Are U.S. States Equally Prepared for a Carbon-Constrained World?

By Mark C. Snead and Amy A. Jones

Climate concerns linked to greenhouse gas emissions, particularly carbon dioxide (CO_2), have taken center stage in the national energy policy debate. Domestic energy use and carbon emissions continue to rise, and forecasts suggest further increases under the existing regulatory structure. However, heightened international and domestic pressure to reduce U.S. carbon emissions suggests that additional changes to the regulatory framework are probable in coming years.

Reducing U.S. carbon emissions will likely require a comprehensive national framework that will alter the pattern of energy use and production in all 50 states. At issue for state-level policymakers is that carbon restrictions are unlikely to affect the states equally. Energy use and emission patterns vary widely across states, and there is no accepted framework for allocating shares of a national carbon reduction goal. As a result, states that emit the most carbon or have the most energy- and carbon-intensive economies may shoulder the greatest burden.

This article evaluates the current energy posture of the states and thus how prepared they are to cope with ongoing trends in energy use, especially restrictions on carbon emissions. The findings suggest that

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the New England, Mid-Atlantic, and West Coast states are generally best prepared. These states have the least energy-intensive economies and use fuel mixes with low average carbon intensity; hence, they already release proportionately less CO_2. The states expected to be hardest hit by carbon constraints are the traditional energy-producing and agricultural states. These states have energy-intensive economies, by both domestic and international standards, and will face a considerable challenge in altering their energy use and emissions patterns.

The first section of the article discusses long-run trends in U.S. energy use and carbon emissions, as well as current regulatory efforts to limit carbon emissions. The second section describes the Kaya Identity, a metric that can help evaluate the preparedness of individual states to adapt to greater carbon constraints. The Kaya Identity is used in the third section to illustrate differences in state-level energy use and emissions and to assess the relative preparedness of states to adapt to future carbon constraints.

I. U.S. ENERGY USE AND CARBON EMISSIONS

Climate concerns linked to greenhouse gas emissions are arguably the most important force driving changes in domestic energy use. Carbon emissions continue to rise substantially and, under the existing regulatory framework, are projected to rise further in coming decades. Recent regulatory proposals calling for curbing emissions, however, suggest that much greater restrictions are increasingly likely.

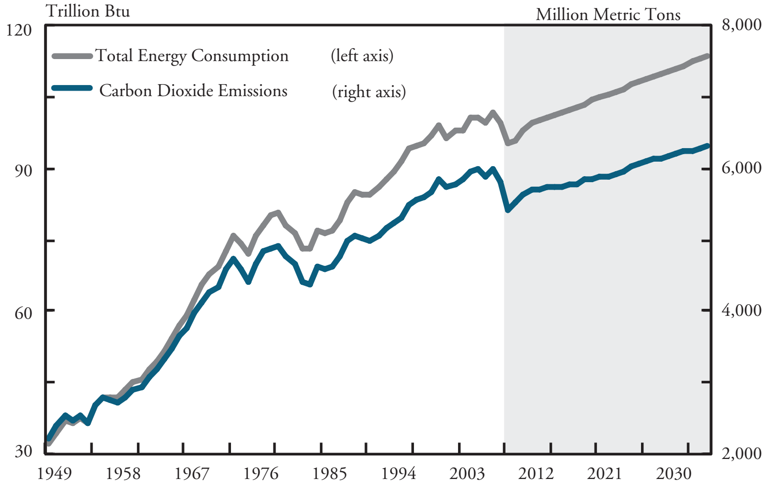
Trends in energy use and emissions

Total energy use—and thus CO_2 emissions—continues to rise in the United States.[1] The growth in energy use has slowed in recent years but remains persistent, with consumption typically declining only during recessions. In the postwar period, the growth of carbon emissions has undergone two distinct phases, and forecasts suggest it recently entered a third phase (Chart 1).

The first phase stretched from the late 1940s to around 1979, when energy prices began to surge upward. Rising energy use in this phase was driven by intense industrialization and rapid expansion of the U.S. economy, along with low energy costs and limited concern for carbon emissions. Total energy use increased more than 150 percent during the

Chart 1

TOTAL ENERGY CONSUMED AND TOTAL CARBON DIOXIDE EMISSIONS—U.S.



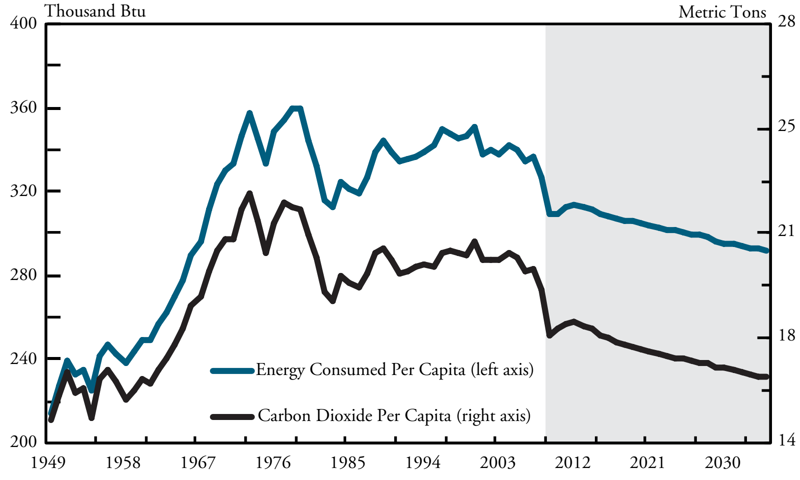
Sources: U.S. Department of Energy, Enviromental Protection Agency

period, raising carbon emissions nearly 125 percent (2.5 percent annual growth). The bulk of these increases took place between 1960 and 1973, as total carbon emissions increased at an annual rate of nearly 4 percent. On a per capita basis, energy consumption increased nearly 50 percent from 1949 to 1979 and produced an increase in carbon emissions from 15 metric tons annually to a peak of more than 22 metric tons (Chart 2).

Following the surge in energy prices in the late 1970s, the U.S. economy transitioned to a second phase in 1979. Characterized by markedly slower growth in both energy use and emissions, the phase extended through 2008, when yet another major energy price spike occurred. During the second phase, total energy use increased 23 percent and carbon emissions about 20 percent (0.6 percent annually). On a per capita basis, both energy use and carbon emissions began to stabilize over the period and eventually turned downward. The accelerated decline in per capita energy use and emissions beginning in 2001 was accompanied by a steady rise in energy prices through 2008. Recent preliminary estimates following the 2008-09 recession suggest

Chart 2

ENERGY CONSUMED AND CARBON DIOXIDE EMISSIONS PER CAPITA—U.S.



Sources: U.S. Department of Energy, Enviromental Protection Agency, Bureau of Economic Analysis

that U.S. carbon emissions fell below 18 metric tons per capita in 2009, a level last experienced in 1965 (U.S. EIA, 2010b).

