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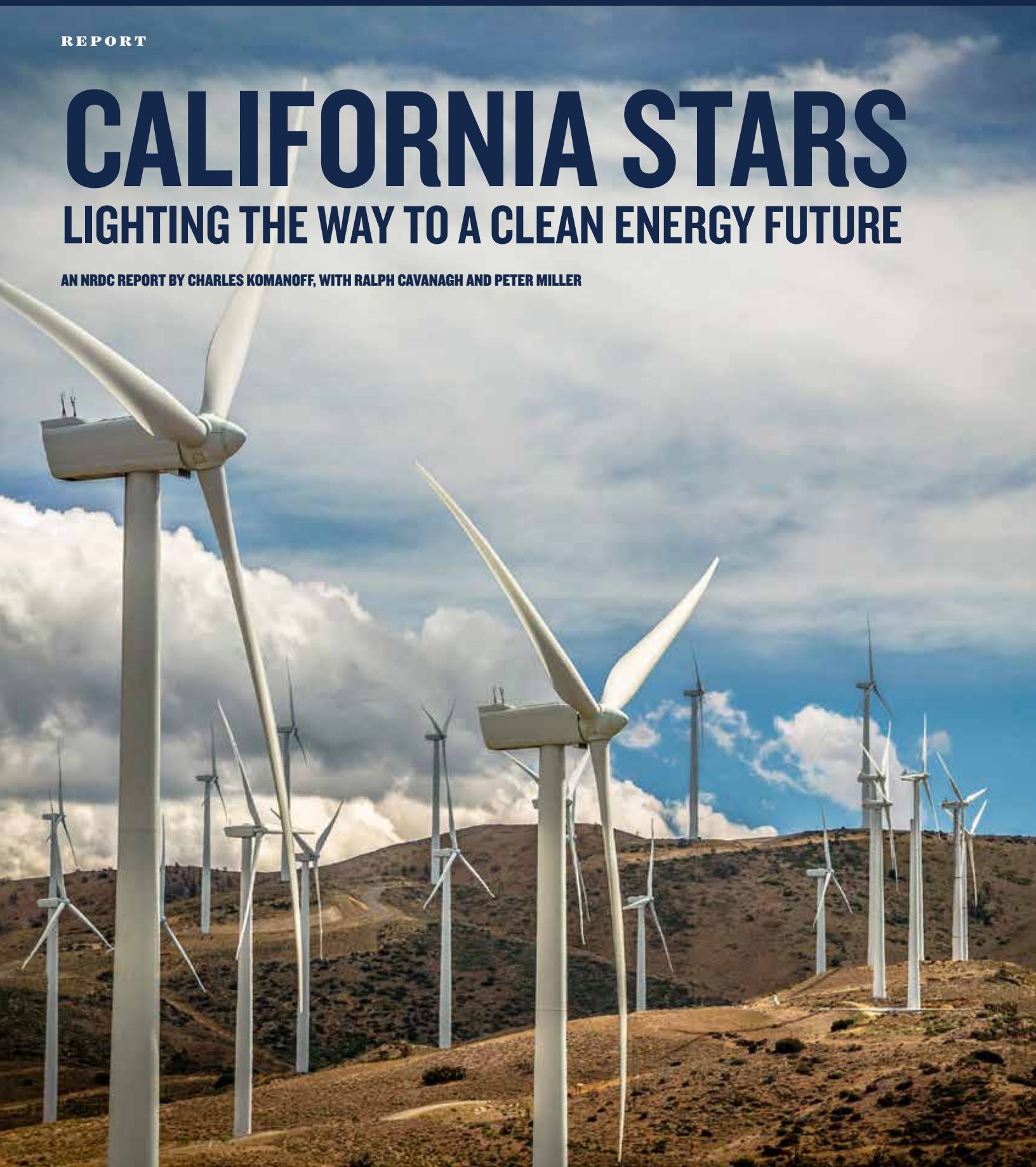
REPORT

CALIFORNIA STARS

LIGHTING THE WAY TO A CLEAN ENERGY FUTURE

AN NRDC REPORT BY CHARLES KOMANOFF, WITH RALPH CAVANAGH AND PETER MILLER



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In its layout and editing, this report bears repeated witness to the diverse skills and high standards of Mary Heglar, NRDC's Director of Publications, and its Policy Publications Editor, Leah Stecher. The author and contributing authors owe an enduring debt to them both.

Caltrans and the California Energy Commission staff were extraordinarily helpful in directing us to data on California economic output, energy use, vehicle-miles traveled, and other key indicators.

University of Chicago sophomore Rohan Kremer Guha helped launch this project as an intern at my consulting firm in September 2018, when he tracked down initial figures on California's historical and current energy consumption; these figures pointed to the divergence in fossil fuel intensity between California and the rest of the United States that animates this report.

Most of all, I acknowledge the vision of Jerry Brown in embedding green energy and sustainability in California's DNA during his first two terms as governor and throughout his public life; and the tenacity and persuasiveness of Ralph Cavanagh in helping to implement that vision from the early 1980s through the present day.

This report is dedicated to the memory of Art Rosenfeld, whom I never met but whose far-seeing leadership laid the groundwork for the accomplishments reported here.

— Charles Komanoff

ABOUT THE AUTHORS

Economist and policy analyst **Charles Komanoff** cofounded the Carbon Tax Center and the pedestrian rights group Right Of Way, and "re-founded" the bicycling advocacy organization Transportation Alternatives. His work includes books (*Power Plant Cost Escalation*, *Killed by Automobile*, *The Bicycle Blueprint*), the spreadsheet model used by New York State government and transit advocates to evaluate congestion pricing for New York City, scholarly articles, and journalism. An honors graduate of Harvard University and parent of two grown sons, Charles lives with his wife in lower Manhattan. Website: www.komanoff.net.

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About NRDC

The Natural Resources Defense Council is an international nonprofit environmental organization with more than 3 million members and online activists. Since 1970, our lawyers, scientists, and other environmental specialists have worked to protect the world's natural resources, public health, and the environment. NRDC has offices in New York City, Washington, D.C., Los Angeles, San Francisco, Chicago, Montana, and Beijing. Visit us at nrdc.org.

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Preface

Reading this report, I was reminded repeatedly of former California energy commissioner Art Rosenfeld, a global giant in the field of energy efficiency. The whole world now claims him, but he was a proud Californian first. A reporter called Art in 2006, after the state enacted the nation's first economy-wide statutory cap on greenhouse gas emissions, and asked him when Californians could expect benefits from their climate leadership to begin emerging. "I'd say roughly in 1975," Art responded. He was not just a leader in documenting those unfolding benefits, but more fundamentally was himself a major contributor to producing them, through pioneering advances in both technology and policy. His "Rosenfeld Curve" showed how decades of sustained and coordinated innovation, investment, and government action helped to cut California's electricity needs dramatically, compared with the rest of the nation.

In this report, Charles Komanoff and his collaborators provide enhanced understanding of the broad benefits produced by our state's long-term commitment to energy efficiency. Behind the simple, powerful visual of the Rosenfeld Curve are robust reductions in economy-wide energy needs and concrete economic benefits that can now be measured in the hundreds of billions of dollars. As a member of the California Energy Commission, I have a deep appreciation of, and am immensely grateful for, my state's achievements. Even so, Komanoff's findings are remarkable and exciting even to me. I hope that they can help other states (including but not limited to Komanoff's native New York) to match and outdistance California's results. California need not seek or receive any credit in this process; a successful collective advance toward a clean energy transition will itself be gratifying enough.

This work helps us learn from the past as we remain laser-focused on the future. How do we further bend the curve, in earnest, toward a low-emissions future? The whole world urgently needs templates for success. As you delve into this report, you'll get a new look at the leading edge of that transition. You will emerge heartened, though—given the challenges we face—not at all complacent. We have much still to do together within and beyond California, but it is crucial to understand how far we have come and how much we have learned and gained.

California Energy Commissioner J. Andrew McAllister, Ph.D.

Executive Summary

For the United States as a whole, economic growth has far outpaced increases in fossil fuel use for decades. Since 1975, this decoupling has been much larger in California than in the rest of the country. This report explores the reasons and consequences, and concludes as follows:

- Had the other 49 states reduced fossil fuel use relative to economic activity at the same pace as California, nationwide carbon emissions would have been lower in 2016 by 1,200 million metric tons, or 24 percent.
- California was able to cut its fossil fuel use relative to economic activity 18 percent faster than the rest of the country, thanks to a sustained commitment to efficiency and clean energy policies and programs.
- While California has been adopting energy efficiency standards and policies to drive down greenhouse gas emissions, its population and economy have grown at faster rates over the past 40 years than have the population and economy of the country as a whole.

