions from the agricultural sector, it will raise the cost of fossil energy used in biofuel production and implicitly raise the costs of biofuels based on their carbon footprint. The cost of corn ethanol, which is more carbon intensive than cellulosic biofuels, will increase more than the cost of cellulosic biofuels. Thus the H.R. 2454 will improve the competitiveness of cellulosic biofuels relative to corn ethanol. However, biofuels will not be priced based on a comprehensive life cycle analysis that includes not only the energy related emissions but also the nitrous oxide emissions due to fertilizer applications. Since agriculture is not capped, the methane emissions from livestock and nitrous oxide emissions from fertilizer use are not going to face a carbon equivalent price. For this reason the H.R. 2454 will create a lower incentive for switching to cellulosic biofuels than would have been the case if agriculture had been included in the cap.

Policies other than an LCFS and a cap-and-trade policy can provide more direct incentives for producing and consuming biofuels. The Energy Security and Independence Act of 2007 established the Renewable Fuels Standard (RFS) which mandates the production of 36 billion gallons of biofuels by 2022 with an upper bound on corn ethanol production set at 15 billion gallons. The RFS requires 5 billion gallons to be advanced biofuels with a potential to reduce GHG emissions by 50% relative to gasoline and 16 billion gallons to be cellulosic biofuels with a potential to reduce GHG emissions by 60% relative to gasoline. The Biomass Crop Assistance Program (BCAP), established by the 2008 Farm Bill to promote the cultivation of energy efficient bioenergy crops, provides incentive payments for the production of perennial and annual biomass crops, as well as cost share payments to establish, harvest, and store and transport perennial biomass crops. In addition to these incentives, there is a tax-credit of $0.45 per gallon for producing corn ethanol and a tax credit of $1.01 per gallon for cellulosic biofuels together with an import tariff of $0.54 per gallon on imported ethanol primarily from Brazil.

While an RFS would also reduce GHG intensity, it differs from an LCFS in the mechanisms and incentives that it creates to do so. Unlike an LCFS, an RFS would not create any disincentives to import tar sands. Moreover, the displacement of gasoline due to the RFS would tend to lower gasoline prices while requiring the blending of particular types of biofuels despite their cost. The net impact on the price of the blended fuel depends on the responsiveness of the gasoline supply curve and of the biofuel supply curve to price. If the gasoline supply curve is relatively steep, the decrease in its price may more than offset the increase in price due to higher biofuel costs. Overall fuel prices for the consumer could fall which could stimulate greater fuel consumption. This together with the potential to import more carbon intensive fuels like tar sands could lead to higher overall GHG emissions with the RFS than without it (see Ando et al., 2009). An RFS that is binding and accompanied by biofuel tax credits simply lowers the cost of biofuels to the blender and further lowers the cost of the blended fuel to the consumers. This can be expected to create further incentives to increase vehicle miles travelled and reduce the potential for the RFS to lower GHG emissions (Khanna et al., 2008).

Several studies have analyzed the GHG implications and economic costs of the ethanol tax credit (Khanna et al., 2008), of the biofuel mandate with the tax credit (Ando et al., 2009) and of the biofuel import tariff and tax credit (Lasco and Khanna, 2009). These studies show that the biofuel mandates, particularly when accompanied by biofuel tax credits, provide incentives to substitute biofuels for gasoline. However, the biofuel mandate lowers the price of gasoline which partially offsets the extent to which biofuels displace gasoline. It also reduces the impact of switching to costly biofuels on fuel prices and thus reduces the incentives for fuel conservation. The studies above show that a biofuel mandate and tax credit has a negligible impact on GHG emissions. Tax credits accompanied by an import tariff create incentives to switch to the relatively carbon intensive domestic corn ethanol rather than importing sugarcane ethanol from Brazil. It also raises the domestic price of ethanol. Both of these effects tend to increase the carbon intensity of domestic fuel and reduce the GHG mitigation benefits of switching to biofuels.

Imposing an LCFS with the existing biofuel policies in place would create additional incentives to produce and blend biofuels with gasoline. The implicit tax on gasoline under an LCFS would further reduce incentives to use gasoline and the implicit subsidy on biofuels would enhance the profitability of producing biofuels and blending them. Depending on the value of carbon reductions under an LCFS, the magnitude of the implicit subsidy under an LCFS could be several times larger than those under BCAP.