U.S. Department of Energy (DOE) long-run forecasts signal that the United States entered a third phase of energy use following the price spike of 2008 (U.S. EIA, 2009e). The projections suggest that this phase will be characterized by further increases in the levels of both energy use and carbon emissions, but the rate of growth will downshift relative to the prior phase. The forecasts also assume only limited reductions in the carbon intensity of the fuel mix used through 2035.

Underlying the projection of slowing growth in energy consumption are two factors: higher expected energy prices through 2035 and only a marginal increase in the use of renewable forms of energy. The 2009-35 forecasts suggest that annual growth will slow to 0.5 percent in total energy use and about 0.3 percent in carbon emissions. Under these assumptions, total energy use is projected to rise 14 percent during the full period and carbon emissions 9 percent. Further reductions are anticipated in per capita energy use and carbon emissions, with total declines of 5 percent and 10 percent, respectively, from 2010 to 2035.

Carbon emissions per capita are projected to fall to nearly 16 tons per person by 2035, a level last seen in 1960.

Carbon reduction and the changing regulatory environment

Current DOE forecasts, based on the existing U.S. environmental regulatory structure, project increased energy use and carbon emissions through 2035. Ongoing efforts to tighten U.S. emissions regulations, however, suggest that the future paths of energy use and carbon emissions may ultimately fall below current DOE forecasts. United States environmental regulators feel growing international and domestic pressure to reduce future carbon emissions.

The factors underlying this pressure—the energy-intensive nature of the U.S. economy and the resulting high level of carbon emissions—are well documented. The United States represents only 4 percent of the world's population but emits nearly 20 percent of the carbon produced from human sources. Relative to Europe, the United States uses more than double the energy per person and 50 percent more energy per dollar of real output (U.S. EIA, 2009e).

Though no longer the world's largest CO_2 emitter, having passed the distinction on to China in 2007, the United States still produces four times more carbon per capita than China and nearly 2.5 times more than Europe (U.S. EIA, 2009e). Efforts to reduce this carbon intensity in the United States remain hampered by the limited progress made to date in transitioning the economy to cleaner alternative forms of energy.

The high levels of domestic energy use and emissions suggest that the United States must be a key player in establishing any successful global carbon reduction strategy. The Kyoto Protocol, operated within the structure of the United Nations, remains the primary international framework for negotiating global commitments to reduce greenhouse gas emissions. Structured as an international environmental treaty, the Protocol's aim is to reduce a range of greenhouse gases to just below 1990 levels by 2012. The agreement has been ratified by more than 180 countries, including China, Russia, and the European Union nations. The United States remains the only major industrialized nonparty to the treaty, citing the lack of binding quantitative emissions limits on developing countries, especially China. The United States nonetheless remains an active party to a nonbinding successor agreement to Kyoto that would put in place a global cap-and-trade program aimed at reducing global CO_2 emissions by 50 percent by 2050.[2]

In the absence of a U.S. commitment to an international framework, federal legislative efforts to reduce greenhouse gas emissions have become the driving force behind emission reduction and fuel mix changes in the United States.[3] The recently proposed American Clean Energy and Security Act of 2009 seeks to establish a cap-and-trade system intended to reduce greenhouse gas emissions to 17 percent below 2005 levels by 2020 and to 83 percent below 2005 levels by 2050.[4] Some in the scientific community have similarly argued for long-term reductions in carbon emissions to roughly 85 percent of 2009 levels by 2050 (Union of Concerned Scientists, 2007). These long-range proposals aimed at reducing emissions by more than 80 percent represent efforts to transition global economies from fossil fuels to cleaner alternatives.

Recent federal legislation has authorized the reporting requirements needed to create a broad system of accounting for use in regulating emissions in the United States. The Consolidated Appropriations Act of 2008 requires that approximately 10,000 facilities report their greenhouse gas emissions annually to the U.S. Environmental Protection Agency (EPA), with an initial report due in 2011. Carbon emissions originating in the transportation sector are also expected to receive increased scrutiny in coming years following a recent Supreme Court decision that gives the EPA authority to regulate and establish standards for tailpipe emissions of greenhouse gases (U.S. EIA, 2009d).

State-level efforts

Translating a national emissions reduction policy to the state level presents considerable challenges. A state- and region-based regulatory framework has long governed energy production and delivery in the United States. State-level entities often serve as the primary regulatory bodies, and both energy production and consumption are typically pursued within state or regional markets.

Recognizing the impending expansion of federal efforts to regulate carbon emissions, many states and regions of the country have already adopted policies designed to encourage energy efficiency and reduce carbon dependency. Historically, these initiatives have been a direct response to local air quality concerns, but they now largely reflect a strategic, early adoption of expected changes in national emissions policy.

A number of regional initiatives to reduce greenhouse gas emissions have gained traction. Ten New England and Mid-Atlantic states formed the Regional Greenhouse Gas Initiative to develop a market-based auction system for greenhouse gas emissions as well as to promote energy efficiency, renewable energy programs, and low-carbon transportation fuel alternatives. The Western Climate Initiative seeks to develop a comprehensive regional, market-based cap-and-trade program with a goal of reducing emissions across participating states to 15 percent below 2005 levels by 2020. The Midwestern Greenhouse Gas Reduction Accord proposed a regional cap-and-trade program in 2009 that establishes emission reduction targets of 18 to 20 percent below 2005 levels by 2020 and 80 percent below 2005 levels by 2050 (U.S. EIA, 2009d).

State and local initiatives to restrain carbon emissions continue as well. In 2006, the city of Boulder, Colorado, became the first government entity to institute a direct carbon tax on electricity consumption. Other cities, including Berkeley, California, and Portland, Oregon, have considered using a carbon tax to reduce emissions. A number of states have instituted binding and nonbinding renewable energy mandates in electricity production in response to both local clean air concerns and anticipated federal limits on carbon emissions. In 2009, California instituted the first state-level emissions fee to fund the state's cap-and-trade program established in 2006. Also in 2009, California and 13 other states negotiated stringent tailpipe emission restrictions with the EPA that exceed the current national standard (U.S. EIA, 2009d).

Despite the efforts of individual states and regional alliances, much of the policy agenda concerning energy emissions will likely be determined at the federal and international levels. In particular, a provision in the proposed American Clean Energy and Security Act of 2009 would prohibit state and regional cooperatives from operating their own cap-and-trade agreements between 2012 and 2017 (Waxman, 2009). The prospect of limited involvement in the negotiation process presents a clear regulatory risk to state policymakers. Within this context, the next section discusses a framework for evaluating the preparedness of the individual states for adapting to future restrictions on carbon emissions.

II. MEASURING THE ECONOMIC EFFECTS OF CARBON CONSTRAINTS

Of particular concern to state-level policymakers in the climate change debate is the potential tradeoff between economic growth and stricter limits on carbon emissions. The Kaya Identity is an established framework for examining the interrelationships and tradeoffs between economic growth, energy use, and carbon emissions. This section describes the framework at the national level using recent DOE forecasts. The following section applies the framework to the individual states.

