**Growth without emissions growth: State progress and drift on emissions ‘decoupling’**

**or**

**Growth without carbon: State progress, and drift, on emissions ‘decoupling’**

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In 2014 and again in 2015, energy-related emissions of carbon dioxide (CO2) remained flat even as the global economy grew.[[1]](#endnote-1) For the first time in 40 years, growth and emissions have “decoupled.”

Moreover, earlier this year separate analyses by the World Resources Institute (WRI) and the climate information website Carbon Brief concluded that as many as 35 countries, including the United States, had increased their real gross domestic product (GDP) over the last 15 years while actually *cutting* their carbon emissions.[[2]](#endnote-3)

If the United States and the rest of the world hope to enjoy rising living standards while curbing greenhouse gas emissions enough to limit the rise in global surface temperatures to 2 degrees Celsius, an objective agreed upon by the international community,[[3]](#endnote-4) decoupling growth and emissions is essential. That 35 countries could grow economically while cutting carbon emissions disproves the long-held assumption that GDP and CO2 must rise in tandem. Instead, it has become increasingly clear that cities, regions, and nations can sever the historical link between growth and emissions and prosper both economically and environmentally.

Where and how has this change taken place in the United States? The question matters because, just as reductions in global emissions originate in nations (for the most part), nations’ reductions originate in their states and cities. States and cities are crucial players in the carbon drama because they retain a unique and strong influence over multiple policy levers that can control emissions levels.[[4]](#endnote-6) States set state-level carbon emissions rules and renewables targets. They regulate investor-owned electric utilities. They shape land-use rules and building codes and transportation systems. In fact, it’s safe to say that progress to meet America’s commitments to the goals of the COP 21 climate change conference is going to depend hugely on state and local policy.[[5]](#endnote-7)

Accordingly, this brief takes a look at state-level decoupling trends by matching data on real GDP growth between 2000 and 2014 for all 50 states and the District of Columbia with data on energy-related carbon dioxide emissions for the same years and locations.[[6]](#endnote-8) In doing so, the brief provides an initial look at the pace and geography of decoupling and its companion trend of decarbonization—the reduction over time of the volume of carbon emitted for every unit of economic activity.

What do these data show? Overall, over 30 states have delinked their growth and carbon emissions. The pace and degree of states’ decoupling vary widely, with distinct regional dynamics.

Ascertaining the precise factors that are influencing these outcomes is beyond the scope of this analysis,[[7]](#endnote-9) but it is clear that many states have made progress in separating emissions from growth thanks to the rapid replacement of coal-burning power plants with natural gas-fired plants over the last decade. The presence of nuclear energy capacity and changes in states’ industrial structure have played a role as well.[[8]](#endnote-10) While formal statistical analyses of the role of clean energy policy in decarbonization is also beyond the scope of this study, it is fair to say that state- and city-level policy choices have also made a difference.[[9]](#endnote-11)

Yet, despite the progress, the numbers confirm that much more work is going to be needed if the nation and the world are going to limit human-driven climate warming to generally accepted levels.

**Where and how growth and carbon have decoupled**

Holding the world’s climate to 2 degrees Celsius of warming will require cutting greenhouse gas emissions 40 to 70 percent from their 2010 levels by 2050 and to zero by the century’s end.[[10]](#endnote-12) Such an accomplishment will entail a profound transformation of every sector of the economy.

At the same time, governments across the globe—especially the developing economies of Asia, Africa, and Latin America—are faced with the massive challenge of promoting faster economic development that can lead to positive outcomes on jobs, income, and opportunity. Even in the United States, slow growth since the Great Recession has increased the political pressure for faster growth in the future.[[11]](#endnote-13)

For most of the 20th century, the possibility of preserving growth and erasing emissions remained theoretical and was most commonly presented as an unsatisfactory, divisive face-off between the “growth imperative” and the “climate imperative.” Consequently, conventional views on the relationship between economic growth on the one hand and energy consumption and greenhouse gas emissions on the other generally claimed that economic growth would lead to an increase in production and therefore to an increase in energy use and emissions.[[12]](#endnote-14)

Yet in recent decades, more and more data have confirmed that it is possible to address global climate challenges while preserving economic growth and prosperity (see Figure 1).

WRI’s analysis of 67 countries, for instance, shows that in the United Kingdom carbon emissions declined even as real GDP grew in five different years between 2000 and 2014. [[13]](#endnote-15) Over the full 14-year period, the United Kingdom reduced its carbon emissions while growing its economy by 27 percent. Carbon Brief’s global analysis found that, while 45 nations reduced their emissions between 2000 and 2014, 35 did so while *increasing* their real GDP.[[14]](#endnote-16) Intensely urban Singapore, for example, scored the most dramatic decoupling, as it doubled its real GDP while slashing its CO2 emissions by 46 percent.