With an LCFS that requires a 10% or 20% reduction in GHG intensity, the implicit tax on gasoline is likely to be relatively small. Whether an LCFS would create incentives to change the mix of biofuels produced (as compared to those required by the Renewable Fuels Mandate) and impact fuel consumption and total GHG emissions is unclear and needs further research.

6. Implications of an LCFS for Land Use

An LCFS will lead to changes in land use both directly and indirectly. Its direct impact on land use will arise because it affects the profitability of crop production in two ways. First, it will create demand for biofuels and raise the price of crops that can be used as feedstocks for biofuels. Secondly, it will affect fuel price and thus the cost of producing feedstocks for biofuels. As mentioned above, an LCFS will impose an implicit tax on gasoline consumption and an implicit subsidy on biofuel; the net impact on the blended fuel price will be passed on to downstream consumers (depending on the responsiveness of the gasoline demand and supply curves to price). Assuming the resulting fuel price is higher implies that farmers will have to pay more for fuel, fertilizer and pesticides. At the same time, the increased demand for biofuels and the implicit subsidy for low carbon fuels will raise the demand for corn production and the price of corn. The impact on land use will depend on the net impact of these two effects that increase both the revenues from corn production and its costs on the profitability of agricultural production. In the event that it increases the overall profitability of agriculture, it could lead to marginal land being brought into crop production, a shift from corn-soybean rotations to continuous corn rotations, reduced fertilizer applications, and a switch to tillage practices that are less fuel and chemical intensive. The extent to which these changes will occur depends on the quantities of energy intensive inputs used by farmers, the amount of flexibility they have to shift towards alternative inputs, the implicit tax on gasoline and the implicit subsidy on ethanol, and the increase in the price of corn. If the LCFS is not too stringent, the implicit subsidy on biofuels will be much higher than the implicit tax on gasoline and this will raise the profitability of agricultural land and land values.

Even with the development of a commercial cellulosic biofuel industry, at least in the near term an LCFS could continue to be met primarily by corn ethanol if its cost of production continues to remain significantly lower than that of cellulosic biofuels (even though it has a relatively smaller GHG mitigation potential and thus a lower implicit subsidy). Additionally, the feedstock likely to be used initially for cellulosic biofuels is crop residues, particularly corn in the Midwest (Khanna et al., 2009). The high upfront establishment costs of perennial grasses like miscanthus are likely to create disincentives for their production until the value of carbon reductions rises high enough to cover their marginal cost of production. Demand for corn stover and for corn for biofuels can be expected to increase the amount of land under corn production and to raise corn prices. This will further enhance incentives to shift crop rotations from a corn-soybean rotation to a continuous corn rotation and will shift tillage practice towards no-till production. The latter is likely to be stimulated by the higher percentage of crop residue that can be harvested sustainably with a no-till practice than with conventional tillage. The reduction in acreage under soybeans and wheat as it shifts to corn can also be expected to raise prices of soybeans and wheat. While the increase in corn prices with the increasing diversion of corn to biofuel production can be expected to reduce the profitability of ethanol production, the increase in corn and soybean prices also increases the opportunity cost of converting the land to energy crops and therefore increases the cost of producing cellulosic biofuels from energy crops.

The effects of an LCFS on land use can be expected to change not only over time but also regionally, since the mix of feedstocks used for cellulosic biofuels can be expected to change over time and across regions in the U.S. Energy crops such as miscanthus and switchgrass require considerable soil moisture, long growing days, and high temperature (Jain et al., 2009). Yields are expected to be higher in the southern Midwest and in the southern U.S. regions. These are also areas where corn and soybean yields are relatively lower and thus the opportunity costs of land use are lower. It would therefore be more profitable to produce energy crops in the southern Midwest and in southern states like Tennessee and Kentucky while continuing to produce corn and corn stover in the upper Midwest.

The increase in crop prices is also likely to create incentives for conversion of land currently under the Conservation Reserve Program (CRP) to switch back to crop production as CRP contracts expire, unless the rental rates for that land increases and keeps pace with the increase in profitability of crop production. While this would reduce the pressure on crop prices, the benefits of using this land for corn production are likely to be dampened by the relatively lower soil quality of this land. CRP land is currently not allowed to be used to grow perennial grasses that can be harvested. CRP land is expected to be much more productive for producing feedstocks for cellulosic biofuels because perennial grasses can be grown productively on marginal land and because the biofuel yield per acre of land is much higher for these grasses than for corn ethanol. However, it is important to examine the biodiversity benefits provided by CRP land and to avoid damage to wildlife habitat that may be adversely affected by growing feedstocks suitable for biofuel production and harvesting them annually.