Energy use, emissions, and economic growth: Kaya Identity

The Kaya Identity[5] is a widely used framework for evaluating the tradeoffs between demographic changes, economic activity, energy use, and emissions. The base form of the identity is as follows:

$$C = P * (G/P) * (E/G) * (C/E), \quad (1)$$

where:

C = CO_2 *emissions from human sources*
P = *population*
G = *real gross domestic product (GDP)*
E = *primary energy consumption*
G/P = *real GDP per capita*
E/G = *energy intensity of real GDP*
C/E = *carbon intensity of energy.*

The identity frames the discussion of carbon emissions and energy consumption within the context of economic growth. In its base form, the identity states that total carbon emissions can be expressed as the product of four inputs: population, economic output per capita, energy intensity of output, and carbon intensity of energy consumed. Thus, constraining carbon emissions is a matter of offsetting increased energy use and emissions due to both population growth and increased output per worker with technical improvements in the amounts (energy intensity) and types (carbon intensity) of energy used to produce output. The identity is widely used to project future levels of CO_2 emissions under alternative economic and energy use scenarios (Raupach and others, 2007; Waggoner and Ausubel, 2002). It can be used globally, nationally, or within smaller regions when adequate data are available.

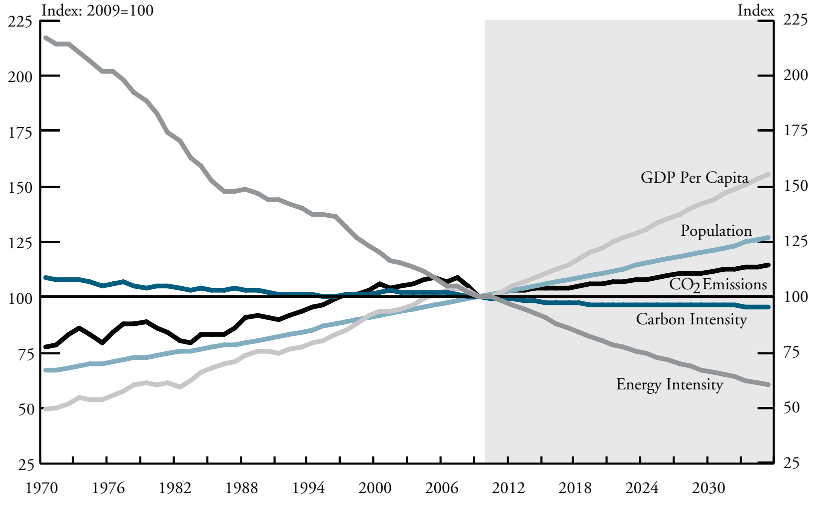
Kaya Identity components—Long-run forecasts

Trends in the individual components of the Kaya Identity reveal the forces underlying rising carbon emissions in the United States in recent decades. Chart 3 details the path of each component of the identity for the United States between 1970 and 2009, along with forecasts through 2035. Trends in the components indicate that the 29 percent rise in carbon emissions from 1970 to 2009 resulted from growth in both population and output per person that outweighed reductions in both energy intensity and carbon intensity. During the period, the U.S. economy experienced a 50 percent increase in population and a 103 percent gain in real GDP per capita. This expansion was partly offset by a 54 percent reduction in energy intensity and an 8 percent decline in carbon intensity.[6]

Reduced energy intensity carried most of the burden of offsetting increased population and output growth in the United States since 1970. Energy intensity, measured as the amount of energy used per dollar of real GDP, declined nearly every year between 1970 and 2009, leaving the U.S. economy only half as dependent on energy to produce output as it was in 1970. The majority of the decline in energy intensity is traced to ongoing structural changes in the economy, with a smaller contribution from energy efficiency efforts.[7] Chief among the structural factors are changes in the industry mix of the economy (such as the ongoing shift in production from goods to services), geographical changes in population (such as migration to more moderate climates), and changes in the mix of activities within sectors (such as the shift within manufacturing to less energy-intensive products and processes) (U.S. EIA, 2009b).

In contrast, much less progress has been made in reducing the carbon content of the domestic fuel mix. The 8 percent decline in carbon intensity between 1970 and 2009 left the U.S. economy nearly as carbon-intensive as it was four decades ago. Most of the reduction in carbon intensity is traced to the gradual introduction of small amounts of less carbon-intensive nuclear and wind-generated electric power. Of

Chart 3
KAYA IDENTITY COMPONENTS—U.S.



Sources: U.S. Department of Energy, Bureau of Economic Analysis, Enviromental Protection Agency

particular concern to climate groups is that U.S. carbon intensity increased markedly between 1995 and 2008 as the use of coal in power production increased in many states. Much of that increase reversed during the recent recession as energy use dipped.

DOE projections of the Kaya components in Chart 3 are based on the current regulatory environment and assume only limited restraints on carbon emissions. Between 2009 and 2035, U.S. GDP per capita is expected to increase more than 50 percent and population more than 25 percent. The underlying annual growth rates of these two components are expected to slow only marginally from current levels. Annual population growth is projected to slow from a current rate of 1.0 percent to 0.9 percent through 2035, while real output per capita slows from 1.8 percent to 1.7 percent.

Carbon intensity is expected to resume its gradual downward trend through 2035, falling about 5 percent in the period. But it will continue to offset only a small share of the expected growth in population and output per capita. Future reductions in carbon intensity are attributed to modest increases in renewable energy in the form of nuclear, wind, biofuels, and solar. Most of the projected offsets to population and output gains are instead derived from an additional 40 percent reduction in energy intensity through 2035. Estimates suggest that approximately three-fourths of the drop in energy intensity will be realized through structural changes in the economy, such as smaller residential and commercial floor space needs, a continued shift away from energy-intensive manufacturing, and gains in automobile fuel efficiency. The remaining drop will be achieved through energy efficiency gains (U.S. EIA, 2009b).

III. STATE-LEVEL ECONOMIC EFFECTS

Like the United States, each state will face tradeoffs among carbon emissions, economic growth, and energy use in coming years. Successfully offsetting the effect of economic expansion on carbon emissions with improvements in energy intensity and carbon intensity will largely determine how well each state adapts to carbon restrictions. This section uses the Kaya Identity to evaluate the relationships between carbon emissions, economic growth, and energy use across the states.

State variation in carbon emissions per capita

Table 1 details the components of the Kaya Identity for the 50 states, with state rankings for the individual components of the identity.[8] Because the level of total emissions in a given state is largely a function of population, the Kaya Identity is rearranged with carbon emissions stated on a per capita basis. Hence, the identity as shown in (*1*) is restated as

$$(2) \qquad (C/P) = (G/P) * (E/G) * (C/E),$$

where (C/P) is carbon emissions per capita and the remaining right-hand side components are unchanged. (Total carbon emissions and total energy consumption at the state level are shown in Appendix Table A1.)

The state rankings in Table 1 illustrate how widely the level of carbon emissions varies across states. A nearly twelve-fold difference in annual per capita CO_2 emissions exists between Wyoming (121.2 metric tons) and New York (10.3 metric tons), the highest and lowest emitting states, respectively.