This is a compelling illustration of how we can protect our environment and grow our economy at the same time. Key policies that contributed to California's achievement include:

- Consistent emphasis on energy efficiency as the fastest, cheapest, and cleanest way to meet the energy needs of a growing economy;
- Empowerment of regulators to adopt and regularly strengthen energy efficiency standards to reduce the amount of electricity and fuel required to operate appliances, equipment, and buildings;
- Coordinated investment in research and development and in incentive programs to bring new technologies from the lab into widespread use, and from there into energy efficiency standards;
- Enlistment of regulated utilities as critical clean-energy partners and investors, while ensuring that their financial health is not linked to increases in energy use;
- Statewide renewable energy requirements that have pushed down the cost of wind and solar electricity while ratcheting targets up to 60 percent of total generation by 2030;
- Clean vehicle and low-carbon fuel standards that reward lower-emissions alternatives to conventional vehicles and fuels
- Aggressive support for efficient electrification, starting with the transportation sector; and
- Statewide targets for reducing greenhouse gas emissions, coupled with diverse programs—including a declining cap on emissions from major sources—that allow flexibility to help minimize the cost of reductions.

Introduction

I'd give this world
Just to dream a dream with you
On our bed of California stars
Woody Guthrie, "California Stars"

Since the 1970s, California has gained prominence for its innovative energy policies. Successive administrations have adopted efficiency standards for appliances and buildings, mileage and emissions standards for motor vehicles, and broad-ranging measures intended to reduce the societal and environmental costs of making and consuming energy. There has been some criticism from proponents of free-market, expansionist energy policies.[1] Still, the California program has been remarkably fruitful in improving energy efficiency and productivity—so much so that elements have been copied nationwide.

Surprisingly, however, no one has examined changes in California's use of fossil fuels over this four-decade period and compared them with changes in the rest of the United States. This omission is especially striking given the alarming rate at which carbon dioxide emissions from burning coal, oil, and gas are baking the earth's atmosphere and oceans and destabilizing our climate.

California's population and economy have also grown at faster rates over the past 40 years than have the population and economy of the country as a whole. Accordingly, this report looks not at raw consumption figures but at the change in California's ratio of fossil fuel consumption to GDP output and compares the state's progress in reducing this ratio relative to the other 49 states since 1975.[2]

Across the United States, economic growth has far outpaced increases in fossil fuel use. However, since 1975 this decoupling has been much larger in California than in the other 49 states. Our singular finding is this: Had the rest of the United States reduced fossil fuel use relative to economic activity at the same pace as California, we would have reduced our nationwide emissions of carbon pollution by 1,200 million metric tons in 2016 *alone*.

That is a staggering amount. Expressed another way, ***because of the failure of the other 49 states to match California's progress in cutting dependence on fossil fuels, the United States today is emitting 25 percent more carbon pollution than if it had followed California's lead.***

This report explains how we arrived at this conclusion and, as much as possible, ties our findings to specific energy policies. It also sets a marker for the other states and our national government to pursue policies that protect our environment and grow our economy at the same time.

UNDERSTANDING OUR FINDINGS

These points explain our units of analysis and place them in context:

- Our basic metric is the ratio of fossil fuel consumption (measured as British thermal units, or Btus) to economic output (in gross domestic product, or GDP), which we quantify for both California and the other 49 states as a whole.
- We compare changes in this metric between 1975, a pivot point for energy policy in California and nationwide, and 2016, the most recent year for which comprehensive data are available for both California and the rest of the country.
- To the extent that GDP growth in California has been concentrated disproportionately in economic sectors that are less energy-intensive, such as technology, our metric may overstate California's progress in reducing fossil fuel dependence.
- Conversely, our calculations treat California's imports of electricity from neighboring states and countries as if they were generated by burning fossil fuels, even though we know that some imports are generated from non-carbon hydroelectric and nuclear sources. Since the amount of electricity imported to California grew enormously over the 41-year period subject to analysis, this assumption leads to more conservative findings than might otherwise emerge.
- A further conservatism is that our 49-state comparative baseline was made less fossil fuel–dependent by efficiency standards and programs pioneered in California.

Detailed information on our data sources, assumptions, and calculations, including links to the spreadsheet we created and used for this report, are in the appendix.

Finally, it is worth noting that a comparative assessment of fossil fuel usage relative to economic activity is a helpful metric, but it can lend itself to an overly optimistic view, since recent and forecasted increases in global temperatures dictate cutting carbon emissions not just relatively but absolutely, as we discuss in the Conclusion.

Why California Excels

Blessed with mild temperatures and abundant hydroelectricity, and with a large share of its population living in urban areas that inherently consume less energy, California has always been among the least fossil fuel–dependent states.[3,4] Throughout the decade from 1964, when California overtook New York as the most populous state, to 1973, the year of the first energy crisis, California consistently required only three-fourths as much coal, oil, and natural gas as the rest of the country to create a given amount of economic output.[5,6]

California's lead over other states began widening in 1975, the start of Jerry Brown's first term as governor and roughly the time that public policymakers began seeking to address energy shortages and environmental concerns both in California and nationwide. In that year, California produced 1.30 times as much economic output per Btu of fossil fuels as the rest of the country. By 2016, the last year with fully representative data, that ratio had increased to 1.75. As Table 1 demonstrates, from 1975 to 2016 California reduced its use of fossil fuels per unit of economic output by 70 percent. For the other 49 states collectively, the reduction was only 60 percent.

TABLE 1: CALIFORNIA VS. THE OTHER 49 STATES, FOSSIL FUELS PER UNIT OF ECONOMIC OUTPUT, 1975 AND 2016

	1975	2016	RATIO, 2016 TO 1975	CHANGE, AS A %
CALIFORNIA				
Fossil Fuel Consumption (10^{12} Btu)	5,389	6,646	1.23	+ 23%
GDP (2009$, billions)	$564	$2,343	4.16	+ 316%
Fossil Fuels/GDP (10^{3} Btu per $)	9.56	2.84	0.30	– 70%
49 OTHER STATES				
Fossil Fuel Consumption (10^{12} Btu)	59,967	72,023	1.20	+20%
GDP (2009$, billions)	$4,838	$14,473	2.99	+ 199%
Fossil Fuels/GDP (10^{3} Btu per $)	12.39	4.98	0.40	– 60%

See appendix for sources and derivation of figures.

At first glance, a 70 percent reduction in fossil fuel use versus a 60 percent reduction may not sound significant. But it equates to 1,200 million excess metric tons of carbon pollution in 2016 alone—a huge missed opportunity for the rest of America.

Those additional 1,200 million metric tons of carbon emissions in 2016 are roughly as much as the tailpipe emissions of all U.S. passenger vehicles that year. In effect, because the United States as a whole didn't act as aggressively as California to reduce economic dependence on fossil fuels, we missed a chance to wipe out the carbon emissions equivalent of our entire fleet of automobiles.

Moreover, based on consumption figures over the past quarter century (1990 to 2016), the failure of the rest of the country to mirror California's fuel progress added an entire percentage point to the annual growth rate of fossil fuel use across the United States.[7]

For the most part, these findings do not depend on California's temperate climate and abundant natural resources. We are not arguing that the rest of the country should have matched California's unusually low *level* of fossil fuel use, but that it could have matched California's *pace of reducing* its reliance on those climate-damaging fuels.

How has California managed to cut its fossil fuel use relative to economic activity faster than the rest of the country? The answer lies in a sustained commitment to efficiency and clean energy policies and programs for more than four decades, an endeavor that has continued with relatively little variation in policy across changes in party in the governor's office. Since 1974, when then governor Ronald Reagan established the California Energy Commission to approve both efficiency policies and power plant permits, California state government has initiated policies that have gone far beyond other U.S. states in putting efficiency at the center of state energy policy.

To be clear, we are not saying that California's relative success in cutting fossil fuel use while growing its economy was solely the result of targeted clean energy policies and programs. A significant, though uncertain, share of the credit goes

to California's unique economic base, which in recent decades has been driven by the technology sector. Technology is less materials-intensive than other industries and more amenable to policy-driven efficiency gains.[8] On the other hand, our analysis also does not account for the spin-off impacts of California's policies on the rest of the nation, a phenomenon that lessens the state's difference from the rest of the country. A full attribution of these influences would increase the overall impact of California's policies, likely offsetting any reduction from the contribution of other factors.

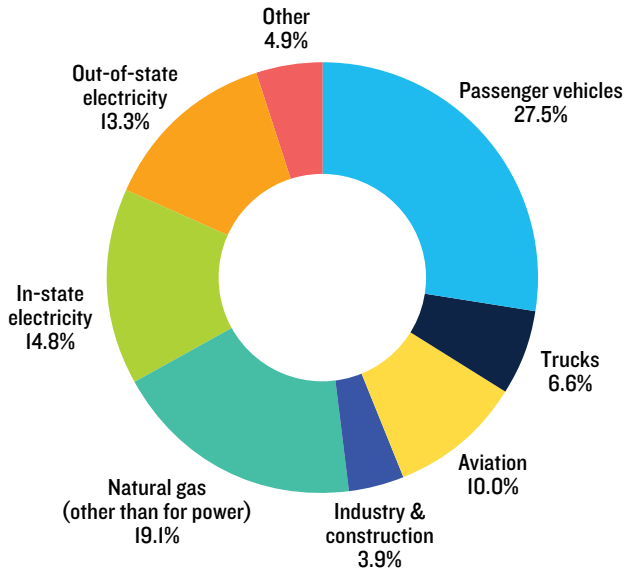
The success of California's approach to energy is most evident in the electricity sector, though it is also visible, to a lesser extent, in transportation and other sectors. Key elements have included:

- Consistent emphasis on energy efficiency as the fastest, cheapest, and cleanest way to meet the energy needs of a growing economy;
- Empowerment of state engineers and regulators to implement energy efficiency standards to reduce the amount of electricity and fuel required to operate appliances, equipment, and buildings;
- Coordinated investment in research and development and in incentive programs to bring new technologies from the lab into widespread use, and from there into energy efficiency standards;
- Enlistment of regulated utilities as critical clean-energy partners and investors, while ensuring that their financial health is decoupled from changes in energy use;
- Statewide renewable energy requirements that have pushed down the cost of wind and solar electricity while ratcheting targets up to 60 percent of total generation by 2030;
- Low-carbon fuel standards that reward lower-emissions alternatives to conventional vehicle fuels;
- Aggressive support for electrification of the transportation sector;
- Starting in 2006, statewide targets for reducing CO_2 emissions coupled with diverse programs (including a cap on total emissions) that allow flexibility to help minimize the cost of reductions.