Figure 1: Insert global emissions and GDP graph

The United States first decoupled its economic growth and emissions in 2001, when it achieved a modest 2 percent reduction in carbon emissions while growing its economy by 1 percent.[[15]](#endnote-17) That was a recession year, but the decoupling occurred again in 2006, a year of solid growth, and again in 2010–2012 and in 2015. Emissions decoupling has become more frequent amid the ongoing large-scale switch from coal to natural gas—driven by the hydraulic fracturing (“fracking”) boom—but numerous other factors, such as changes in the structure and growth of the national economy, investment decisions, technology change, land-use change, and the availability of new clean energy resources, are influencing outcomes as well.[[16]](#endnote-18)

To examine decoupling trends at the state level, this analysis matches state-level GDP data to state-level carbon emissions information. We also examine the factors influencing these trends, especially those involving states’ fuel mix and industry structure.[[17]](#endnote-19)

Four major findings stand out:

***Decoupling is occurring in most states****.*

Between 2000 and 2015 (the latest year available for national data), the United States expanded its GDP by 30 percent while cutting its emissions by 10 percent—making it the largest country that has had multiple years in which economic growth has been decoupled from growth in carbon emissions (see Figure 2).[[18]](#endnote-20)

Figure 2: Insert U.S. 1990-15 decoupling line chart

Altogether 33 states and the **District of Columbia** managed to expand their economies between 2000 and 2013 while reducing their carbon emissions (see Figure 3). As a group, these jurisdictions expanded their economies by 22 percent while reducing their emissions by nearly 12 percent.[[19]](#endnote-21) **Maine** achieved the largest CO2 decline among the 50 states, at 25 percent, while growing its economy by 9 percent.[[20]](#endnote-22) Among the larger states (in terms of GDP), **Massachusetts,** **New York,** and **Georgia** have had some of the largest reductions in emissions since 2000. Massachusetts managed to cut its emissions by 22 percent even as its GDP grew 21 percent. New York and Georgia decreased their emissions by 20 percent and 17 percent while growing their GDP by 24 percent and 15 percent, respectively.

The pace of decoupling has accelerated over time, with more and more states breaking the historically tight link between GDP growth and increased carbon emissions. For instance, only 14 states and the District of Columbia managed to sever the link between growth and emissions between 2000 and 2007. Among these pioneers were five New England states—**Connecticut**, **Maine**, **Massachusetts**, **Rhode Island**, and **Vermont**—as well as **New York**. As a group, these early decouplers reduced their aggregate carbon emissions by nearly 4 percent between 2000 and 2007 while expanding their economies by 18 percent. However, since 2008, coinciding with the onset of the Great Recession, the number of decoupled states has doubled, with new states such as **California**, **Georgia**, **New Hampshire**, **South Carolina,** and **Virginia** joining the ranks (while a few from the earlier group, such as **Connecticut**, **Maine,** and **Nevada**, fell off the list).[[21]](#endnote-23) Across this 36-state group of 2008-2014 decouplers, the average reduction in carbon emissions was 10 percent and GDP growth was 6 percent.

Overall, as discussed in more detail below, the largest reductions in energy-related carbon emissions, especially after 2007, can be attributed to the fuel use changes in the electric power sector.

***The pace and extent of decoupling varies greatly.***

Decoupling has spread widely in the last decade, but not evenly. The trend is strongest among 11 states—mainly in the Northeast—and the District of Columbia that all reduced their carbon emissions by more than 15 percent during the years 2000-2014. Collectively these states have reduced their emissions by 19 percent while expanding their GDP by a robust 22 percent. These strong decouplers also tend to have the lowest per capita carbon emissions. **New York**,for instance, had the lowest per capita carbon emissions at 8.6 metric tons (mt) per capita in 2014, followed by **Massachusetts, Connecticut**, and **Maryland,** which emitted around 10 mt per capita.[[22]](#endnote-24)

Figure 3: Insert matrix of 50-states GDP and emissions graphs,

At the same time, about eight states have experienced a weaker form of decoupling, reducing emissions about 6 percent while still experiencing economic growth in the neighborhood of 25 percent or more. **California** falls in this category: despite its record of adopting stringent climate action policies, California reduced its emissions by only 6 percent but expanded its economy by 28 percent between 2000 and 2014.[[23]](#endnote-25) States like **Kansas, Kentucky,** and **Wisconsin**, which generate an average of about 17.4 mt per capita—close to the national per capita emissions level of 17.0 mt per capita—are also exhibiting “weak” decoupling. However, it must be noted that California and **Hawaii** have exceptionally low carbon emissions per capita, at 9.3 mt and 12.8 mt, respectively.

In between the strong and weak decouplers, meanwhile, lie about 14 states such as **Indiana**, **Ohio**, **Pennsylvania**, and **Washington** that have each reduced their emissions by 8 percent to 15 percent while increasing the size of their economy by an average of 19 percent. As a group, these states have average per capita carbon emissions of 20.9 mt per capita.

Finally, the data reveal that 16 states, including **Arizona**, **Colorado**, **Iowa**, and **Oklahoma**, have not decoupled and instead experienced rising emissions (an average of 4 percent) along with rising GDP (32 percent) between 2000 and 2014. Several of these states have shown dramatic *increases* in emissions—for example, 26 percent in **Nebraska** and 16 percent in **North Dakota**. Not surprisingly, these 16 states also have some of the highest per capita carbon emissions in the nation. **Wyoming’s** carbon emissions, at 111.6 mt per capita, are the highest, followed by North Dakota’s, at 74.8 mt.

***Changes in the states’ economic structures influence carbon emissions and decoupling****.*

Multiple factors are influencing the pace of decoupling across states, and one of these factors may be the shifting nature of states’ economies. The nation’s economy has been shifting steadily from “dirtier,” more carbon-intensive goods production to less energy-intensive high-tech goods and services provision, and this transition may be contributing to decoupling in some states.