Ranked with New York as the lowest carbon emitters are two additional Mid-Atlantic states (Maryland and New Jersey), the New England

Table 1

KAYA IDENTITY COMPONENTS— STATE-LEVEL SUMMARY (2008)

Kaya Identity (C/P) = (G/P) * (E/G) * (C/E)								
	Carbon Dioxide Emissions (*) Per Capita (C/P)		Real GDP Per Capita (G/P)		Energy Intensity of Economic Activity (E/G)		Carbon Intensity of Energy (C/E)	
State	Metric Tons	Rank	Thousands of 2005 Dollars	Rank	Btu per 2005 Dollar of GDP	Rank	Metric Tons per Million Btu	Rank
New York	10.3	1	58.79	5	3.5	1	50.5	10
Vermont	10.4	2	40.97	31	6.1	14	42.0	5
Rhode Island	10.5	3	44.96	24	4.6	6	50.4	9
Idaho	10.7	4	34.53	47	10.0	36	30.8	1
California	11.0	5	50.48	9	4.5	5	48.1	7
Connecticut	11.5	6	61.71	4	3.7	2	49.7	8
Oregon	11.5	7	42.71	29	6.8	20	39.4	3
Massachusetts	12.2	8	55.78	6	4.0	3	54.2	16
Washington	12.6	9	49.16	17	6.3	17	40.3	4
Maryland	13.8	10	48.30	19	5.3	9	53.9	15
Florida	13.9	11	40.39	34	6.0	12	57.6	25
New Hampshire	14.4	12	45.39	22	5.2	8	61.1	31
Maine	15.1	13	37.67	42	9.4	33	42.5	6
New Jersey	15.5	14	54.82	7	5.6	10	50.9	13
Arizona	15.6	15	38.29	40	6.2	15	65.4	33
Nevada	15.9	16	50.17	13	5.7	11	55.5	17
Virginia	16.4	17	50.93	8	6.3	16	50.9	12
North Carolina	16.6	18	43.28	27	6.8	19	56.8	23
South Dakota	17.1	19	45.94	21	9.5	35	39.4	2
Michigan	18.3	20	38.24	41	7.6	25	62.7	32
Wisconsin	18.6	21	42.72	28	7.7	26	56.1	19
Hawaii	18.8	22	49.59	15	4.4	4	85.2	45
Illinois	18.9	23	49.34	16	6.5	18	59.4	28
Georgia	19.0	24	41.01	30	7.6	24	61.0	30
Minnesota	19.1	25	50.25	12	7.5	23	50.5	10
Delaware	19.8	26	70.56	1	4.8	7	58.8	27
South Carolina	19.8	27	34.73	46	10.6	38	53.8	14
Colorado	19.9	28	50.37	10	6.0	13	65.5	34
Tennessee	20.6	29	40.40	33	9.0	30	56.8	22

Table 1 (continued)

	Kaya Identity (C/P) = (G/P) * (E/G) * (C/E)							
	Carbon Dioxide Emissions (*) Per Capita (C/P)		Real GDP Per Capita (G/P)		Energy Intensity of Economic Activity (E/G)		Carbon Intensity of Energy (C/E)	
State	Metric Tons	Rank	Thousands of 2005 Dollars	Rank	Btu per 2005 Dollar of GDP	Rank	Metric Tons per Million Btu	Rank
Pennsylvania	21.8	30	44.03	25	7.0	21	70.3	39
Arkansas	22.2	31	34.29	48	11.4	41	56.6	21
Mississippi	23.1	32	31.22	50	12.9	45	57.2	24
Ohio	23.2	33	40.90	32	8.5	28	67.1	36
Missouri	23.5	34	39.92	38	8.1	27	72.3	41
Nebraska	24.6	35	46.73	20	9.4	32	56.1	20
Utah	25.4	36	40.25	35	7.3	22	86.6	46
Texas	27.8	37	50.34	11	9.4	34	58.6	26
Kansas	28.1	38	43.87	26	9.3	31	69.1	38
Iowa	28.5	39	45.32	23	10.4	37	60.2	29
New Mexico	29.5	40	40.22	36	8.7	29	84.5	44
Oklahoma	30.0	41	40.19	37	11.0	39	68.2	37
Alabama	31.1	42	36.35	45	12.1	43	70.3	39
Indiana	36.1	43	39.89	39	11.2	40	80.8	43
Kentucky	36.6	44	36.48	44	12.7	44	79.1	42
Montana	38.9	45	37.08	43	12.1	42	86.8	47
Louisiana	43.8	46	49.92	14	15.7	50	55.9	18
Alaska	62.7	47	69.63	2	13.6	47	66.3	35
West Virginia	64.1	48	33.97	49	13.5	46	140.1	50
North Dakota	76.4	49	48.65	18	14.1	48	111.1	48
Wyoming	121.2	50	66.25	3	15.3	49	119.2	49
Tenth District States	27.4		34.74		10.9		72.4	
United States	**19.7**		**46.54**		**7.0**		**60.2**	

Sources: U.S. Department of Energy, Bureau of Economic Analysis, Census Bureau, Environmental Protection Agency, and authors' calculations

(*) Most recent data available from 2007 states (Connecticut, Maine, Massachusetts, New Hampshire, Rhode Island, and Vermont), the West Coast states (California, Oregon, and Washington), the Sun Belt states of Arizona and Florida, and hydroelectric power-intensive Idaho. These states tend to produce approximately 10 to 15 metric tons of carbon annually per person versus an average of 19.7 tons nationally. The level of carbon emissions per capita in these states is on par with many major high-income nations, including Germany, Japan, Russia, South Korea, and the United Kingdom.[9]

Most important, the low-carbon states tend to be the greatest users of coal-alternatives in electric power production. Most of the New England and Mid-Atlantic states achieve their emissions advantage by using significant amounts of relatively more expensive but carbon-free nuclear power. Mild summers and winters, coupled with heavy use of renewable energy (primarily hydroelectric power), play a key role in the high rankings of the West Coast states and Idaho.

Four traditional energy-producing states—Wyoming, North Dakota, West Virginia, and Alaska—stand out as emitting more than triple the national level of carbon per capita (Table 1). These states represent four of the five most energy-intensive state economies and use roughly twice the energy required at the national level to produce a dollar of per capita gross domestic product. Among the defining characteristics of energy use in these states are a nearly exclusive reliance on coal for electric power production, an industry mix heavily dependent on energy, and cold winters.