Current Fossil Fuel Use in California

California has taken great strides in reducing its dependence on fossil fuels. Continuing on this path will require first accounting for current fossil fuel use and then identifying potential areas of improvement.

FIGURE I: HOW FOSSIL FUELS ARE USED IN CALIFORNIA



Source: 2016 EIA data, compiled into categories by the author

As shown in Figure 1, no one category dominates fossil fuel consumption in California. The largest category, travel in passenger vehicles, accounts for about 27 percent of total fossil fuel use, and no other usage category reaches 20 percent.

But if we combine passenger vehicles, trucks, and aviation, this transportation "super sector" accounts for a robust 44 percent of the state's total fossil fuel use, and even more if "upstream" fuel (that is, fuel used in refining oil into gasoline) is allocated to this sector. Electricity generation accounts for another 28 percent of the total, which our graph displays in two sections: electricity generated in-state (nearly all from natural gas) and electricity generated out of state and transmitted to California across state and national borders.

The imported electricity category is almost as large as the in-state one, indicating that generating stations across the American West and in Canada and Mexico provide nearly as much electricity to California as do in-state fossil fuel plants. However, this is based on a conservative assumption made

in our methodology: that all electricity transmitted to California from outside the state is generated from fossil fuels, even though this is not the case.

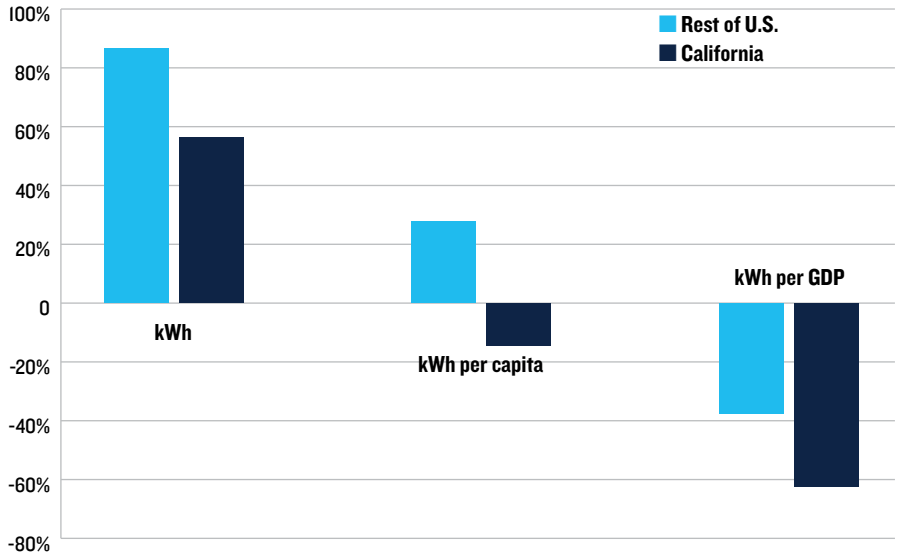
In fact, while we made that assumption for simplicity's sake, we know that a large amount of electricity brought to California from outside the state originates as hydroelectricity in Oregon and Washington, and an additional amount is from the Palo Verde nuclear power plant in Arizona, the nation's largest reactor complex. Our assumption thus overstates the fossil fuel contribution of California's imported electricity. A granular accounting would show California with an even lower rate of growth in fossil fuel use over time.

Electricity: Where California Most Stands Out

Electricity is the energy sector most easily influenced through policy. It is also the one in which California has most distinguished itself in reducing fossil fuel dependence. Fully half of California's reductions in fossil fuel use relative to the rest of the nation come from the electricity sector.

Let's be clear up front: California did not cut its electricity generation from fossil fuels in absolute terms over the entire 1975–2016 period of our analysis (though it has done so since 2008). Over the four decades as a whole, California's generation of fossil fuel-derived electricity actually increased by 56 percent. But during the same period, the state's population grew by 82 percent. As a result, *per capita* fossil fuel power generation decreased by 14 percent.

FIGURE 2: CHANGES IN FOSSIL FUEL ELECTRICITY USE, 1975–2016



Moreover, state GDP more than quadrupled during the period. Per dollar of economic output, California's generation of fossil fuel-based electricity fell by 62 percent from 1975 to 2016.

Figure 2 shows those changes along with analogous changes for the other 49 states. The differences are striking: fossil fuel–generated electricity for the 49 states increased by 87 percent versus California's 56 percent; fossil fuel electricity per capita was up 28 percent nationwide while California's *fell* by 14 percent; and fossil fuel electricity per unit of economic activity decreased by 38 percent in the rest of the country, whereas California's dropped 62 percent.[9]

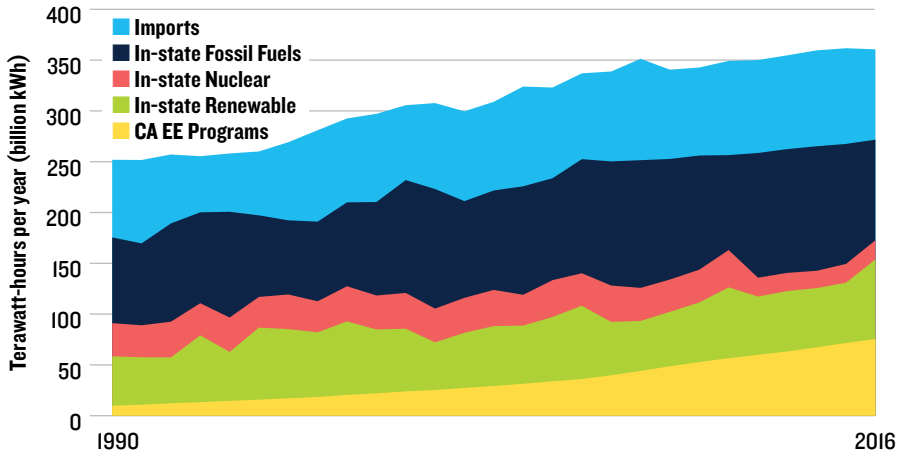
The difference between California's 62 percent reduction in fossil fuel electricity use per GDP and the 49 states' 38 percent reduction signals a massive divide between California and the rest of the country: If from 1975 to 2016 the other 49 states had reduced their consumption of fossil fuel-generated electricity relative to GDP at California's rate of 62 percent instead of the actual 38 percent, ***the U.S. economy today would be consuming nearly one trillion fewer kilowatt-hours a year from coal, oil, and gas.***[10]

That enormous amount of "unsaved" fossil fuel electricity by the 49 states easily exceeds the celebrated drop in U.S. electricity generated from coal from its historic peak in 2007 to 2016.[11] The unsaved electricity each year equals the theoretical output of around 320 medium-size (500 MW capacity) coal-fired generating plants. It is also comparable to the total electricity generated every year by Japan, the world's fifth-largest power producer.[12]

INSIDE CALIFORNIA'S ELECTRICITY NUMBERS

Detailed, consistent data on California's electricity generation and usage go back only to 1990, so this discussion originates in 1990 rather than 1975.

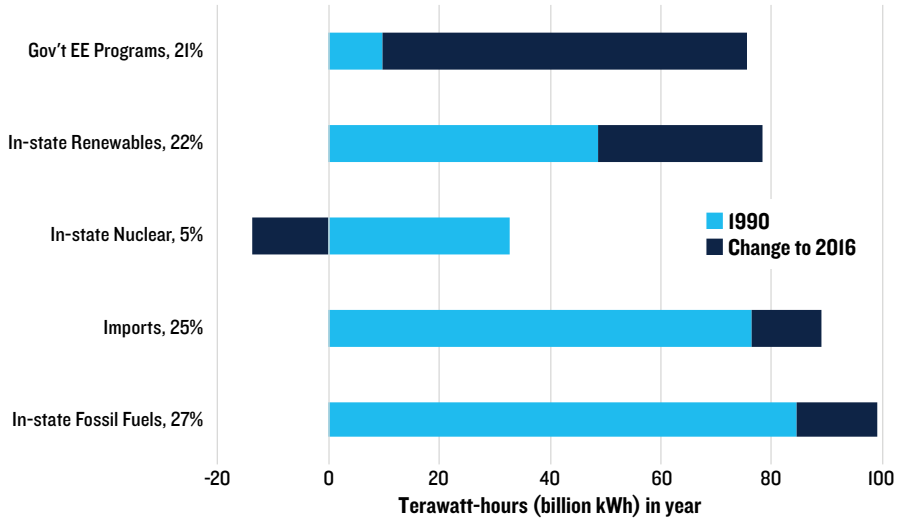
FIGURE 3: CALIFORNIA'S ELECTRICITY SOURCES, 1990–2016



Our data in Figure 3 shows that:

- From 1990 to 2016, electricity imports and in-state generation from fossil fuels each grew by around one-sixth. Those increases were far smaller than growth in the state's economy, which doubled in size.
- Nuclear power generation, which in 1990 accounted for 13 percent of California's electricity, currently supplies only 5 percent, owing both to the closure of the San Onofre nuclear power station and to growth in the electricity sector as a whole.