These land use effects could differ from those likely to occur under the H.R. 2454, which will result in a lower carbon price for at least two reasons - the provision’s broader scope and the allowance it makes for carbon offsets. Since the cap on emissions includes the electricity sector, from which it will be less costly to reduce GHG emissions, the need for reductions from the transportation sector will be lessened (transportation fuel producers may prefer to buy permits rather than make reductions if the price of carbon is low enough). Secondly, the allowance for carbon offsets implies the availability of low cost carbon credits from soil carbon sequestration, via the switch from conventional tillage to conservation tillage practices. This will put a downward pressure on the price of carbon. Dhungana (2007) finds that even a low price of carbon would create incentives for co-firing bioenergy with coal for producing electricity and for switching land to conservation tillage in the Midwest. Babcock (2009) estimates that the carbon sequestered by no-till farming, at 0.4 tons of CO_2 per acre, would yield $8 per acre if the CO_2 price is $20 per ton. At this price, there is likely to be significant adoption of conservation tillage in the Midwest. On the other hand, very high carbon prices would be needed to make cellulosic biofuels competitive with gasoline.

hereFurthermore, unlike the LCFS which implicitly subsidizes low carbon fuels like ethanol, the carbon price under H.R. 2454 would make all fuels more expensive based on their GHG intensity. Although the H.R.2454 does not price biofuels based on their full lifecycle GHG emissions, it is likely that the H.R. 2454 will lead to lower use of corn for ethanol, greater production of bioenergy crops and use of other sources of renewable energy for electricity generation, as well as lower crop prices and lower land values than an LCFS. Recent economic analysis by Baker et al. (2009) shows that biofuel policies and H.R. 2454 are likely to increase agricultural income and net welfare for the agricultural sector because gains in crop revenues and income from offsets are larger than the increase in input costs due to higher energy prices.

7. Conclusions

The effects of an LCFS on GHG emissions and the economy will depend on the specific design of the LCFS and the other policies that accompany it. If the policy goal is to achieve reductions in GHG emissions, not only from the transportation sector but from other energy intensive sectors as well, then the least cost approach would be to have an economy-wide cap and trade policy. However a cap-and-trade policy that does not impose an economy-wide cap is likely to be less effective in accounting for the full life-cycle GHG emissions associated with different fuels and less effective in creating incentives for biofuels with lower GHG intensity. If the goal of the policy is to encourage domestic production of renewable fuels, the incentives are likely to be greater under an LCFS. An LCFS policy within a cap-and-trade policy is likely to be either redundant or if it is binding it will raise the costs of meeting the cap since it limits the flexibility of options to reduce GHG emissions.

The extent to which an LCFS will achieve GHG mitigation and the economic costs at which it will do so is subject to uncertainty because it depends (among other things) upon technological breakthroughs in alternative fuel and vehicle technologies and the costs at which these are commercially produced. There is also uncertainty about the GHG emissions due to indirect land use changes induced by any policy that encourages greater biofuel production. These uncertainties are greater under a policy approach that relies more heavily on biofuels to achieve compliance.

The incentives for biofuel production provided by an LCFS are likely to be different from those under the H.R. 2454 due to differences in the implicit/explicit value per ton of carbon. An LCFS is likely to provide greater certainty of demand for cellulosic biofuels and encourage more research, development, and investment in new biofuel technologies. However, if the cost of cellulosic biofuels turns out to be very high in the near term, an LCFS could impose high costs on fuel consumers. An LCFS could also enhance demand for corn ethanol and raise corn prices to the detriment of food consumers relative to a cap-and-trade policy.

Thus the distributional impacts of an LCFS would be very different from those of the H.R. 2454 type cap and trade policy. Biofuel producers are likely to gain, food consumers are likely to be adversely impacted, and the effect on fuel consumers is unclear. Producers and consumers of high carbon fuels would have to bear the cost of the implicit tax. In contrast, under a cap-and trade policy in which a large percentage of allowances are distributed free to energy intensive sectors, producers of high carbon fuels would only have to bear the cost of the additional permits they need to comply with the cap imposed on them, while firms that sell permits would gain. Moreover, farmers will gain income from the carbon offsets they create through carbon sequestration.