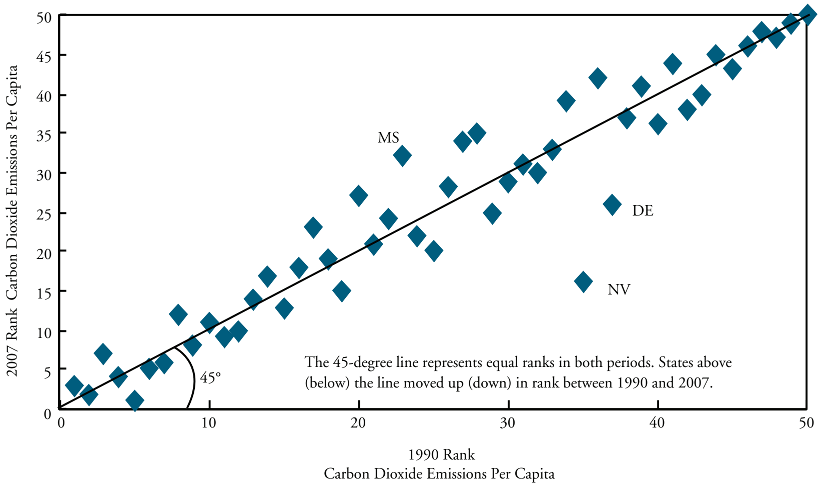
Traditional agricultural states such as Indiana and Iowa also tend to rank among the highest carbon emitting states. In fact, of the 15 states with the greatest carbon emissions per capita in Table 1, all but Alabama are either traditional energy-producing or agricultural states, or both. The industry structure in these states reflects abundant natural endowments in the form of arable land and fossil fuel deposits. Reducing carbon emissions may prove exceedingly difficult in these states, given the historical role of energy-intensive commodity production.

Changes in state carbon emission rankings (1990-2007)

The relative rankings of the states have evolved only slowly over time. Chart 4 compares state rankings on per capita carbon emissions

Chart 4

STATE PER CAPITA CARBON DIOXIDE EMISSIONS—1990 VS. 2007



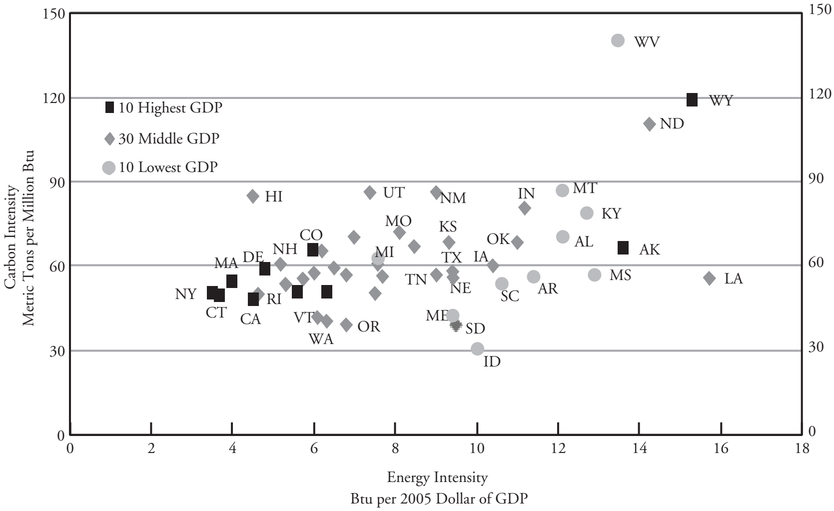
Sources: U.S. Department of Energy, Bureau of Economic Analysis, Environmental Protection Agency

in 1990 to rankings in 2007 and illustrates how persistent relative emission levels across the states have remained in recent years.[10] Since 1990, the ranks of roughly half the states reflect small relative improvements in carbon per capita (those below the line in Chart 4) while the other half slipped (those above the line in Chart 4).

Some states nevertheless experienced significant changes in carbon emissions per capita and rank relative to the other states. The two greatest relative improvements in the period occurred in Nevada and Delaware. Both states achieved reductions in carbon emissions per capita of 7 to 8 percent between 1990 and 2007 by reducing carbon intensity 20 to 30 percent. Nevada improved relative to 19 states as a result of closing a highly carbon-intensive, coal-fired electric plant in 2005 rather than upgrading it to current emission standards. Delaware advanced ahead of 11 states by shifting electricity production from petroleum-based fuels to natural gas in the early 1990s. Conversely, Mississippi increased carbon emissions per capita by 13 percent as a result of doubling the amount of coal used in power production, slipping nine spots in the rankings.

Chart 5

STATE-LEVEL ENERGY INTENSITY AND CARBON INTENSITY BY GDP PER CAPITA (2008)



Sources: U.S. Department of Energy, Bureau of Economic Analysis, Environmental Protection Agency

Balancing the Kaya factors—GDP per capita, energy intensity, and carbon intensity

The states use a variety of strategies to balance economic growth, energy use, and carbon emissions. Chart 5 illustrates the various combinations of Kaya factors across the states by showing energy intensity and carbon intensity delineated along ranges of GDP per capita. The states are partitioned into three groups containing the ten highest GDP states, the ten lowest GDP states, and the 30 middle GDP states. (See Appendix B for additional discussion on patterns in energy and carbon intensity across the states.)

The states naturally cluster into three distinct groups based on energy and carbon intensity. The high GDP states tend to have the least energy-intensive economies and the least carbon-intensive fuel mix. Low GDP states tend to rank among the most energy-intense but vary considerably in terms of carbon intensity. The middle GDP states tend to range uniformly around U.S. levels of both energy- and carbon-intensity. Most of the outliers to the three GDP groups are high and middle GDP energy-producing states with highly energy-intensive economies.

Table 2

STATE ENERGY AND CARBON INTENSITY BY LEVEL OF GDP PER CAPITA

Level of GDP	Mean		Median	
	Energy Intensity of Economic Activity (E/G)	**Carbon Intensity of Energy (C/E)**	**Energy Intensity of Economic Activity (E/G)**	**Carbon Intensity of Energy (C/E)**
	Btu per 2005 Dollar of GDP	Metric Tons per Million Btu	Btu per 2005 Dollar of GDP	Metric Tons per Million Btu
10 Highest GDP	6.9	61.7	5.6	50.9
30 Middle GDP	8.0	62.4	7.6	59.0
10 Lowest GDP	11.2	68.0	11.8	60.0

In Table 2, both mean and median energy and carbon intensities rise consistently from high to low GDP states, with much greater variation in energy intensity than carbon intensity. To produce a dollar of output, high GDP states use only about half as much energy on average as low GDP states. In contrast, average carbon intensity is only about 10-15 percent lower in high GDP states than in low GDP states.

High GDP states in the New England, Mid-Atlantic, and West Coast regions appear the best prepared for a carbon-constrained world (Chart 5). Despite high levels of GDP per capita in many of these states, they manage to consume far less energy and use cleaner fuels than most other states.[11] High GDP states such as California, Connecticut, Massachusetts, and New York rank among the ten lowest carbon emitters by maintaining extremely low energy and carbon intensities. The relatively low energy and carbon intensity of these states leaves them well prepared to adapt to future carbon limits.

Two traditional energy-producing states, Alaska and Wyoming, rank among the ten highest output per capita states, averaging 45 percent more real output per person than the nation. But these two states use double the energy in the process. The combination of high economic output and high energy use presents these states with a significant challenge in adjusting to a highly carbon-restricted environment.

Low GDP states such as Alabama, Kentucky, and West Virginia produce well-above-average levels of carbon per capita due to both an energy-intensive industry mix and significant use of coal in electricity

TENTH DISTRICT ENERGY USE AND CARBON EMISSIONS (1990-2007)

The states of the Tenth Federal Reserve District provide a useful illustration of the Kaya Identity in evaluating changing state-level energy use patterns over time.[14] The Tenth District is historically energy- and carbon-intensive with all but one of the seven states (Missouri) considered either traditional energy-producing or agricultural states, or both. On a per capita basis, carbon emissions in the district are currently 40 percent higher than in the nation.