To be sure, a statistical analysis of the impact of changing industry structure on states’ carbon emissions did not find a highly visible relationship between state industry mix and emissions.[[24]](#endnote-26) Nevertheless, copious research highlights the link of sector change and emissions declines. These analyses document that traditional manufacturing is relatively energy- and carbon-intensive while higher-value, high-tech manufacturing is much less so. Services are even less energy- and carbon-intensive.[[25]](#endnote-27)

Regardless of exactly how large the role of industry structure has been in reducing emissions to date, the present analysis does surface some interesting observations. States that have seen their economies shift significantly toward service delivery, for example, have tended to score declines in carbon emissions. In fact, almost all of the states that experienced the largest shift toward services industries also registered large declines in their carbon emissions during 2000-2014. For example, as **Maine’s** service sector’s share of real GDP (in millions of chained 2009 dollars) expanded from 75 percent in 2000 to 83 percent in 2014, its carbon emissions declined by 25 percent. Similarly, **Delaware**, **Georgia**, **North Carolina**, and **Virginia** all experienced some of the largest relative expansions of their service sectors among states and likewise achieved substantial carbon emissions declines of 20 percent, 17 percent, 15 percent, and 15 percent, respectively.[[26]](#endnote-28)

Parallel trends have followed many states’ shifts away from energy-intensive manufacturing to cleaner forms of production, such as computer chip and electronic component manufacturing.[[27]](#endnote-29) **Nevada’s** carbon emissions, for example, declined by 18 percent between 2000 and 2014 as the state’s output from energy-intensive manufacturing industries dropped from 44 percent of manufacturing output to 24 percent. **Connecticut**, **Delaware**, **Maryland**, **New Jersey**, and **Oregon** witnessed similar trends as they shifted from commodity manufacturing to advanced manufacturing during the 15-year period. Clearly, changes in state and local industrial structure have been playing an important role in decoupling and will continue to do so.

***Region and fuel mix matter a lot****.*

Also underlying the varied state-by-state decoupling stories are significant differences in energy sourcing across regions (see Figure 4 and Appendix Table B). Northeastern and many Southern states, for example, have achieved some of the most impressive feats of decoupling, and the shift owes to favorable changes in the states’ fuel mixes.

Figure 4: Insert 50-states map showing change in carbon emissions

Overall, Northeastern states have achieved the largest declines in carbon emissions among states—at 15 percent—even as they significantly expanded their economies by 19 percent between 2000 and 2014. Heavily influencing these trends have been changes in the region’s energy systems.

The Northeastern states, for instance, have been generating more electricity from natural gas and importing more hydroelectric power from Canada. The dramatic shift away from petroleum and coal-fired generation to natural gas-fired output has raised concerns about overreliance on a single fuel, but it has clearly reinforced decoupling.[[28]](#endnote-30) Natural gas accounted for 95 percent of **Rhode Island’s** net electricity generation in 2014, for example, and enabled significant delinking of growth and emissions. In **Connecticut** the share of net generation from natural gas jumped from 12 percent in 2000 to 44 percent in 2014; in **Massachusetts** it jumped from 28 percent to 60 percent. New England states have also maintained or expanded the capacity of multiple zero-emissions nuclear plants, although the Vermont Yankee plant was taken out of service late in 2014.[[29]](#endnote-31) Nuclear plants accounted for no less than 35 percent of Northeastern states’ electricity generation in 2014—the highest share among all regions. These choices have allowed these states to substantially reduce the use of coal and oil as generation fuels even while expanding their economies. In addition, the New England states along with **New York** and **Delaware** are members of the nation’s first regional cap-and-trade program, the Regional Greenhouse Gas Initiative, which has capped carbon dioxide emissions from the power sector. It is not surprising, therefore, that a number of these states have led the national decoupling trend while driving their per capita CO2 emissions to some of the lowest levels among states.

In similar fashion, power-sourcing choices across the South have allowed multiple states there to sever the growth/emissions link. While not as impressive as the Northeastern states, the Southern states reduced their carbon emissions by 7 percent while growing their economies by 30 percent.

Most notably, significant coal-based power generation has been replaced by cleaner natural gas plants, as the share of net electricity generation from natural gas in the South increased from less than 20 percent in 2000 to 35 percent in 2014. **Alabama**, **Delaware**, **Florida**, **Georgia**, and **Virginia** have all shifted significant power generation to natural gas. In addition to natural gas, nuclear plants, which operate in 12 of the 17 Southern states, generated 19 percent of net electricity generation in the South in 2014. Maryland’s sole nuclear power plant supplies 38 percent of the state’s net electricity generation, and the state has curbed its emissions by 20 percent while expanding its economy by 33 percent. Georgia has reduced its emissions by 17 percent while expanding its economy by 15 percent in part because its four nuclear reactors account for more than a quarter of the state’s net electricity generation. In fact, the combination of nuclear plants and coal’s replacement by natural gas has enabled many Southern states to pull off some of the most dramatic decouplings in the country. Like Georgia, **North Carolina**  has supported its double-digit growth and emissions reductions in large part by sourcing nearly 32 percent of its electricity from nuclear and 22 percent from natural gas. Coal-based generation has fallen to just 36 percent.[[30]](#endnote-32) That four new nuclear reactors are under construction in Georgia and **South Carolina** (with another due to begin commercial operation soon in Tennessee) suggests that multiple Southern states will continue to have zero-carbon power at their disposal as they continue to grow.