American Clean Energy and Security (ACES) Act Forestry Provisions and Implications[26]

This section summarizes the forestry provisions of ACES and provides a brief analysis, based on a review of secondary literature, of the possible impacts of the provisions. The forestry sector plays a key role in three of the five main title sections of H.R. 2454: Title I: Clean Energy, Title III: Reducing Global Warming and Pollution and Title V: Agricultural and Forestry Related Offsets. The role of the forestry sector in each of these titles in briefly summarized below.

Title I: Clean Energy

Title I establishes provisions for increasing the use of renewable fuels in both the electricity and transportation sectors. The title lays out provisions for a combined efficiency and renewable energy standard (CERES), which would require electric utilities to meet 20% of their electricity demand from renewable sources by 2020. Previous versions of the bill mandated the EPA to implement a Low Carbon Fuel

[26] This section was authored by Jennifer Baka.

Standard (LCFS) to regulate transportation emissions. However, this provision was stripped from the final version of the bill that passed the House.

The title defines eligible renewable resources and certain forest products would qualify as renewable biomass resources under the provision. The bill adopts the Farm Bill definition of renewable biomass on private lands.

Forest products deemed eligible by the definition would include:

1. Pre-commercial thinnings and other forest residues removed from the National Forest System and public lands using environmentally sustainable harvesting practices.
2. Any organic matter occurring on a renewable or recurring basis on non-federal lands or lands belonging to Indian tribes. Forestry-related materials include plants and trees and waste materials such as construction wastes.
3. Residues and byproducts from wood, pulp, or paper products facilities.

The definition excludes materials from federal conservation lands and from old growth and late-successional public lands. The definition is found in Section 126 of the bill.

The bill further calls for the National Academies of Science to conduct a study within one year of the bill's enactment that will evaluate the potential of various biomass resources for contributing to the bill's goals of improving energy independence, protecting the environment and reducing global warming.

The definition has been a source of debate since earlier versions of the bill were introduced back in April. The bill that passed the House included a more inclusive definition than early bills, specifically the inclusion of construction wastes. At present, a consortium of 76 organizations led by the National Alliance of Forest Owners is pressing the Senate to further expand the definition of renewable biomass to include additional forest sources from federal lands. The consortium is urging the Senate to adopt the Farm Bill's definition of renewable biomass from federal lands to achieve this goal (25x'25, 2009).

Title III: Reducing Global Warming and Pollution

Forestry plays a crucial role in Title III of the bill, the section of the bill that outlines the cap and trade program. Most importantly, the forestry and agricultural sectors are exempted from emissions caps under the bill. This means the forestry and agricultural sectors do not have to purchase emissions allowances.

Secondly, the forestry sector will be a key sector in the offset program established under the emissions trading system. Much of the offset program centers on reducing emissions from deforestation, which presently accounts for nearly 20% of global emissions (IPCC, 2007). Offsets play a role in three components on the cap and trade system proposal.

1. The offset program

Under the cap and trade system, participants can purchase domestic or international offsets to help achieve their emissions reductions targets. The bill sets a cap of 2 billion tons of greenhouse gas emissions per year, split equally between domestic and international offset projects. The EPA Administrator could adjust that amount to up to 1.5 billion for international offsets, if there were insufficient domestic offsets available in a given year. The offset cap of 2 billion tons is equivalent to nearly 27% of current US annual emissions.

The percentage of a covered entity's compliance obligation that could be met via offset credits would start at approximately 30 percent in 2012 and gradually increase as the overall cap on emissions declines. Half of that percentage may come from domestic offset credits, and the other half from international offset credits. For example, in 2012 a covered entity could satisfy up to 15 percent of its total compliance obligation with domestic offset credits, and up to 15 percent more with international offset credits. For compliance purposes, one domestic offset credit would equal one emission allowance, and one international offset credit would equal one emission allowance until 2018. Starting in 2018, 1.25 international offset credits would equal one emission allowance.

The EPA, in conjunction with a newly established committee, the Offsets Integrity Advisory Board, will determine eligible offset projects within two years of the bill’s enactment. However, offsets from deforestation projects, particularly Reducing Emissions from Deforestation and Degradation (REDD) credits from the Kyoto Protocol, are expected to feature prominently in the US portfolio as they are viewed as a cost-effective offset alternative (Bendana, 2009).

Eligible offset projects are subject to periodic review. Every five years, the Advisory Board must conduct a transparent, scientific review of the list of eligible project types, offset methodologies, monitoring practices, policies for mitigating potential project reversals and other accountability measures, and they will make recommendations for changes to the program accordingly.