The economies of three district states in particular, Missouri, Nebraska, and New Mexico, experienced sharp changes in carbon emissions per capita in the period. Missouri and Nebraska experienced 17 to 18 percent increases, while New Mexico managed a 14 percent decline. The relative changes in the Kaya Identity components underlying these changes in the district states are detailed in Table B1.

The increase in emissions per capita in both Missouri and Nebraska is traced to limited progress in reducing energy intensity. While most carbon gains have historically come from reduced energy intensity, both states managed cuts of less than half the national rate in the period. Relatively slower GDP growth gave Missouri a clear advantage over faster growing Nebraska in cutting emissions. However, Missouri coupled limited progress on energy intensity with a 4.2 percent increase in carbon intensity due to increased coal usage. Nebraska instead managed an impressive 7.1 percent cut in carbon intensity by increasing the amount of nuclear-generated electric power, recovering losses and co-products from the production of ethanol, and shifting electric power production from coal to natural gas. Nonetheless, in both a relatively fast and slow growth region, GDP growth simply outweighed the combined progress achieved in reducing energy and carbon intensity.

Like Nebraska, New Mexico faced strong economic growth in the 1990 to 2007 period but instead managed a meaningful decline in carbon emissions per capita. The state far outpaced the nation in reducing both intensity measures, with an especially sharp reduction in energy intensity. New Mexico increased population by more than 30 percent in the period but increased total energy use by only 15 percent and total carbon emissions by only 11 percent. In terms of fuel use, most of the gains were realized through restrained use of coal and increased use of natural gas in electric power production. New Mexico provides an example of restricting state level energy use and carbon emissions during a period of strong economic and population growth.

TABLE B1

KAYA IDENTITY COMPONENTS FOR THE TENTH DISTRICT STATES

			Kaya Identity Percent Change (1990-2007)			
State	**Carbon Dioxide Emissions**	**Total Energy Consumed**	**Carbon Dioxide Emissions Per Capita (C/P)**	**Real GDP Per Capita (G/P)**	**Energy Intensity of Economic Activity (E/G)**	**Carbon Intensity of Energy (C/E)**
	Million Metric Tons	Billion Btu	Metric Tons	Thousands of 2005 Dollars	Btu per 2005 Dollar of GDP	Metric Tons per Million Btu
Colorado	47.1	60.9	0.5	47.5	-25.5	-8.6
Kansas	12.8	9.0	0.8	37.6	-29.2	3.5
Missouri	35.2	29.7	17.3	29.7	-13.2	4.2
Nebraska	32.4	42.5	18.3	45.8	-12.7	-7.1
New Mexico	11.4	18.7	-13.9	61.9	-43.3	-6.2
Oklahoma	23.2	15.6	7.4	29.7	-22.3	6.6
Wyoming	11.8	30.4	-3.1	18.9	-5.0	-14.2
Tenth District States	25.6	27.8	3.4	38.9	-24.2	-1.7
United States	**19.2**	**19.8**	**-1.3**	**36.4**	**-27.3**	**-0.5**

Sources: U.S. Department of Energy, Bureau of Economic Analysis, Environmental Protection Agency, and authors' calculations production. These states may be far worse positioned relative to many high GDP states for future carbon constraints and could face considerable challenges in reducing emissions, despite their output advantage.

The cluster of low GDP states in Chart 5 provides insight into why the traditional energy-producing and agricultural states are likely the least prepared for carbon constraints. Most energy and agricultural states fall below the U.S. average in GDP per capita and cluster among the states with the highest energy and carbon intensities. Elevated measures for both energy and carbon intensity simply offset the effect of relatively low GDP per capita.

Three energy-producing states in particular, North Dakota, West Virginia, and Wyoming (a high GDP state), face potentially the greatest regulatory risk among the states. These states use exceptionally high amounts of energy relative to the other states and rely heavily on coal in electricity production. The energy use in these states is so high that GDP per capita will matter little in their adjustment to carbon restrictions. Two other energy states, Alaska and Louisiana, have similar energy intensities but have managed to mitigate their risk by limiting the carbon content of their fuel mix at approximately the U.S. average. Nevertheless, these five energy-producing states are likely to face great challenges in adapting to carbon constraints.

The Kaya Identity suggests, however, that some low GDP states, such as Rhode Island, Vermont, Washington, Oregon, and New Hampshire, with similarly low energy and carbon intensities, are among the lowest emitting states and should have an easier path to adapting to more stringent future standards. Low output states such as Idaho and Maine have high energy-intensity levels but also attain low carbon emissions through substantial use of nuclear and hydroelectric power.[12]

The middle GDP states typically have near-average measures on all three Kaya components and emit roughly average levels of carbon per capita. These states will certainly face regulatory risk under future carbon constraints but are unlikely to be affected disproportionately, either positively or negatively.

IV. IMPLICATIONS AND CONCLUSIONS

This article explored whether the individual states are equally prepared to adapt to greater restrictions on carbon emissions. The results suggest the states are far from equally prepared. The Kaya Identity reveals stark differences in carbon emissions, energy intensity, and carbon intensity across the states. States with high levels of GDP per capita, energy-intensive economies, and carbon-intensive fuel mixes will likely face the greatest adjustment challenges.

The New England, Mid-Atlantic, and West Coast states appear to have a distinct advantage relative to most other states in adapting to future carbon constraints.[13] These states uniformly depend less on energy in production, use cleaner fuels, and have emission levels that are already on par with many high-income nations. Despite high GDP per capita in many of these states, they have managed to maintain the lowest levels of energy and carbon intensity.

In contrast, the traditional energy-producing and agricultural states have the most energy- and carbon-intensive economies and will likely face the greatest challenges in reducing future emissions. These states have developed highly energy-dependent economies over the years, relative to both domestic and international standards. The energy-producing states in particular face an additional production-side risk under many recent carbon reduction proposals that aim to replace fossil fuels.

Until a workable process is developed for allocating the burden of a national carbon reduction goal, the states will face considerable uncertainty over the potential impact of future carbon constraints. In addition, state policymakers may ultimately lose control over many of these decisions if the process requires much of the existing state- and region-based regulatory structure to be altered or dismantled. For federal officials, balancing the state-level differences in establishing national carbon legislation may be a daunting task.