FIGURE 4: CALIFORNIA'S ELECTRICITY SOURCES IN 1990, AND CHANGES TO 2016



- Renewable electricity grew considerably, as can be seen in Figure 4. Between 1990 and 2016 its annual contribution increased by 30 TWh, an increase greater than the growth in in-state fossil generation and imports combined. And while the increase was partly due to unusually ample hydroelectricity in 2016, it also reflects rapid growth in solar electricity.
- If we aggregate renewables with electricity saved from California state efficiency programs, the combined total accounted for about 43 percent of total state electricity supply in 2016, up from just over 23 percent in 1990. Half of this nearly 20-point increase occurred from 2010 to 2016, indicating that the uptake of green electricity is increasing rapidly.[13]

The true star of California electricity's evolution since 1990 has been the state's efficiency programs. In 2016 these programs were delivering the energy-services equivalent of 75 TWh, more than eight times the 9 TWh attributed to such programs in 1990. That 66 TWh growth is more than twice the gain made over the same period in renewable electricity. (The Diablo Canyon nuclear plant's annual generation, by contrast, averages about 17 TWh; this contribution is scheduled to disappear in 2024–25 with the planned closure of both reactors there.[14]) In fact, the 1990–2016 growth in "delivered efficiency"—the energy demand that is avoided through more efficient equipment and buildings—exceeds the increases in renewables, imports, and in-state fossil electricity combined.[15]

These trends accelerated after 2008. From 2008 to 2016, electricity from renewables and state efficiency programs rose 60 and 70 percent, respectively, as can be seen in Figure 3. This enabled respective drops of 20 and 10 percent in in-state fossil fuel electricity generation and electricity imports.

California Efficiency Standards—Origins and Impacts

During Governor Reagan's administration in the early 1970s, the California legislature commissioned a study of how to best meet surging electricity demand without blanketing the state's prized coastline with massive power stations.[16] One result of that study was the Warren–Alquist Act, a bill establishing an energy commission empowered to create energy efficiency standards for equipment and buildings.[17]

Less than two years after Governor Reagan signed the bill into law, the California Energy Commission (CEC) adopted the nation's first electricity-usage efficiency standards. These standards, codified in California's Title 20, required manufacturers to substantially reduce the amounts of electricity needed to operate major home appliances such as refrigerators and window air conditioners.[18] In 1978, the commission adopted Title 24, Part 6, establishing efficiency standards for new residential and commercial buildings as well as existing buildings undergoing substantial alterations.[19]

It is difficult to overstate the impact and value of these standards. Because of them—both the initial iterations and periodic upgrades—households got a break on their electric bills, the California landscape avoided dozens of new generating stations, and thousands of tons of harmful particulate emissions and smog were prevented.

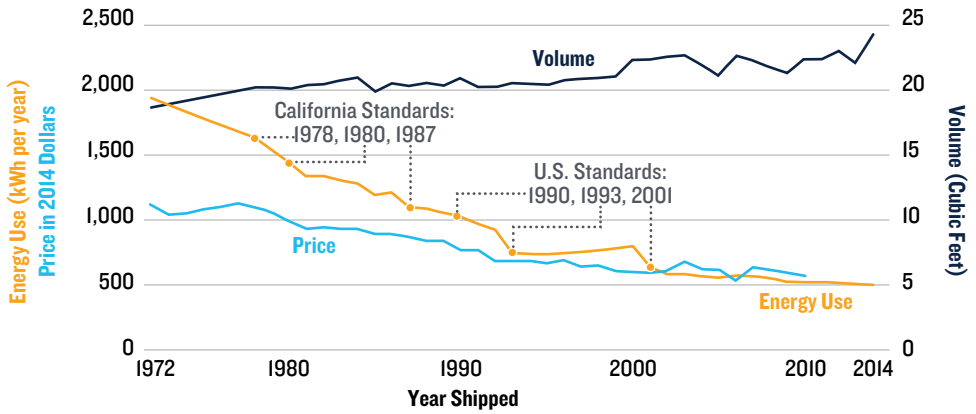
To draw up the standards, the CEC recruited engineers and drew on allies in academia (e.g., the University of California's Lawrence Berkeley National Laboratory) and the independent sector (e.g., NRDC and the Washington, D.C.–based American Council for an Energy-Efficient Economy). The commission painstakingly codified existing best practices and built on available technology to avoid expensive retooling by manufacturers or problems with adoption by consumers. The standards spurred manufacturing innovations and design changes that, over time, enabled Californians' everyday needs to be met with progressively less electricity.

To take just one example, new refrigerators today provide the same cooling and freezing as new models 40 years ago while consuming nearly 85 percent less electricity, as Figure 5 shows below. Analogous savings have been achieved in a host of other electricity- and water-using devices such as computers, TVs, clothes washers, dishwashers, room and central air conditioners, and heat pumps. (Note that these more efficient appliances also give off less heat, which further reduces air-conditioning and refrigeration needs.) To this list can be added plumbing components such as showerheads, toilets, and faucets, whose low-flow water requirements yield energy savings in water heating as well as reductions in pumping for water supply.

These savings are supplemented by voluntary incentive programs, administered by the state's utilities with the approval of the California Public Utilities Commission, that reward households, property managers, and developers for using appliances that exceed the state standards. The incentive programs and standards programs go hand in hand: The test methods developed for standards are used to rate better-than-standards equipment, and the incentivized products typically surpass the standards by 10 to 20 percent.[20] Additionally, widespread market success of the higher-achieving products provides important evidence that subsequent rounds of standards can safely aim for those higher efficiency levels.

By law, the CEC tracks its standards for electricity savings, cost effectiveness, and other measures of efficacy. Figure 6 shows the commission's estimates of annual saved electricity in three categories: buildings, appliances, and "other."[21] The latter encompasses a variety of CEC programs and initiatives ranging from weatherization and efficiency loans for low-income households to programs providing energy audits and technical assistance to California cities, counties, public health care facilities, and colleges and universities.

FIGURE 5: PERFORMANCE STANDARDS HAVE TRANSFORMED REFRIGERATORS



Source: Energy Innovation

Figures 3 and 6 show that the three categories of CEC-supported electricity savings together accounted for 75 TWh of electricity in 2016—21 percent of the 2016 statewide supply.[22] And this figure does *not* include electricity savings from an overall conservation ethic that suffused the state due to decades of governmental prioritization of energy saving and efficiency; nor does it include savings from national standards that were adopted first in California.

To meet increasing energy needs as populations and economies grow, efficiency savings (saved kilowatt-hours) are the functional equivalent of additional energy generation. And substituting such savings for additional generation benefits society as a whole, if system costs decline with no loss of performance or comfort.

ENERGY PERFORMANCE STANDARDS ARE THE GIFT THAT KEEPS ON GIVING

Recent work by energy strategist Hal Harvey and his consultancy, Energy Innovation, further explains why California's energy performance standards have been so successful.

In a 2018 interview Harvey praised upgradable performance standards as "the killer app in energy policy."[23] He lauded California energy regulators for going beyond static standards and setting rates of improvement, a tactic that Harvey called "the gift that keeps on giving." Standards that ratchet up periodically, he said, "tell [appliance] manufacturers, you have to get better and better and better. It helps them structure their R&D. Maybe most importantly, it uses political bandwidth once and delivers the goods forever."[24]

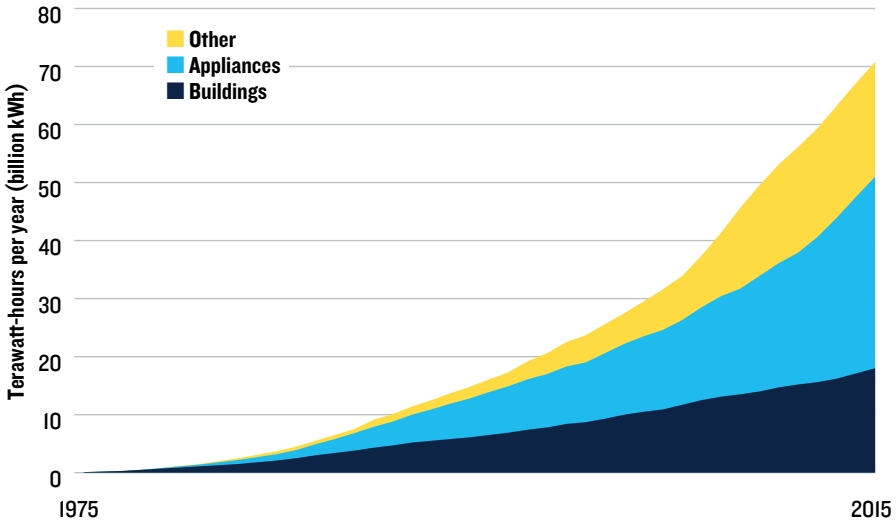
Harvey singled out California's building code for special praise:

> "[California's building code] gets tighter every three years. It only took one law, in the 1970s, to make that happen. That bill, [which established] Title 24 [in the state building code], was signed when Jerry Brown was the youngest governor in California's history. He's now the oldest governor in California's history. In between, Republicans and Democrats alike saw the building code get stronger and stronger. It didn't require cashing in political capital, going back to the legislature, debating it—it just happens."