Decoupling trends in the Midwest and West, by contrast, reflect a far less optimal set of fuel sourcing trends. Both Midwestern and Western states managed carbon reductions of just 5 percent each, while economic growth came in at 14 percent and 30 percent, respectively. Behind these trends lie distinctive energy-sourcing patterns. Most notably, Midwestern states have been able to switch far fewer coal-burning power plants over to natural gas than states in the Northeast and South. In 2014, for example, Midwestern states sourced just 7 percent of their electricity from natural gas generation, compared to 35 percent each for Northeastern and Southern states. That leaves the Midwest far more dependent on coal for generating power—61 percent in 2014 compared to 17 percent in the Northeast, 38 percent in the South, and 27 percent in the West. For example, in 2014 **Iowa**, **Missouri**, and **Nebraska** depended on carbon-intensive coal for 60 percent, 82 percent, and 63 percent of their electricity production, respectively. The West burns more natural gas (enough to account for 30 percent of electricity generation) than the Midwest, and it runs far fewer nuclear plants. At present only **Arizona**, **California**, and **Washington** possess nuclear plants in the West, and the share of net electricity generated by nuclear *declined* from 10.5 percent in 2000 to 7.7 percent in 2014. (This drop may reflect the closure of the San Onofre plant in California in 2013). Overall, compared to states in other regions, most Western states have fewer options to draw on for zero-carbon electricity as they grow.

Wind and solar generation have yet to register an impact on decoupling—even in the green West. In this regard, while solar and wind’s share of electricity generation has been on the rise, its large-scale growth in some states only dates to the last decade, and so this analysis does not find a strong statistical relationship between states’ emissions reductions and solar and wind’s share of power generation.[[31]](#endnote-33) That said, however, wind’s share of electricity generation grew from less than 2 percent in 2009 to 19 percent in 2014 in **Idaho**,and similar trends can be seen in **Kansas**, **North Dakota**, **South Dakota**, **Texas**, and **Wyoming.** However, in most of these states carbon emissions rose between 2001 and 2014, and so the positive impact of solar and wind energy deployment is probably being undercut by other factors. But it is likely that renewables will soon contribute to decoupling and decarbonization.

In sum, it is impossible to overestimate the importance of states’ decisions about electricity sourcing in states’ decarbonization. Overall, the Energy Information Administration concludes that changes in the national mix of electricity production—especially the shift toward cleaner-burning natural gas—accounted for more than two-thirds of the country’s and states’ emissions reductions between 2005 and 2015.[[32]](#endnote-34) That link is extremely visible here. On the one hand, the rapid switch from coal to natural gas in scores of power plants has been a core driver of state-level decoupling and emissions reductions.[[33]](#endnote-35) Overall, the data presented here show a strong relationship between declining reliance on coal for electricity generation in the states and reduced carbon emissions (see Figure 5).[[34]](#endnote-36) Three states—**Idaho**, **Vermont**, and **Rhode Island**—and the **District of Columbia** do not use coal at all for power generation. On the other hand, nuclear power has played an important role in helping the Northeast and Southern states curb their carbon emissions over the past decade even as their economies grew.[[35]](#endnote-37) That **New Hampshire** and **Maryland** obtain 52 and 38 percent of their electricity from nuclear plants allows them to power growth with plentiful zero-carbon energy. At a time when more plants are being shut down than opened, it is important that **Maryland**, **Tennessee**, and **New York** are all increasing the nuclear share of their total generation.

Figure 5: Insert scatterplot showing change in emissions and coal consumption

***Despite significant progress, all states need to do more to decouple emissions from growth and decarbonize their economies.***

Many states have made impressive progress in reducing carbon emissions and decarbonizing their economies. Much of this progress has been aided by the surging domestic production and use of natural gas; in fact, in 2016 natural gas became the number one fuel source for electricity generation.[[36]](#endnote-38) However, much more needs to be done for the United States to come anywhere near to meeting the Paris goal of long-term decarbonization.

According to an analysis by PricewaterhouseCoopers, to prevent global warming in excess of 2 degrees Celsius, the global economy will need to cut its carbon intensity (meaning its emissions of CO2 per dollar of GDP) by a rapid 6.3 percent every year from now to 2100.[[37]](#endnote-39) For its part, the United States will need to decarbonize its economy by 4.3 percent a year from now till 2030.[[38]](#endnote-40) What does that say about the current pace of decarbonization in the United States? It says that the nation and its states—notwithstanding recent progress—are falling short of the goal.

At the national level, for example, the United States decarbonized its economy at a rate of 2.3 percent a year between 2000 and 2014—a pace just over half of the needed pace.

Some states have reduced their carbon intensity faster than others and could be better positioned than others to achieve the needed 4.3 percent a year benchmark (see Figure 6). The decarbonization of state economies has been driven by two forces: the change in the energy intensity of the economy and the change in the carbon intensity of the energy supply.[[39]](#endnote-41) At least 14 states and the District of Columbia, have been decarbonizing their economies at rates above the national rate and sometimes approaching the needed rate of 4.3 percent. At 3.7 percent, 3.3 percent, 3.0 percent, and 2.8 percent, for example, **North Dakota,** **the** **District of Columbia, Alaska,** and **Maryland** accomplished the biggest average annual reductions in carbon intensity between 2000 and 2014 and come close to meeting the 4.3 percent a year mark. The District of Columbia, for example, a city, has been able to lead the nation in decarbonization thanks to a combination of density, progressive energy policies, and fast growth across its relatively low-carbon service industries.[[40]](#endnote-42) Maryland has achieved its rapid rate of decarbonization thanks to significant change in its energy intensity. Maryland’s economy is not energy intensive: service industries contribute two-thirds to the state's GDP while manufacturing, including the manufacture of chemicals and electronics, contributes less than 6 percent.[[41]](#endnote-43) North Dakota’s decarbonization is in some ways deceptive and cautionary as it has been driven more by large oil and gas shipments from its fracking rigs than by a modest shift in its electricity mix from coal to wind energy. By contrast, **Missouri** (0.4 percent), **Mississippi** (0.6 percent), **Nebraska** (0.6 percent), and **Illinois** (0.7 percent) have barely decarbonized their economies at all. In short, all states will need to do significantly more to decarbonize their economies so that they can contribute to the national decarbonization target of 4.3 percent per year going forward.