APPENDIX A

TABLE A1
STATE ENERGY USE AND EMISSIONS (2008)

State	Carbon Dioxide Emissions (*)		Total Energy Consumed		Total Energy Average Price	
	Million Metric Tons	Rank	Billion Btu	Rank	Dollars per Million Btu	Rank
Alabama	145.2	37	2,065.0	35	19.21	11
Alaska	43.2	12	650.8	12	23.78	40
Arizona	101.5	29	1,552.8	27	23.77	39
Arkansas	63.7	17	1,124.7	20	20.01	17
California	402.8	49	8,381.5	49	23.03	36
Colorado	98.1	27	1,498.1	26	19.77	15
Connecticut	40.2	10	809.9	17	28.83	49
Delaware	17.4	5	295.3	4	24.23	41
Florida	256.3	46	4,447.4	48	25.02	42
Georgia	184.0	41	3,015.4	42	20.95	29
Hawaii	24.2	8	283.8	3	36.21	50
Idaho	16.3	4	529.3	10	18.12	6
Illinois	242.8	45	4,088.7	47	19.91	16
Indiana	230.8	44	2,857.4	40	17.15	2
Iowa	85.2	25	1,414.4	23	17.99	5
Kansas	78.5	22	1,135.6	21	20.10	18
Kentucky	156.8	39	1,982.8	33	19.05	10
Louisiana	194.9	42	3,487.5	43	17.92	3
Maine	19.9	7	469.3	9	20.57	27
Maryland	77.9	21	1,446.9	24	25.12	43
Massachusetts	79.9	23	1,475.0	25	27.51	48
Michigan	183.0	40	2,918.3	41	19.61	13
Minnesota	99.9	28	1,979.1	32	19.58	12
Mississippi	67.8	19	1,185.6	22	21.23	31
Missouri	140.0	36	1,937.0	31	20.32	22
Montana	37.7	9	434.3	7	20.14	19
Nebraska	43.9	14	781.9	15	18.69	9
Nevada	41.6	11	750.1	14	23.48	37
New Hampshire	19.0	6	311.3	5	26.64	46
New Jersey	134.3	35	2,637.1	38	23.71	38
New Mexico	58.6	16	693.3	13	22.54	35
New York	201.3	43	3,988.1	46	25.21	44

APPENDIX A (CONTINUED)

TABLE A1
STATE ENERGY USE AND EMISSIONS (2008)

State	Carbon Dioxide Emissions (*)		Total Energy Consumed		Total Energy Average Price	
	Million Metric Tons	Rank	Billion Btu	Rank	Dollars per Million Btu	Rank
North Carolina	153.6	38	2,702.2	39	22.04	34
North Dakota	49.0	15	440.9	8	15.77	1
Ohio	267.7	47	3,987.0	45	20.30	21
Oklahoma	109.3	31	1,603.4	28	20.56	26
Oregon	43.5	13	1,104.7	19	20.83	28
Pennsylvania	274.3	48	3,899.7	44	21.32	32
Rhode Island	11.1	2	220.1	2	26.24	45
South Carolina	89.3	26	1,659.5	29	20.54	24
South Dakota	13.8	3	350.2	6	19.65	14
Tennessee	128.4	34	2,261.1	36	20.54	24
Texas	676.8	50	11,552.2	50	21.50	33
Utah	69.2	20	799.4	16	18.68	8
Vermont	6.5	1	154.4	1	27.26	47
Virginia	128.0	33	2,513.7	37	21.14	30
Washington	82.6	24	2,050.2	34	20.53	23
West Virginia	116.4	32	830.8	18	18.16	7
Wisconsin	104.4	30	1,862.4	30	20.18	20
Wyoming	64.6	18	541.6	11	17.97	4
Tenth District	592.9		8,190.9		20.00	
United States	**5,986.4**		**99,382.10**		**21.44**	

Sources: U.S. Department of Energy, Bureau of Economic Analysis, Census Bureau, Environmental Protection Agency, and authors' calculations

(*) Most recent data available from 2007

APPENDIX B
ENERGY AND CARBON INTENSITY

To constrain carbon emissions, states can offset the impact of GDP growth with improvements in either energy or carbon intensity. Across the states, both intensity measures are strongly positively correlated with carbon emissions per capita (Charts B1 and B2). Hence, logical policy options for reducing the level of U.S. carbon emissions would be to target either the most energy-intensive industries and regions or the most carbon-intensive fuels. Targeting either option could present disproportionate concerns for those states with either high energy intensity or high carbon intensity.[15]

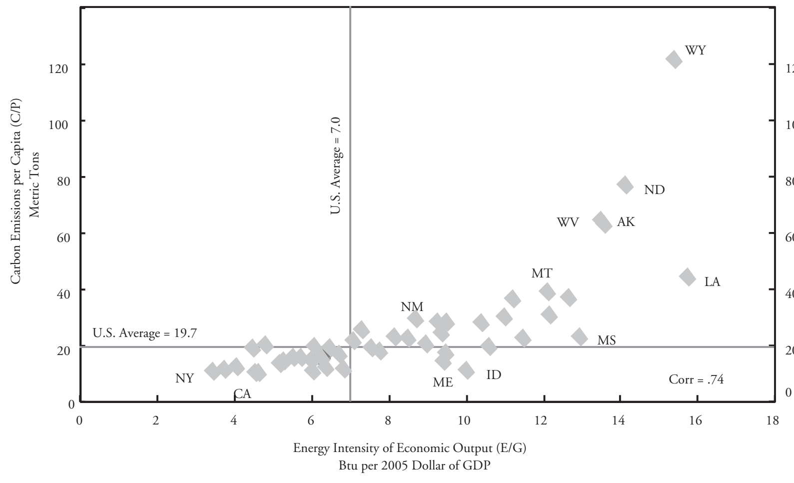
In terms of energy intensity, five states (Alaska, Louisiana, North Dakota, West Virginia, and Wyoming) standout in Chart B1 as having highly energy-intensive economies that require more than double the amount of energy used nationally per dollar of real GDP. All five are energy-producing states and rank as the five highest carbon-emitting states per capita. The extreme levels of both energy use and emissions in these states suggest that being ranked among the greatest carbon emitters is more a function of the amount of energy than the mix of energy used within a state. In these states, high energy intensity outweighs any potential offset from carbon intensity, even in Alaska and Louisiana, two energy states with relatively low carbon intensity.

Other energy-intensive states with CO_2 emissions more than 50 percent above the U.S. average include Alabama, Indiana, Kentucky, Montana, and Oklahoma. Policy options aimed at the most intense users of energy could have a larger potential impact on these states as well. However, not all energy-intensive states are likely to face the same policy risk. Arkansas and Mississippi both have very high energy intensity levels but only average levels of carbon emissions. They offset high energy intensity with very low GDP per capita and cleaner fuel mixes.