Sharing California's Energy Policies With the Rest of the Country

The efficiency standards pioneered in California have largely spread to the rest of the country—even, in many instances, to much of the world.[25] On the federal level, the 1987 National Appliance Energy Conservation Efficiency Act embraced the California standards as a starting point for appliance energy efficiency and required the U.S. Department of Energy to review and upgrade these standards on a regular schedule, based on new technologies, market developments, and evolving cost data.

FIGURE 6: CALIFORNIA'S ELECTRICITY SAVINGS FROM STATE EFFICIENCY PROGRAMS



Source: California Energy Commission, Demand Analysis Office, 2018

Two factors motivated the creation of the federal standards, which were signed into law by then president Reagan: the desire of appliance manufacturers for uniform rules that would apply across all 50 states, and a widening understanding that such efficiency regulations were evidence based, consumer friendly, and generally in the public interest.[26]

Federal adoption of California's efficiency standards, along with the state's code and performance standards for buildings, brought the other 49 states closer in line with California's energy reductions. Imagine how much farther ahead California would be, were that not the case.

The Growth of Renewable Energy

FIGURE 7: RENEWABLE ELECTRICITY IN CALIFORNIA: CHANGES FROM 1990–2016

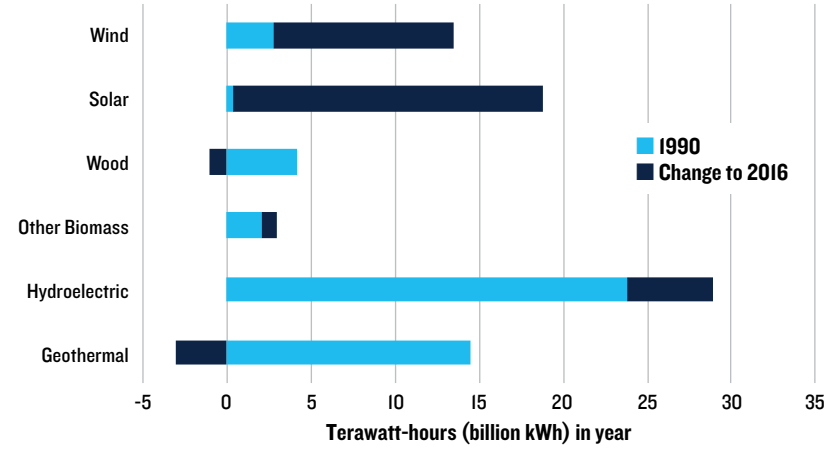
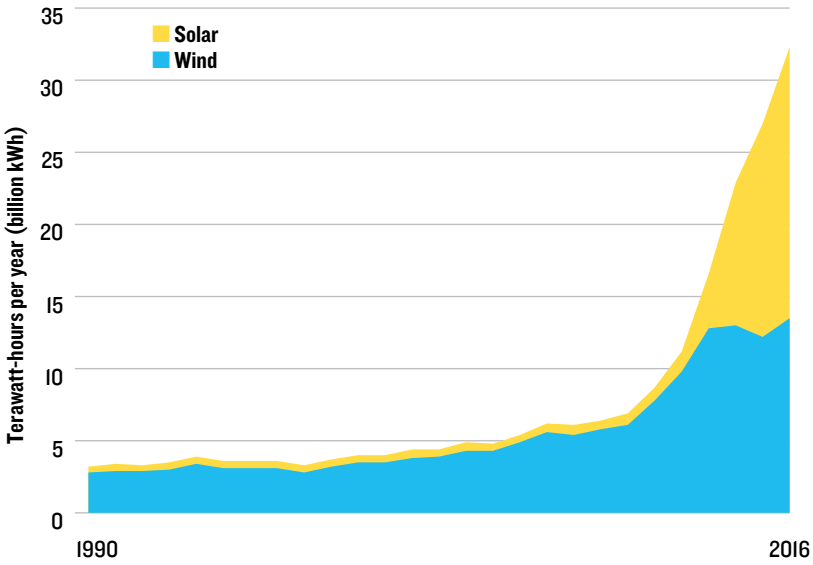


FIGURE 8: CALIFORNIA WIND AND SOLAR ELECTRICITY, 1990–2016



Electricity generation from renewable sources in California grew by around 30 TWh from 1990 to 2016, as was shown in Figure 3. This growth came primarily from the state's wind and solar sectors, as shown in Figure 7.

The big story here is the explosive growth in solar, as Figure 8 starkly illustrates. Solar grew from just under 1 TWh in 2011 to almost 19 TWh in 2016 (exceeding the 17 TWh annual contribution of the Diablo Canyon nuclear power plant, the state's largest single generation source). In 2016 California accounted for more than one out of every three solar-produced kilowatt-hours in the United States.[27]

California's leadership in promoting solar and wind electricity dates to the 1970s, although the state's iconic inaugural projects—the wind farm at Altamont Pass and the Solar One solar-thermal project in the Mojave Desert—didn't start producing electricity until the early 1980s. In 2002 California became one of the first states to adopt a renewable portfolio standard (RPS) when it mandated that a minimum of 20 percent of the state's electricity generation come from renewable resources by 2017.[28]

Development of renewable energy accelerated around 2010, first with new wind facilities and subsequently with solar. Growth in solar-generated electricity was encouraged by the California Solar Initiative (CSI), established in 2006 during the administration of Governor Arnold Schwarzenegger.[29] The CSI provided incentives for installing solar panels on residential rooftops, with the magnitude of the incentives diminishing over time to enable limited program funds to drive increasing levels of adoption as prices of solar panels declined.

Support from the CSI, along with programs spurring wind and solar generation elsewhere, especially in Spain and Germany, helped drive technological improvements and production efficiencies that dramatically reduced the cost of new facilities. The price reductions in turn helped accelerate the implementation of policies supporting renewables, leading to even more ambitious goals and expanded programs.

In 2010 California raised its RPS target to 33 percent by 2020. After meeting that higher target in 2016, the state set a new goal of 50 percent for 2030, which was raised again in 2018 to a goal of 60 percent by 2030.[30] The state has consistently achieved its renewable energy goals ahead of schedule and below cost estimates.[31]

Passenger Vehicles Continue to Be a Weak Point

California's impressive decoupling of economic growth from fossil fuel–generated electricity since the 1970s has unfortunately not been matched when it comes to fossil fuel use in passenger vehicles. From 1975 to 2016, gasoline use grew faster in California than in the rest of the United States, by 45 percent versus 39 percent.

FIGURE 9A: CHANGES IN GASOLINE CONSUMPTION, 1975 TO 2016

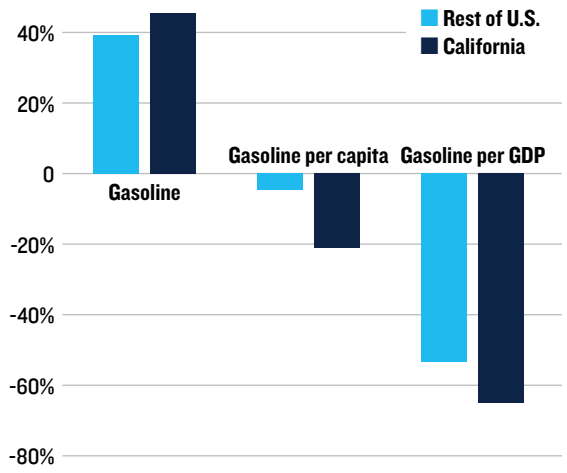
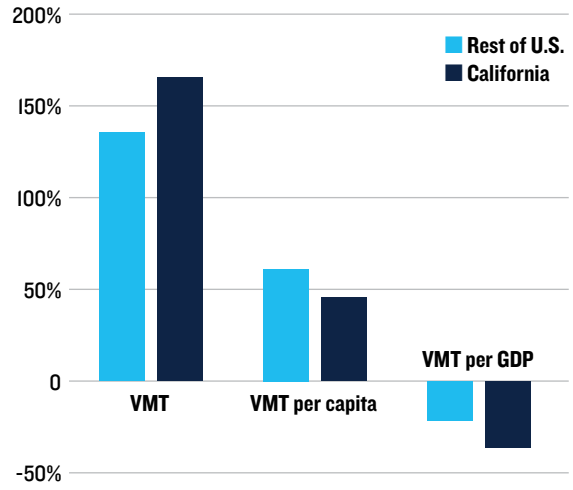


FIGURE 9B: CHANGES IN VEHICLE MILES TRAVELED, 1975 TO 2016



However, when we look at fossil fuel consumption for passenger vehicles on a per capita basis or per unit of GDP (Figure 9a), we see that the growth from 1975 to 2016 was smaller in California than in the other 49 states. Nevertheless, those differences between California and the rest of the country were far less pronounced than they were for electricity. The same goes for the volume of driving itself, denoted by vehicle miles traveled, as shown in Figure 9b.