Figure 6: Insert state carbon intensity numbers 2000-2014

**What needs to happen next?**

The data on decoupling across all 50 U.S. states and the District of Columbia add to the accumulating evidence that places can sever the historical link between economic growth and carbon emissions.

Much more rigorous analysis is needed to understand the many factors that are shaping decoupling state by state and city by city—including policy and fuel-sourcing decisions.

Nevertheless, these data represent an encouraging development: fuel change, technology change, and public policy can reduce in relatively short order the emissions required to generate each unit of economic output. The trends detailed here highlight genuine progress toward environmental responsibility.

Yet in terms of the challenge ahead, the shift toward decoupling across a majority of U.S. states can only be viewed as a beginning. For one thing, not enough states are making enough progress at decarbonizing their economies. For another, what progress has been made has been made largely thanks to the one-time opportunity of switching to natural gas, which is an interim fuel and not a zero-carbon solution.

The essential next step is greatly increased policy action and much stronger investments in technology innovation, both at the state and federal levels.

At the federal level, the strong relationship between coal consumption and carbon emissions highlights the importance of effectively implementing the Environmental Protection Agency’s Clean Power Plan. Continuing to reduce states’ use of coal generation and managing the continued retirement of coal plants is a critical first step toward transforming the power system. At the same time, the importance of nuclear power in many states’ progress combined with the continued reluctance of the private sector to invest in nuclear, given the low price of natural gas, underscores the need for strong federal engagement. Much innovation in business models and economic efficiency is going to be needed to help the nation’s existing fleet of nuclear plants survive. Federal authorities should take steps—in partnership with state and local regulatory authorities—to use production payments and other supports to ensure the continued operation of plants and the possibility of new plants coming on line.[[42]](#endnote-44)

Policy choices at the state level are going to be equally important. Renewable portfolio standards, for example, have already played an important role in increasing the production of energy from renewable sources in many states.[[43]](#endnote-45) Looking forward, the important role of nuclear power in decarbonization underscores the importance of state-level regulatory support. More states need to expressly include nuclear energy in their renewable energy plans, and more states should consider, as New York has done recently, ways that might further subsidize struggling nuclear plants.[[44]](#endnote-46)

In any event, all states can and should advance smart regulatory frameworks for decarbonizing their economies without fearing that their actions will depress economic growth.

Besides policy changes, continued decarbonization will require continued innovation. The federal government and the states need to double down on technology development and diffusion,[[45]](#endnote-47) and the path toward this goal is already visible in the states’ decoupling progress. Technological advances have made wind and solar power cost competitive with coal for electricity generation in many markets.[[46]](#endnote-48) Likewise, the innovation of combining horizontal drilling with hydraulic fracturing enabled the fracking boom, which has allowed the rapid substitution of cleaner natural gas for coal in power plants.[[47]](#endnote-49)

Looking ahead, the potential remains large for new advances that will drive improvements in next-generation energy storage, solar photovoltaic, nuclear, and carbon capture technologies that offer high performance at a fraction of the cost of existing technologies. Among priorities, the development and demonstration of advanced new reactor technologies with lower cost factors rank near the top of a long list of the nation’s innovation needs. Unfortunately, U.S. investment in clean energy research, development, and demonstration has been flat in actual dollars since 2003. That level of resolve won’t get us where we need to be. A step change in our commitment to clean energy innovation is essential if states are to decarbonize their economies at the pace that will be required to prevent warming in excess of 2 degrees Celsius.

**Summing Up**

Ultimately, the reality of emissions decoupling across nations and across states confirms that the transition to a modern energy system can occur without sacrificing growth. In fact, the decoupling of economic growth from carbon emissions in so many states demonstrates that states and cities alike have the opportunity now to craft a new sort of growth that at once widens the circle of prosperity and achieves environmental sustainability.

To seize that opportunity, however, and realize it at the needed scale, states as well as Washington must pile onto decarbonization with a vengeance—with much more concentration than has yet been demonstrated. Notwithstanding the significant progress to date, all of the relevant actors need to do much more to further decouple growth from emissions and decarbonize their economies. The challenge now is to broaden the decoupling of growth from emissions to all states, increase the pace of decarbonization, and maintain it for decades to come.