Overall, low energy-intensity states should be relatively more prepared to adapt to a carbon-reduction mandate that targets the most intense users of energy. However, the low carbon-release states of Idaho, Maine, and South Dakota could face greater risk from carbon constraints than other low-emitting states because of their high energy intensity. They are able to maintain relatively energy-intensive economies

Chart B1

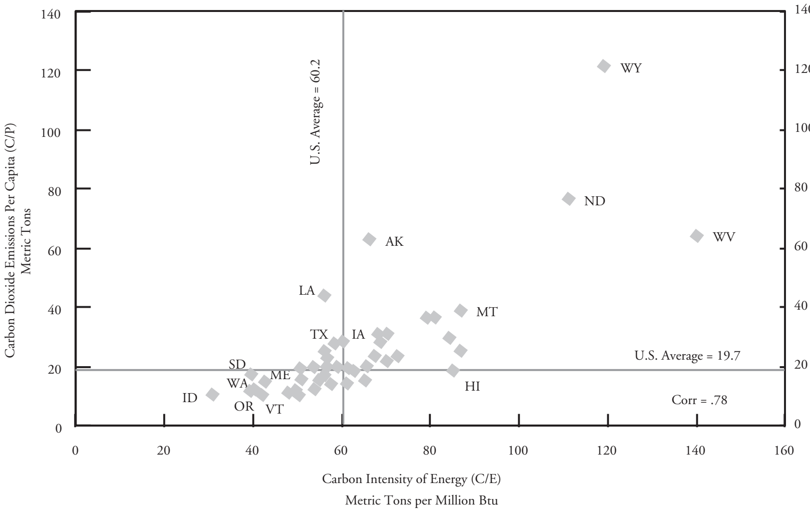
STATE CARBON EMISSIONS PER CAPITA AND ENERGY INTENSITY



Sources: U.S. Department of Energy, Bureau of Economic Analysis, Environmental Protection Agency

Chart B2

STATE CARBON EMISSIONS PER CAPITA AND CARBON INTENSITY



Sources: U.S. Department of Energy, Bureau of Economic Analysis, Environmental Protection Agency and emit less carbon because they are low GDP states with significant hydroelectric and nuclear power.

The most carbon-intensive states are likely to face significant regulatory risk as efforts accelerate to curb the domestic use of fossil fuels, particularly coal. Three coal-intensive states, North Dakota, West Virginia, and Wyoming, standout in Chart B2 as having carbon intensity levels more than 50 percent above the U.S. average. Of added concern is that these three states also rank among the most energy-intensive states. Wyoming and West Virginia face an additional production-side risk as the nation's two largest coal-producing states.

Few other states have extremely high carbon intensity levels. Excluding North Dakota, West Virginia, and Wyoming, the state-level variation in carbon intensity is considerably less than in energy intensity. The carbon intensity of most states is within 30-40 percent of the U.S. level of 60.2 metric tons of carbon per million Btu. In other words, the nation is more uniformly carbon-intensive than energy-intensive.

A group of six states including Idaho, Maine, Oregon, South Dakota, Vermont, and Washington stand out as low carbon-intensity economies, emitting roughly one-third less carbon than the nation. These low carbon states appear well prepared to adapt to future carbon restrictions. They achieve low emissions through limited use of coal and various combinations of carbon-free biomass, nuclear, and hydroelectric power. Low carbon-intensity states also dominate the ranks of the lowest emitting states. This suggests that achieving a ranking among the lowest emission states is more a function of fuel mix than overall energy use.

ENDNOTES

[1]Carbon dioxide emissions as discussed throughout the article include only those generated through fossil fuel combustion and do not include emissions from other non-fuel uses such as industrial processes, agriculture, and waste. Nationally, nearly 80 percent of total carbon dioxide emissions come from fossil fuel combustion in 2007 (EPA, 2009b).

[2]The proposed agreement will be negotiated further at international meetings in Cancun, Mexico, in 2010, South Africa in 2011, and in either Qatar or South Korea in 2012.

[3]Federal efforts are also under way to reduce noncarbon emissions. These programs include the Clean Air Mercury Rule (CAMR) and the Clean Air Interstate Rule (CAIR). CAMR would mandate reductions in mercury in electricity production while CAIR is a cap-and-trade program in the electric power sector that would reduce nitrogen oxides (NO_x) and sulfur dioxide (SO_2) emissions. The aim of both programs is to reduce fine particle pollution and ground-level ozone resulting from power generation.

[4]The bill was passed by the U.S. House of Representatives but remains under debate in the Senate.

[5]Japanese energy economist Yoichi Kaya introduced the identity in 1990 at the Intergovernmental Panel on Climate Change (IPCC) in Paris (Kaya, 1990).

[6]The reported total changes in population, real GDP per capita, energy intensity, and carbon intensity reflect average annual changes of 1.0 percent, 1.8 percent, 2.0 percent, and 0.2 percent, respectively.

[7]Energy efficiency is typically defined as the amount of energy related services (e.g., heat from a furnace or light output lamp) relative to the amount of energy consumed.

[8]Washington, D.C., is excluded from the analysis.

[9]It is not always clear who is responsible for certain carbon emissions. Carbon released in one state is frequently linked to energy use in another. Examples include electric power generated in one state and exported to another, and energy used in the production of energy. In the high carbon release states of Wyoming, North Dakota, and West Virginia, for example, electric power production is based almost exclusively on carbon-intensive coal, yet more than one-third of the electricity is exported to other states. California ranks among the cleanest states in terms of carbon emissions per capita but currently imports roughly one-third of its electricity from other states. And more than 30 percent of total energy production in the U.S. is lost either during the production of energy (e.g., refining and pipeline operation) or through electric system losses (U.S. EIA, 2010a). These emissions have embedded carbon costs that are not transferred to out-of-state consumers. Apportioning carbon emissions generated by these activities to the states will likely prove much more difficult than simply assigning it to the state of origin.

[10]1990 is the first year for which state-level carbon emission estimates are available from EPA.

[11]The Kaya Identity suggests that high GDP states will face a greater challenge in restraining carbon dioxide emissions than low GDP states (Aldy, 2007). International data similarly confirm that higher-wealth regions of the world tend to use more energy and emit more carbon per capita (U.S. EIA, 2009e). However, lower (higher) energy use in higher (lower) income regions is consistent with behavior suggested by environmental Kuznets curves (Stern, 2004).

[12]Idaho has well-above-average energy intensity but is the least carbon-intensive state. It emits only half the national level of carbon per capita and approximately 25 percent less than the next closest state. Idaho provides a glimpse into a carbon-constrained future in the sense that it uses almost no coal in power production and generates nearly 25 percent of its total energy using renewable hydroelectric power and biomass fuels. The energy profile of the state approximates the level of carbon emissions likely needed to achieve some of the recent short-run carbon reduction proposals.

[13]Many of these states, particularly the high-population states of New York and California, may be at a disadvantage as well. Energy use and emissions in the U.S. can be aptly described as a "big state" phenomenon, where high population states tend to be the largest energy users and consequently produce the most carbon emissions. Currently, the five largest energy-use states (Texas, California, Florida, Illinois, and New York) consume one-third of the nation's energy, while the bottom 20 states use only 10 percent. Viewed on a more even footing, the ten most populous states account for 50 percent of total energy consumption; the remaining 40 states share the other 50 percent (U.S. EIA, 2010a). The risk exists that high-population states may have to make the largest relative adjustments in fuel use to sway overall national energy use and emission levels.

[14]The Tenth Federal Reserve District comprises the states of Colorado, Kansas, Nebraska, Oklahoma, and Wyoming, as well as northern New Mexico, and western Missouri.

[15]Similarly, policies that target industrial sources of carbon would have a disproportionate effect on a small number of states. The greatest impacts would likely be felt in seven states: California; the energy-producing and refining states of Louisiana and Texas; and the traditional manufacturing states of Illinois, Indiana, Ohio, and Pennsylvania. These seven states currently account for nearly half of the total fuel used by the nation's industrial sector.

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