There are many reasons why California did not lead in reducing gasoline consumption or driving to nearly the extent it did in reducing fossil fuel use for electricity:

- California is prohibited by federal law from explicitly regulating vehicle efficiency. (Current vehicle regulations limit greenhouse gas emissions and are not framed in terms of miles per gallon of fuel.)[32]
- Federal home financing criteria have traditionally privileged suburban sprawl, creating housing developments that require driving—a phenomenon that afflicted California no less than the rest of the country.
- State government, which was so proactive in electricity and energy policy, has largely taken a back seat to local and metropolitan governance concerning land use.
- Governmental policy and environmentalist advocacy have focused largely on "greening" the design of automobile engines—for instance, replacing internal combustion engines with electric propulsion—often with a single-mindedness that has detracted attention from more difficult and diffuse approaches addressing land use and ingrained preferences for single-occupant vehicles.

Underlying and exacerbating these factors is the anti-urban bias running through American history, coupled with a prejudicial identification of cities as "minority" dominated and thus not worthy of investment in infrastructure such as public transit.[33] Films, television, and other popular culture, no less than mortgage underwriting and real estate development, promoted the "clean" (and white) suburban ideal over the inner-city jumble and celebrated the personal car as an emblem of freedom. As a result, 20th-century development locked both California and most of the country into a driving culture based around suburbs.

Finally, toward the end of the last century, when migration to the suburbs might otherwise have begun to run its course, it was instead extended and boosted by the conjoined trends of exurban development, the advent of big-box stores, and the enshrinement of larger (and more fuel-intensive) sport utility vehicles as the default family car(s). This cemented our dependence on gasoline.

Federal automobile fuel-mileage standards were meant to be the antidote to this addiction. And these have achieved real gains. Over the four-decade period covered here, federal Corporate Average Fuel Economy (CAFE) mandates helped lift miles-per-gallon averages by 80 percent in California and 70 percent in the rest of the country.[34]

However, gasoline consumption increased as our driving increased; fuel-mileage standards helped to contain this growth, but they could not eliminate it. One reason is that the mileage gains fell far short of the possibilities offered by improved automotive technology. As Hal Harvey explained:

> "[President] Gerald Ford doubled fuel efficiency in [new] cars between 1975 and 1985 with a fuel efficiency standard. And then we went to sleep for 25 years. For 25 years, we didn't increase fuel efficiency. We took all the technological improvement that was coming down the pike and devoted it to mass and power—cars doubled power and increased weight by 40 percent."[35]

According to Harvey, U.S. lawmakers in the 1970s should have legislated automobile efficiency as they did appliance efficiency. "[I]f Gerald Ford had simply said '4 percent a year' instead of '26 miles per gallon,' we would have avoided all that."

That is perhaps a simplistic view of history. The dominance of fuel-intensive SUVs owes a great deal to a 1991 accommodation in which environmental advocates backed away from demanding stringent fuel efficiency standards for so-called light trucks in return for automakers' support of a ban on oil drilling in the Arctic National Wildlife Refuge.[36] Auto manufacturers also exploited drivers' concerns about road safety to sell bigger and heavier cars, even as those concerns were exacerbated by the bulked-up SUVs themselves.[37]

The upward trend in vehicle miles traveled (VMT) finally began to ease somewhat after the turn of the century, both in California and nationally. This has been due largely to economic and demographic trends: increased urbanization, the relative impoverishment of millennials and their lower rates of household formation, the uptake of digital technology that appears to substitute for some travel, and (until recently) costlier gasoline.

A turning point for automobile dependence and gasoline use in California may have come in 2008 with the enactment of SB 375, the Sustainable Communities and Climate Protection Act, which explicitly sought to bend land use and transportation policy to mitigate climate change.[38] SB 375 has resulted in a broad range of planning processes, mandates, and funding grants to enhance low-carbon transportation modes and transit-oriented development. These have spurred initiatives ranging from higher-density zoning—even if the result could be slower traffic—to redirecting investment away from highway widening and toward walking, cycling, and transit infrastructure.

Though California is synonymous with car culture, there have been major mass transit expansions in Southern California. Los Angeles opened its first rail line in 1990 and now has six lines and 93 stations, with 100 new miles of rail under construction or in planning. Transit ridership in America's iconic freeway city is now around 15 percent as great as New York City's, according to a recent report in *The New York Times*.[39]

California is also transitioning the state's fleet of passenger vehicles from internal combustion engines fueled by gasoline to electric vehicles (both battery-electric and plug-in hybrid). This long-term shift was set in motion in 1990, when the California Air Resources Board adopted a zero-emission vehicle (ZEV) regulation that in turn spurred both state and federal subsidies encouraging the purchase of ZEVs, along with the state's first charging facilities.[40]

Though initially the state's ZEV regulations were aimed more at improving local and regional air quality than reducing greenhouse gas emissions, the two goals now converge, as electric vehicles are increasingly powered with decarbonized electricity. With more than 400,000 electrics and plug-in hybrids registered in the state since 2010, electric vehicles are finally emerging as a factor in reducing both carbon emissions and fossil fuel dependence in California's transportation sector.[41]

Still, the biggest payoffs from these policies are yet to come. Changing land-use patterns and providing new infrastructure take time, as do legislating and implementing many of these initiatives. Legislation encouraging people to live near transit and job centers—essential not just for making public transit viable but for reducing the number and length of automobile trips—has been fought by NIMBY interests who cling to low-density zoning restrictions.[42] Road pricing, a blanket term for policy measures such as congestion pricing and curbside parking pricing in denser urban areas—all of which would reduce driving and thus gasoline use—is also hamstrung by policy inertia, despite its proven track record in reducing traffic congestion and improving quality of life in cities abroad.

Sharing the Wealth: Spreading Green Policies Beyond California's Borders

Even more than curbing its own fossil fuel usage, California's biggest contribution to decarbonizing the economy has been to test and then spread its policies across the rest of the United States. Some of this has been accomplished through the importation and refinement of California policies by other states, some as a natural if unexpected consequence of market dynamics and of the innovations spurred by California's leadership, and some of it has come about through the harmonization of policies and standards between the state and the federal government. California led the way in standards we now take for granted across the country, such as appliance efficiency standards, building efficiency standards, emissions standards for motor vehicles, mandated procurement of solar and wind power, "least-cost" electricity planning, and lowest-carbon grid dispatch.

For example, the state's groundbreaking standards in the 1970s for home refrigerators—at the time the largest consumer of electricity in the home—became the de facto national standard as manufacturers, distributors, and retailers found that making and stocking a 49-state suite of models in addition to the California set made poor business sense. California's advances in energy codes for buildings spread to national model codes and thus to most other states, and products introduced to promote compliance also developed national markets.

By spreading these innovations beyond the state's borders, California to no small degree pulled the other 49 states along with it in reducing dependence on fossil fuels. Unfortunately, the rest of the country did not fully keep pace. Yes, the other 49 states shrank their fossil fuels per GDP ratio by 60 percent, but if the shrinkage had duplicated California's 70 percent, fossil fuel use by those 49 states in 2016 would have been one-fourth less than the actual figure.[43] As we previously mentioned, the unnecessary 1,200 million metric tons of CO_2 now emitted each year because the United States as a whole failed to decarbonize at California's pace is the same as total emissions from Japan, the world's fifth-largest carbon polluter.[44]

The California Dividend—and America's Missed Opportunity

Once again our baseline is 1975, the year that Ronald Reagan passed the governorship to Jerry Brown. It was also the California Energy Commission's inaugural calendar year. It was two years after the Arab oil embargo and OPEC price increases wreaked havoc on the energy market and the U.S. economy. The mid-seventies also saw publication of several iconoclastic books that propelled energy efficiency into the public consciousness, such as the Ford Foundation's *A Time to* Choose, Wilson Clark's *Energy for Survival,* and, preeminently, Amory Lovins's *Soft Energy Paths*, including his seminal *Foreign Affairs* article, "Energy Strategy: The Road Not Taken?"[45,46,47,48]

In that baseline year, 1975, for every 100 units of fossil fuels that the United States (minus California) required to produce a dollar's worth of economic output, California required 77 units. Put another way, in 1975, for every 100 units of fossil fuels that California required to produce a dollar's worth of economic output, the rest of the country required 130 units.

By 2016, the ratio of U.S. fossil fuel use per GDP relative to California had ballooned to 175. In that year, fueling everything from homes and highways to hospitals and farms in the other 49 states consumed 72.0 quads' worth of fossil fuels.[49] Had the rest of the country maintained its 1975-level relationship to California in terms of fossil fuels required per unit of economic output, its fossil fuel consumption in 2016 would have been only 53.2 quads—18.8 quads less than the actual amount consumed.[50]

There are several ways to visualize these missed reductions:

- As a country, we could have burned 24 percent less fossil fuel in 2016.
- As a country, we could now be emitting 1,200 million fewer metric tons of carbon dioxide each year. As noted earlier, that's nearly equal to the CO_2 emitted annually by our entire nationwide fleet of passenger vehicles.