The bill outlines certain key criteria for determining the eligibility of deforestation offsets, which are detailed below:

- The United States has a bilateral or multilateral agreement or arrangement with the country where the offset takes place and it is considered a developing country.

- The activity occurs in an eligible country which is defined as one that has the capacity to participate in international deforestation reduction activities at a national level. It must have the technical capacity to monitor and measure forest carbon fluxes for all significant sources of greenhouse gas emissions from deforestation with an acceptable level of uncertainty, and it must have the institutional capacity to reduce emissions from deforestation, including strong forest governance and mechanisms to deliver deforestation resources for local actions.
- The quantity of the international offset credits has been determined by comparing the national emissions from deforestation relative to a national deforestation baseline for that country established in accordance with an agreement or arrangement. The baseline should be national, should take into consideration the average annual historical deforestation rates of the country during a period of at least 5 years to ensure additionality, should establish a trajectory that would result in zero gross deforestation by not later than 20 years after the national deforestation baseline has been established, should be adjusted over time to take account of changing national circumstances, and should be designed to account for all significant sources of greenhouse gas emissions from deforestation.
- The reduction in emissions from deforestation has occurred before the issuance of the international offset credit and has been demonstrated using ground-based inventories, remote sensing technology, and other methodologies to ensure that all relevant carbon stocks are accounted.
- The activity is designed, carried out, and managed in accordance with widely accepted, environmentally sustainable forestry practices and it promotes native species and conservation or restoration of native forests.

2. Supplemental Emissions Reductions from Reduced Deforestation

The cap and trade program will include a supplemental program whereby a certain percentage of emissions allowances will be set aside each year to help developing countries reduce deforestation. For vintage years 2012-2025, 5% of allowances will be set aside for the program, 3% will be set aside from 2026-2030 and 2% will be set aside from 2031-2050.

The EPA, USAID, and other relevant agencies will develop a program within two years of the bill's enactment. The goal is to achieve supplemental emissions reductions of at least 720 million tons of greenhouse gases by 2020, 6 billion tons of greenhouse gases by December 31, 2025 and additional reductions in subsequent years.

3. Strategic Reserve Auction

Lastly, the bill establishes a strategic reserve auction whereby the EPA will auction off a certain percentage of allowances each quarter and use the proceeds from the auction to purchase international offset credits for reducing deforestation. The EPA will then retire these credits and establish new allowances equal to 80% of the offset value.

From 2012-2019, 1% of allowances will be auctioned off on the strategic reserve auction, 2% will be auctioned off from 2020-2029 and 3% will be auctioned off from 2030-2050.

Title V: Agriculture and Forestry Related Offsets

Title V addresses the role of domestic offsets from agriculture and forestry in the cap and trade program outlined in Title III. The USDA will oversee this portion of domestic offsets. The bill mandates the USDA to develop a program for governing domestic offsets within a year of the bill's enactment.

The bill contains general provisions as summarized below:

- Offset quality. Offsets must represent additional, verifiable emission reductions, avoidance, or sequestration. Sequestration projects can only be issued for GHG reductions that result in a permanent net reduction in atmospheric GHGs (Sec. 502, pg. 1391).
- Offset project types. Requires the Secretary to, within 1 year of date of enactment, consider a broad range of potential emission reduction and sequestration projects. This includes a list of projects to be considered as long as they meet offset provisions in the bill. It also provides a petition process for adding project types to the list (Sec. 503, pg. 1392).
- Offset baselines. The Secretary shall set baselines to reflect a conservative estimate of performance or activity for the relevant type of practice (excluding previous changes in performance or activities due to the availability of offset credits) such that the baseline provides an adequate margin of safety to ensure the environmental integrity of offset credits calculated in reference to such baseline (Sec. 504, pg. 1396).
- Additionality. Offset projects are considered additional only to the extent that they result from activities that: 1) are not required by existing government regulation, as determined by the Secretary, 2) were not commenced prior to January 1, 2009 (with exceptions for certain types of sequestration projects that started after 2001), and 3) exceed the applicable activity baseline established under paragraph 2 (Sec. 1396).

- Crediting periods. Offsets crediting periods are specified: 5 years for agricultural sequestration, 20 years for forestry and 10 years for other practice types. Crediting period renewals are unlimited, but can be limited for some project types by the Secretary (Sec. 504, pg.1404).

Finally, Title V includes an exemption for biomass-based diesel plants. The bill exempts plants constructed before the 2007 Energy Independence and Security Act (EISA) from the renewable fuel standards program. Up to one billion gallons of biodiesel production per year would qualify for the exemption. This is roughly equivalent to 1.2% of total US petroleum usage.