APPENDIX A: U.S. + 50-states and DC change of GDP, change of emissions, decarbonization rate

APPENDIX B: Fuel mix for 50 states and DC

1. International Energy Agency (IEA), “Global Energy-Related Emissions of Carbon Dioxide Stalled in 2014,” March 13, 2015; IEA, “Decoupling of Global Emissions and Economic Growth Confirmed,” March 16, 2016. [↑](#endnote-ref-1)
2. WRI found that 21 countries, including the United States, have fully “decoupled” their economic growth from carbon emissions over the last 15 years. Carbon Brief, which extended the data to include all 216 countries, not just the 67 used in the WRI study, found that 35 countries increased their real GDP at the same time they cut their carbon emissions. For more information, see Nate Aden, “The Roads to Decoupling: 21 Countries Are Reducing Carbon Emissions While Growing GDP” (Washington: World Resources Institute, 2016); and Sophie Yeo and Simon Evans, “The 35 Countries Cutting the Link Between Economic Growth and Emissions” (London: Carbon Brief, 2016). [↑](#endnote-ref-3)
3. For more details about COP 21, see United Nations Framework Convention on Climate Change, “Paris Agreement,” <http://unfccc.int/paris_agreement/items/9485.php>. The United States and China, the two top emitters of greenhouse gases, formally ratified the Paris Agreement on September 3, 2016; see Jean Chemnick, “U.S. and China Formally Commit to Paris Climate Accord,” *Scientific American*, September 6, 2016. [↑](#endnote-ref-4)
4. Barry Rabe, “Statehouse and Greenhouse: The States Are Taking the Lead on Climate Change” (Washington: Brookings Institution, 2002). [↑](#endnote-ref-6)
5. Don Grant et al., “Effectiveness of State Policies in Reducing CO2 Emissions From Power Plants,” *Nature Climate Change* 4 (2014): 977-82.