Conclusion

Over the past four decades California has reduced its fossil fuel consumption per unit of GDP by a compound rate of 2.9 percent per year. For the other 49 states, the compounded annual reduction rate was 2.2 percent. This difference now manifests as a yawning gap between California and the rest of the country when it comes to energy efficiency and fossil fuel usage. Today that gap represents an opportunity for the rest of the country to step up the pace and reap the many economic benefits from increased green energy that California already enjoys.

California's clean energy progress is best seen as a long-running exercise in enlightened self-interest, not self-sacrifice. Rather than suffering economic harm, the state is reaping huge dividends from extracting ever more economic product from each unit of fossil fuel. Between 1975 and 2016, California grew its GDP faster than the rest of the country, more than quadrupling its real economic activity while the other 49 states merely tripled theirs.[51] Job creation also accelerated due to climate investments. If California were a country, its economy would now rank as the world's fifth largest.[52]

Indeed, California's long-running economic boom probably owes much of its vitality to the state's green energy transformation. New economic modeling from the United Kingdom finds that as much as 25 percent of the increase in that country's GDP since 1971 has been driven by energy efficiency gains, and that in general, "investments in energy efficiency are a key driver of economic growth."[53] Similarly, we find that California's economy today is effectively one-third larger than it would have been if the state's ratio of economic activity to fossil fuel use had grown only at the rate of the rest of the United States. This dividend equates to almost $700 billion in increased economic activity in California in 2016—an amount in the same ballpark as the entire domestic product of Pennsylvania or Ohio.[54]

Not only has the state's economy thrived, but its residents, landscape, and overall environment have been spared damage from unnecessary fossil fuel use. Other states have not been idle in the meantime, and there are compelling energy efficiency and renewable energy stories in every part of the nation. But the findings of this report signal to the other 49 states that their slower aggregate rate of progress is leaving significant economic and environmental benefits on the table.

From the vantage point of 2019, it is also important to note that California didn't wait for federal direction to start down this wholly bipartisan course. The tools that California used—energy efficiency standards for appliances and buildings, mandates for renewable electricity, incentives for low- or zero-emission vehicles, and a conservation ethic embedded in state governance—are available to every state in the union. And while it is true that California is unusually blessed with sunlight, wind, and water, significant amounts of these resources are available to be tapped throughout the country.

California is no energy policy utopia, and its leaders would be the first to acknowledge that it still has much to do to reach its increasingly ambitious targets. Indeed, even if all 50 states had matched California's 1975–2016 rate of progress in reducing fossil fuel use relative to GDP, nationwide consumption of fossil fuels would have fallen from 1990 (a common baseline year) to 2016 at an average annual rate of just 0.73 percent. Going forward, the United States will have to reduce its fossil fuel dependence more than three times as fast as that hypothetical rate for our country to meet its Paris climate commitment.

Nevertheless, this report shows concretely that California's extensive and integrated suite of clean energy incentives, standards, mandates, and technology research is very much worth emulating.

Appendix

This appendix presents the data sources, quantitative methods, and calculations underlying the assertions and conclusions in the report.

All data used in the report and sourced in this appendix are compiled, developed, and sourced in an Excel spreadsheet titled "Fossil Fuel Dependence, California vs. U.S." The spreadsheet is available at https://assets.nrdc.org/sites/default/files/california-stars-clean-energy-future-data.xlsx.

Please note that we refer to "fossil fuels" and "carbon emissions" interchangeably. Rather than calculate California's and the 49 states' carbon emissions individually for each fossil fuel (coal, oil, natural gas)—a herculean task with its own imprecisions—we prorate aggregate CO_2 emission figures by percentage changes in consumption of fossil Btus. This approximation, though imperfect, enables us to translate our fossil fuel calculations into the more comprehensible metric of carbon emissions.

GDP (GROSS DOMESTIC PRODUCT)

Annual U.S. GDP data dating to 1963 were downloaded from an official U.S. government site maintained by the St. Louis office of the Federal Reserve, https://fred.stlouisfed.org/series/GDP. Figures are seasonally adjusted and in nominal dollars (unadjusted for inflation).

Annual California GDP figures dating to 1963 were downloaded from the California Department of Finance, http://www.dof.ca.gov/Forecasting/Economics/Indicators/Gross_State_Product/. Data were downloaded from "Gross State Product." Figures for 1963–1997 are SIC-based (Standard Industrial Classification). Figures for 1998–2016 are NAICS-based (North American Industry Classification System). Figures are seasonally adjusted and in nominal dollars (unadjusted for inflation).

GDP figures for the 49 states dating to 1963 were calculated as each year's difference between U.S. GDP and California GDP.

All GDP data were converted to 2009 constant dollars using the U.S. government's GDP Deflator. To each year's nominal-dollar GDP we applied that year's July 1 value of the GDP Deflator from the table "Annual Gross Domestic Product: Implicit Price Deflator, Index 2009=100, Quarterly, Seasonally Adjusted," https://fred.stlouisfed.org/series/GDPDEF. (The link currently uses 2012 dollars as its base rather than 2009 dollars in the data series we used in the fall of 2018, but the difference affects all inflation adjustments equally.)

FOSSIL FUEL CONSUMPTION

United States

Total annual U.S. consumption of fossil fuels dating to 1963, expressed in quads (a unit equal to one quadrillion, or a million billion, Btus), was obtained from the U.S. Energy Information Administration (EIA) publication, *Monthly Energy Review*. The source was Table 1.3, "Primary Energy Consumption by Source," downloaded as a spreadsheet from https://www.eia.gov/totalenergy/data/monthly/. We used the data column "Total Fossil Fuels Consumption" from the spreadsheet's "Annual" tab.

California

Total annual California consumption of fossil fuels dating to 1963 was obtained from the EIA series *State Profile and Energy Estimates*, from the Web page for California titled "Table CT2, Primary Energy Consumption Estimates, 1960–2016, California." That page was downloaded as a spreadsheet from https://www.eia.gov/state/seds/data.php?incfile=/state/seds/sep_use/total/use_tot_CAcb.html&sid=CA.

That table (CT2) includes a column, "Fossil Fuels Total," which is the sum of three prior columns for coal, natural gas (excluding supplemental gaseous fuels), and petroleum. Note that natural gas supplemental gaseous fuels are counted in the column "HGL (Hydrocarbon gas liquids, include natural gas liquids and refinery olefins)," which is counted as part of petroleum.

To that "Fossil Fuels Total" we added, in each year, Btu equivalents for two column entries in the table: "Net Interstate Flow of Electricity" and "Net Electricity Imports."

The first item, "Net Interstate Flow of Electricity," is expressed in the table as Btus (per footnote k in Table CT2, which states, "Includes the energy losses associated with the generation, transmission, and distribution of the electricity flowing

across state lines."). Therefore, no conversion of or adjustment to the interstate electricity figures was required. The second item, "Net Electricity Imports," is expressed in the table as the Btu value of the electricity imports (per footnote l in Table CT2, which states, "Electricity traded with Canada and Mexico. Calculated by converting net imports in kilowatt-hours by 3,412 Btu per kilowatt-hour.") We multiplied each annual figure in that column by the ratio of 10,000/3,412 to conform to our convention of treating electricity imports whether from neighboring states or countries as if every kWh were generated by burning fossil fuels; 10,000 Btu is a generally accepted figure for the average number of Btus burned in generating a kilowatt-hour at a fossil fuel power station.

Total California Btus consumed in any year was then calculated as the sum of the three entries just discussed: total fossil fuels, net interstate electricity, net (no adjustment required), and electricity traded with Canada and Mexico (adjusted as discussed above).

The 49 States

Fossil fuel consumption data in Btus for the 49 states were calculated as each year's difference between U.S. consumption and California consumption.

FOSSIL FUELS CONSUMED RELATIVE TO ECONOMIC ACTIVITY

The primary metric used in this report to compare California's progress in reducing fossil fuel dependence with that of the rest of the country is fossil fuels consumed per unit of GDP. In our data spreadsheet we express that ratio as thousands of Btus per 2009 constant dollar, a convention that yields easy-to-visualize numbers, as we discuss directly below.

For the most part, we use 1975 and 2016 as our marker years. The former year was when Jerry Brown began serving as governor of California as well as the first full year in which policy responses to the 1973–74 energy crisis began taking shape. The latter is the most recent year for which energy data are available on a state as well as national level.