Potential Benefits of Forestry-Related Sections

This section outlines the potential benefits from the sections of the bill relevant to the forestry sector.

Slowing Deforestation

As previously mentioned, deforestation currently accounts for nearly 20% of annual global emissions. By incentivizing forest preservation and afforestation efforts, the bill could make a significant contribution to halting deforestation.

Moderating Costs of Cap and Trade Program

Entities may choose to purchase offsets rather than invest in technological improvements for meeting their emissions reductions target if the cost of offsets is lower than that of technological investment. This in turn would help reduce the cost of implementing the cap and trade system. According to the Congressional Budget Office, by allowing offsets, the cost of the cap and trade system would be 60% less than if offsets were not allowed (CBO, 2009). The CBO estimated the cost of the cap and trade system from 2012-2030.

Criticisms of Forestry-Related Sections

This section reviews the main criticisms of the forestry-related provisions of the bill. Many criticisms resemble those raised with regard to the offset program of the Kyoto Protocol or the European Union Emissions Trading System (ETS).

Ability to reduce overall emissions

If enacted in its current form, the bill would create the largest offset pool in the world, which raises concerns over the emissions reduction potential of the bill. While offsets can help control the costs of achieving emissions reductions, it has proved challenging to verify the authenticity of emissions reductions from offset credits under the Kyoto Protocol and EU ETS trading schemes (GAO, 2009). It is therefore difficult to determine whether offset provisions lead to genuine emissions reductions. Because of the size of the allowance pool under H.R. 2454, some groups fear US emissions would actually increase over the short-term horizon, at least until 2026 (International Rivers and Rainforest Alliance, 2009).

Additionality

To qualify under the bill, offset programs must satisfy the condition of additionality, meaning the emissions reductions would not have occurred but for the offset program. Verifying this condition can be challenging. The CDM uses three mechanisms to verify additionality. First, the offset projects must not be a mandated government activity, must not be normal practices and must not be activities that reduce greenhouse gases after a certain date. Second, offsets can be verified by using performance standards of the technology associated with the offset activity. Finally, offset program developers must demonstrate that the offset program would constrain an alternative, potentially more profitable use of the resources to the offset project. For example, for a reforestation program, developers must demonstrate that the land will not be cleared for cultivation. As described previously, H.R. 2454 would implement similar mechanisms to verify additionality.

Permanence

Proving the permanence of offsets has also been a challenge for other cap and trade programs. The long-term emissions reduction potential and the possibility of unforeseen consequences (such as forest fires) must be considered when evaluating offset projects. Other climate programs have dealt with permanence in various ways. Some require legal assurances that the carbon will remain stored while others assign expiration dates to offsets. Other programs hold a portion of the offset credit in reserve for use as insurance in case actual emissions reductions deviate from estimated reductions at the time that the offset was established.

Leakage

Leakage is another concern often raised in relation to offset projects. Leakage occurs when a carbon reduction (or sequestration) activity in one location leads to a carbon emitting activity in another location. For example, leakage occurs if an area of forest that would have been cleared in the absence of an offset project results in the clearance of a forest area in another location that is not protected through an offset program. Leakage can also occur with regards to tree planting activities. Trees planted to sequester carbon under offset programs could reduce investment in industrial forests if there is an expectation that some products from the carbon forest might be sold in timber markets in the future. Leakage can be dealt with by designing offsets to minimize leakage, for example, by allowing both carbon and industrial forests to participate in offset programs. Further, offsets can be discounted to account for leakage that cannot be avoided.

Cost of Allowances

Related to the point above, there is concern that the size of the offset pool could decrease demand for allowances, thus reducing the price of allowances. This would reduce incentives for participants to invest in efficiency measures or technological improvements. This could increase the cost of compliance over the long term as the emissions cap is lowered (Stevenson, 2009).

Institutional Readiness

In 2007, forest carbon transactions accounted for approximately 7.5 million tons of greenhouse gases (Hamilton et al., 2008). The offset pool of H.R. 2454 would substantially increase this amount (depending on the amount of forest carbon offsets purchased) and there is concern about whether adequate policies, market infrastructure and management provisions can be put into place before the offset program starts in 2012. Further, the EPA, State Department and USDA would each play a role in managing the offset program but none of these agencies has previous experience with managing similar programs in the past. Thus there is additional concern over the ability of these agencies to oversee the program.

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