   [↑](#endnote-ref-7)
6. Energy-related carbon dioxide emissions data at the state level are available at the EPA website <https://www.epa.gov/statelocalclimate/state-energy-co2-emissions>. The data include state CO2 emission inventories from fossil fuel combustion, by end-use sector (commercial, industrial, residential, transportation, and electric power), in million metric tons of carbon dioxide (MMTCO2) from 1990 through 2014. EPA developed these state-level CO2 estimates using (1) fuel consumption data from the Department of Energy (DOE)/Energy Information Administration (EIA) State Energy Data 2014 Consumption tables and (2) emission factors from the Inventory of U.S. Greenhouse Gas Emissions and Sinks 1990-2014. State GDP has been obtained from the Bureau of Economic Analysis and is in millions of chained 2009 dollars. See <http://www.bea.gov/regional/>. [↑](#endnote-ref-8)
7. As an exploratory analysis, Brookings researchers employed ordinary least squares (OLS) and fixed effects (by state) estimation techniques to evaluate the impact of a number of factors on state change in carbon emissions between 2000 and 2014. The dependent variable in all the models is the percent change of CO2 emissions by state from year to year. The independent variables employed include: economic structure variables relating to the percent change in share of private industries output of goods-producing sectors, service-producing sectors, manufacturing sectors, and energy-intensive manufacturing sectors; the percent change of fuel sources as a share of total electricity generation with sources of coal, natural gas, nuclear, hydro, wind and solar combined; the percent change in state gross GDP from year to year; region of the state; the percent change in population density from year to year; the percent change in population from year to year; and a series of year dummy variables for 2001 to 2014 (with 2001 as the reference group). With 50 states and the District of Columbia, there were 714 observations across all the models. A total of six models was run and the R-squared was between 0.415 and 0.421 across the models, indicating a relatively strong model fit. [↑](#endnote-ref-9)
8. While the literature discussing the energy intensities of industries in the services sector, such as information, finance, and health care, is limited, it is generally believed that these industries emit comparatively less carbon than the manufacturing sector. See Brynhildur Davidsdottir and M. Fisher, “The Odd Couple: The Relationship Between State Economic Performance and Carbon Emissions Economic Intensity,” *Energy Policy* 39, no. 8 (2011): 4551-562; B.W Ang., “Is the Energy Intensity a Less Useful Indicator Than the Carbon Factor in the Study of Climate Change?” *Energy Policy* 27, no. 15 (1999): 943-46. [↑](#endnote-ref-10)
9. Renewable portfolio standards (RPS), for instance, have been found to have a negative and significant impact on state carbon intensities through their influence on state electricity prices. Additionally, the adoption of RPS was found to reduce overall U.S. carbon emissions by 4 percent by 2010. See Samantha Sekar and Brent Sohngen, “The Effects of Renewable Portfolio Standards on Carbon Intensity in the United States” (Washington: Resources for the Future, 2014). Another paper found significant and robust decreases in carbon emissions associated with the introduction of public benefit funds, a form of carbon tax, adopted by various states. See Monica Prasad and Steven Munch, “State-Level Renewable Electricity Policies and Reduction in Carbon Emissions*,” Energy Policy* 45 (2012): 237-242; and Grant et al. (2014). [↑](#endnote-ref-11)
10. International Panel on Climate Change (IPCC), “Climate Change 2014: Mitigation of Climate Change” (Geneva: IPCC, 2014). [↑](#endnote-ref-12)
11. Terence Jeffrey, “U.S. Has Record 10th Straight Year Without 3% Growth in GDP,” *CBS News*, February 26, 2016. [↑](#endnote-ref-13)
12. The issue of whether GDP growth can be delinked from carbon emissions is usually framed in terms of the Carbon Kuznets Curve (CKC). The CKC hypothesis holds that carbon emissions initially increase with increasing growth (due to industrialization), but later peak and decline after a threshold level of per capita GDP as countries become more energy efficient, more technologically sophisticated, and more inclined to reduce emissions by corresponding legislation. The empirical work to test the CKC hypothesis has produced varying results. Some studies have found that CO2 and other greenhouse gases do not decline after a country reaches a higher stage of economic development; rather CO2 emissions increase monotonically with income. Other studies have found that CO2 emissions continue to increase only for developing countries. For a good discussion of the literature, see Kris Aaron Beck and Pratibha Joshi, “An Analysis of the Environmental Kuznets Curve for Carbon Dioxide Emissions: Evidence From OECD and Non-OECD Countries,” *European Journal of Sustainable Development* 4, no. 3 (2015): 33-45. [↑](#endnote-ref-14)
13. Aden (2016). [↑](#endnote-ref-15)
14. Yeo and Evans (2016). [↑](#endnote-ref-16)
15. Looking at GDP and emissions data from 1990 to 2015. [↑](#endnote-ref-17)
16. David Victor et al., “Introductory Chapter,” in *Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* (Cambridge, England: Cambridge University Press, 2014). [↑](#endnote-ref-18)
17. Data on state industry structure have been obtained from Bureau of Economic Analysis, “State Output by Industry,” <http://www.bea.gov/regional/index.htm>. Data on state fuel mix are from EIA, “Net Generation by State by Type of Producer by Energy Source (EIA-906, EIA-920, and EIA-923), 1990-2014,” <https://www.eia.gov/electricity/data/state/>. [↑](#endnote-ref-19)
18. The decline over the years can be mainly attributed to changes in the electric power sector—arising from decreased use of coal and increased use of natural gas for electricity generation. See EIA, “U.S. Energy-Related Carbon Dioxide Emissions in 2015 Are 12% Below Their 2005 Levels,” May 9, 2016. [↑](#endnote-ref-20)
19. Michigan is an outlier, having reduced its carbon emissions by 16 percent while also experiencing a negative GDP growth of 2 percent. [↑](#endnote-ref-21)
20. The District of Columbia reduced its carbon emissions by 30 percent while growing its economy by 32 percent during the same period. [↑](#endnote-ref-22)
21. During the 2008-2014 period, for instance, Connecticut, Maine, and Nevada decreased their carbon emissions by 7 percent, 13 percent, and 9 percent, respectively, but their GDP declined significantly following the Great Recession, by 4 percent, 2 percent, and 7 percent, respectively. Feng et al. found that 83 percent of decrease in carbon emissions between 2007 and 2009 can be attributed to economic decline and the remaining 17 percent to changing energy sources; see Kuishuang Feng et al., “Drivers of the US CO2 Emissions 1997-2013,” *Nature Communications* 6 (2015). [↑](#endnote-ref-23)
22. Brookings analysis of EPA’s “CO2 Emissions From Fossil Fuel Combustion—Million Metric Tons CO2 (MMTCO2)” and state population data for 2014. [↑](#endnote-ref-24)
23. California is an interesting example for a variety of reasons. The state has some of the strictest policies in place to curb greenhouse gas emissions. It also has one of the lowest carbon intensities as well as per capita carbon emissions among all states. And yet, compared to other climate-friendly states like Massachusetts and New York, it experienced a slower reduction in carbon emissions between 2000 and 2014. [↑](#endnote-ref-25)
24. In all regressions, variables measuring the economic structure of a state were found to be statistically insignificant. It possible that the impact of this variable is weaker, slower moving, or more diffused than other factors. More data and better model specification in future research will likely uncover the impact of states’ economic structure on change in carbon emissions over time. Four variables were used to measure state economic structure: percent change in the share of goods-producing sectors’ output to all private industry output, percent change in the share of services-producing sectors’ output to all private industry output, percent change in the share of manufacturing sectors’ output to all private industry output, and percent change in the share of energy-intensive manufacturing sectors’ output to all private industry output. [↑](#endnote-ref-26)
25. See, about manufacturing, Lee Schipper et al., “Carbon Emissions From Manufacturing Energy Use in 13 IEA Countries: Long Term Trends Through 1995,” *Energy Policy* 29, no. 9 (2001): 667-88; and Oak Ridge National Laboratory, “U.S. Manufacturing Energy Use and Greenhouse Gas Emissions Analysis” (Oak Ridge, Tenn.: 2012). For discussion that includes the energy and emissions performance of services industries see Davidsdottir and Fisher (2011) and Ang (1999). [↑](#endnote-ref-27)
26. Georgia’s service sector’s share of real GDP grew from 75 percent in 2000 to 82 percent in 2014, North Carolina’s from 63 percent to 72 percent, and Virginia’s from 76 percent to 83 percent. [↑](#endnote-ref-28)
27. EIA, “Chapter 7. Industrial Sector Energy Consumption,” in *International Energy Outlook 2016* (Washington: EIA, 2016). Energy-intensive industries emit large quantities of CO2, related to both their energy consumption (combustion emissions) and their production processes (process emissions). For purposes of this analysis, Brookings researchers have placed in the energy-intensive category food manufacturing (NAICS 311); paper manufacturing (NAICS 322); petroleum and coal products manufacturing (NAICS 324); chemical manufacturing (NAICS 325); primary metal manufacturing (NAICS 331), which includes the iron and steel and alumina and aluminum industries; and non-metallic mineral product manufacturing (NAICS 327), which includes the cement and glass industries. [↑](#endnote-ref-29)
28. EIA, “Northeast Grows Increasingly Reliant on Natural Gas for Power Generation,” November 12, 2013. As increasing amounts of natural gas are being used for electricity generation in the New England states, assurance of natural gas supply has become a critical energy issue for the region. [↑](#endnote-ref-30)
29. Vermont is an exception. At the end of 2014, Vermont shut down the Vermont Yankee Nuclear Plant and with that the state lost 55 percent of its electricity generating capacity and the source of more than 70 percent of its net generation in recent years. See Vermont’s energy profile, <http://www.eia.gov/state/analysis.cfm?sid=VT>.

    [↑](#endnote-ref-31)
30. For more details, see North Carolina’s energy profile, <http://www.eia.gov/state/?sid=NC>. [↑](#endnote-ref-32)
31. Both OLS and fixed-effects (by state) estimation techniques were used with cluster-robust standard errors (states being the clusters) to estimate the impact of solar and wind combined on carbon emission change across states. The dependent variable is percent change of CO2 emissions by state from year to year. In all of these regressions, the coefficients on the percent change of wind and solar sources as a share of total electricity generation were statistically insignificant, with p-values all below 0.10. The magnitudes were all negative, which conforms with expectations and suggests that further study may possibly show statistically significant decreases in CO2 emissions due to larger shares of solar and wind electricity generation. [↑](#endnote-ref-33)
32. EIA, “U.S. Energy-Related Carbon Dioxide Emissions in 2015 Are 12% Below Their 2005 Levels,” May 9, 2016. [↑](#endnote-ref-34)
33. Coal still represents 34 percent of electricity generation in the United States, but its use is in decline. Several factors have contributed to the gradual decline in coal consumption, including the availability and price of other electricity-generating fuels like natural gas and cleaner energy generation options like wind and solar. While coal’s share of electricity generation has fallen from 54 percent in 1990 to 34 percent in 2015, the natural gas share of electricity generation has grown tremendously, from 11 percent in 1990 to 32 percent in 2015. At the same time, renewables other than hydropower have been growing their share of electricity generation in recent years. Wind and solar’s share of generation has increased from a mere 1 percent in 2005 to 6 percent in 2015. Hydropower contributed 6 percent in 2015 as well. See Brookings analysis of EIA’s “Share of Three Fossil Fuels and of Non-Fossil Fuel Generation 1990-2014,” <http://www.eia.gov/environment/emissions/carbon/>. The 2015 data are available at <https://www.eia.gov/tools/faqs/faq.cfm?id=427&t=3>. [↑](#endnote-ref-35)
34. In all regressions, the coefficients on the percent changes of coal as a share of total electricity generation were statistically significant. For each 1 percentage point increase in the share of total generation by coal, CO2 emissions increased by 0.044 to 0.045 of a percentage point. [↑](#endnote-ref-36)
35. In all regressions, the coefficients on the percent changes of nuclear as a share of total electricity generation were statistically significant. For each 1 percentage point increase in the share of total generation by nuclear, CO2 emissions decreased by 0.094 to 0.097 of a percentage point. [↑](#endnote-ref-37)
36. EIA, “Natural Gas Expected to Surpass Coal in Mix of Fuel Used for U.S. Power Generation in 2016,” March 16, 2016, <http://www.eia.gov/todayinenergy/detail.cfm?id=25392>. [↑](#endnote-ref-38)
37. PricewaterhouseCoopers (PwC), “Conscious Coupling? Low Carbon Economy Index 2015” (London: PwC, 2015). [↑](#endnote-ref-39)
38. Ibid. [↑](#endnote-ref-40)
39. The energy intensity of a state is measured by the amount of energy consumed per unit of economic output. The carbon intensity of energy supply is reflective of the energy fuel mix within a state. The product of these measures gives the carbon intensity of the economy. [↑](#endnote-ref-41)
40. The District of Columbia has a very different carbon emissions breakdown compared to other cities. Buildings—including the administrative hubs for massive federal agencies, foreign embassies, lobbying groups, and think tanks—generate 75 percent of all greenhouse gas emissions in the city. DC, therefore, has one of the most progressive green building policy and implementation frameworks in the nation. It was the first U.S. city to pass a green building law. It is the leading metro area for number of Energy Star certified buildings. For more information see <http://database.aceee.org/state/district-columbia>. [↑](#endnote-ref-42)
41. Brookings analysis of U.S. Bureau of Economic Analysis, Interactive Data, GDP and Personal Income, Regional Data, Annual Gross Domestic Product (GDP) by State, GDP in current dollars, All industries, Maryland, 2013. [↑](#endnote-ref-43)
42. Secretary of Energy Advisory Board (EAB), “Task Force on the Future of Nuclear Power: Draft Report” (Washington: EAB, 2016). [↑](#endnote-ref-44)
43. Galen Barbose, “Renewable Portfolio Standards in the United States: A Status Update” (Berkeley, Calif.: Lawrence Berkeley National Laboratory, 2013). [↑](#endnote-ref-45)
44. See, for example, Richard Martin, “New York State Has a Plan to Rescue Nuclear Power,” *MIT Technology Review*, August 2, 2016, and Vivian Yee, “Nuclear Subsidies Are Part of New York’s Clean-Energy Plan,” *New York Times,* July 20, 2016. [↑](#endnote-ref-46)
45. Varun Sivaram and Teryn Norris, “The Clean Energy Revolution” *Foreign Policy,* April 18, 2016. [↑](#endnote-ref-47)
46. Camila Stark et al., “Renewable Electricity: Insights for the Coming Decade” (Golden, Colo.: Joint Institute for Strategic Energy Analysis, 2015). [↑](#endnote-ref-48)
47. John Golden and Hannah Wiseman, “The Fracking Revolution: Shale Gas as a Case Study in Innovation Policy,” *Emory Law Journal* 64, no 4 (2014-2015): 955-1040. See also Ted Nordhaus et al., “High Energy Innovation: The Case of Shale Gas” (Oakland, Calif.: Breakthrough Institute, 2014). [↑](#endnote-ref-49)