TABLE A1: CALIFORNIA VS. THE 49 OTHER STATES, 1975 AND 2016

	1975	2016	RATIO, 2016 TO 1975	CHANGE, AS A %
CALIFORNIA				
Fossil Fuel Consumption (10^{12} Btu)	5,389	6,646	1.23	+ 23%
GDP (2009$, billions)	$564	$2,343	4.16	+ 316%
Fossil Fuels/GDP (10^{3} Btu per $)	9.56	2.84	0.30	– 70%
49 OTHER STATES				
Fossil Fuel Consumption (10^{12} Btu)	59,967	72,023	1.20	+20%
GDP (2009$, billions)	$4,838	$14,473	2.99	+ 199%
Fossil Fuels/GDP (10^{3} Btu per $)	12.39	4.98	0.40	– 60%

Table A1 is our report in a nutshell. Note particularly the final two columns, which show:

- Fossil fuel consumption grew at roughly the same rate in California as in the rest of the country—actually, slightly faster in California, by 23 percent, versus 20 percent in the other 49 states.
- At the same time, economic activity grew far faster in California. Controlling for inflation, the level of economic activity in California in 2016 was more than four times as high as in 1975, whereas the same ratio for the rest of the U.S. was only around three (2.99).
- **Fossil fuels consumed per unit of GDP declined by 70 percent in California, versus a decline of just 60 percent for the other 49 states.**

Data in Table A1 also support our finding on page 7 that whereas California in 1975 was producing 1.30 times as much economic output per Btu of fossil fuels as the rest of the country, by 2016 that ratio had increased to 1.75. This can be seen by comparing the fossil fuels/GDP ratios given in the last rows of each section: In 1975, the 49 states consumed 30 percent more fossil fuels than California to produce a dollar of GDP (12.39 versus 9.56); the difference in 2016 was 75 percent (4.98 versus 2.84).

QUANTITATIVE DERIVATION OF AND SUPPORT FOR THE ASSERTIONS IN THIS REPORT

Here we provide calculations and supports for the assertions in the report.

From the section "Why California Excels"

From 1975 to 2016 California reduced its use of fossil fuels per unit of economic output by 70 percent. For the other 49 states collectively, the reduction was only 60 percent.

See Table A1, last column.

Had the rest of the United States reduced fossil fuel use relative to economic activity at the same pace as California, we would have reduced our nationwide emissions of carbon pollution by 1,200 million metric tons in 2016 alone.

U.S. emissions of carbon dioxide from burning fossil fuels in recent years are extensively documented and widely known. For this report, we chose to rely on author Komanoff's work in this area, as compiled in a spreadsheet model of fossil fuel use and carbon emissions in the U.S. economy that he has maintained for more than a decade for the Carbon Tax Center, which he directs. (The current version of the spreadsheet may be downloaded via this link.)

The spreadsheet reports that U.S. emissions of CO_2 from burning fossil fuels totaled 5,019 million metric tons in 2016. For the purposes of this report, we apportion these emissions to California and the other 49 states on the basis of their respective 2016 consumption of fossil fuels shown in Table A1: California, 6.646 quads; 49 states, 72.023 quads. Translated into percentages, those figures equate to an 8.45% share of 2016 U.S. fossil fuel use for California, and the remaining 91.55% for the 49 states.

Applying those percentages to 2016 U.S. CO_2 emissions imputes 424 million metric tons (8.45% x 5,019) to California and the remaining 4,595 million metric tons to the 49 states.

As Table A1 shows, in 2016 the 49 states required .401 times as much fossil fuel to produce a dollar of GDP as in 1975 (the table rounds down .401 to .40). Similarly, California in 2016 required .297 times (which the table rounds up to .30) as much fossil fuel to produce a dollar of GDP as in 1975. **Had the 49 states gone as far as California from 1975 to 2016 in reducing their fossil fuels per GDP, their fossil fuel use in 2016 would have been .297/.401, or 74 percent, as much as the actual figure.** In that case, the 49 states' CO_2 emissions would have been 26 percent less than the imputed 4,595 million metric tons, or 1,200 million metric tons less. (Before rounding, the calculation is the product of 4,595 and 1 minus .297/.401.)

Those additional 1,200 million metric tons of carbon emissions in 2016 are roughly as much as the tailpipe emissions of all U.S. passenger vehicles that year.

The carbon tax spreadsheet cited above breaks down U.S. 2016 CO_2 emissions as follows. Quantities are in million metric tons (MMT); "upstream" refinery emissions are included in the respective functional category, e.g., automobiles, freight, etc.

- Electricity Generation, 1,811 MMT
- Automobiles (includes ATVs, recreational boats, etc.), 1,244 MMT
- Natural Gas, other than for electricity generation (in industry, heat/hot water, etc.), 588 MMT
- Freight (goods movement by road, rail, ship, air), 532 MMT
- "Other" Petroleum Products (industry, heating, construction, etc.), 363 MMT
- Aviation (passenger travel), 245 MMT
- Miscellany (non-electricity uses of coal, non-energy uses of fossil fuels, other), 236 MMT

The automobile CO_2 emissions figure, 1,244 million metric tons, is only 3 to 4 percent greater than the additional 1,200 million metric tons that the 49 states emitted because they failed to match California's pace in reducing fossil fuel use relative to GDP from 1975 to 2016.

Throughout the decade from 1964, when California overtook New York as the most populous state, to 1973, the year of the first energy crisis, California consistently required only three-fourths as much coal, oil, and natural gas as the rest of the country to create a given amount of economic output.

This statement sets the table for the discussion to follow of California's and the 49 states' divergent fossil fuel paths beginning in 1975. The spreadsheet for this report shows that during each year from 1964 through 1973, California's ratio of fossil fuels to GDP was never more than 0.77 and never less than 0.73 times as great as the corresponding ratio for the 49 states. (In 1975 the ratio was 0.77; in 2016 it was 0.57.)

In 1975 . . . California produced 1.30 times as much economic output per Btu of fossil fuels as the rest of the country. By 2016, the last year with fully representative data, that ratio had increased to 1.75.

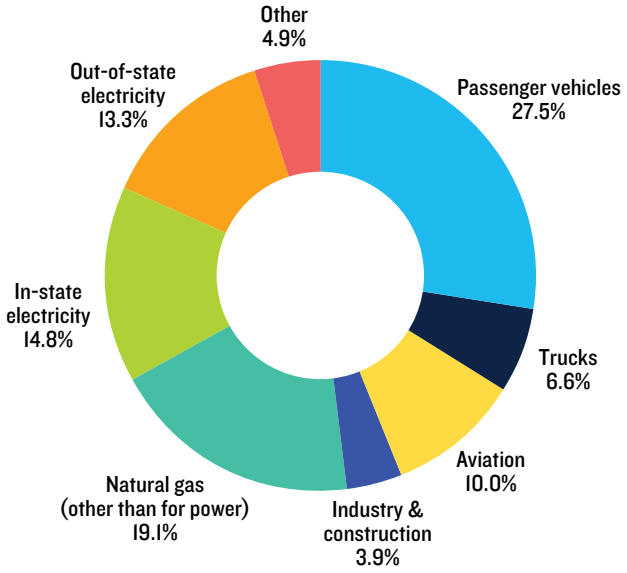
Those ratios (1.30 in 1975 and 1.75 in 2016) are the reciprocals of the corresponding ratios directly above (0.77 in 1975 and 0.57 in 2016).

The other 49 states shrank their fossil fuels per GDP ratio by 60 percent, but if the shrinkage had duplicated California's 70 percent, fossil fuel use by those 49 states in 2016 would have been one-fourth less than the actual figure.

The "one-fourth" figure is a conservative approximation of the 26 percent decrease implicit in the statement in our long derivation earlier in this appendix of the 49 states' forgone reduction of 1,200 million metric tons of CO_2 emissions: **Had the 49 states gone as far as California from 1975 to 2016 in reducing their fossil fuels per GDP, their fossil fuel use in 2016 would have been .297/.401, or 74 percent, as much as the actual figure.**

Data sources for graph of California's fossil fuel use

FIGURE AI: HOW FOSSIL FUELS ARE USED IN CALIFORNIA



Source: 2016 EIA data, compiled into categories by the author

The graph at left (a larger version appears as Figure 1 in the main text) is derived in the **Fuel** tab of the spreadsheet for this report. Although the *breakout* of California's 2016 uses of fossil fuels doesn't bear on the report's conclusions, which concern the *total* for that year (and others), we present a table summarizing the figures and their derivation.

All figures in Table A2 originate from the EIA spreadsheet "Table CT2, Primary Energy Consumption Estimates, 1960–2016, California," which was sourced and linked to earlier in this appendix in the section "Fossil Fuel Consumption (California)."

TABLE A2: CALIFORNIA FOSSIL FUEL USE, 2016

CATEGORY	BTUS (10^{12})	FUEL USES INCLUDED IN CATEGORY
Passenger vehicles	1,845.7	Motor gasoline including fuel ethanol
Trucks	440.5	Trucks' share of distillate fuel oil (see note below)
Aviation	672.6	Jet fuel
Industry and construction	264.0	Distillate fuel oil less trucks' share + residual fuel oil minus GWh generated with oil divided by 100 (see note)
Natural gas (other than for power)	1,277.7	Natural gas excluding supplemental gaseous fuels, minus GWh generated with gas divided by 100 (see note)
In-state electricity	989.9	Sum of GWh generated with coal, oil, or gas, divided by 100
Out-of-state electricity	889.2	Net interstate flow of electricity x 100 (to convert GWh to 10^{12} Btu) + net electricity imports x 10,000 divided by 3,412
Other	325.3	Includes asphalt, road oil, aviation gasoline, kerosene, lubricants, petroleum coke, and "other petroleum products"
Total	6,704.9	

Table A2 Notes

Trucks: Trucks' share of distillate fuel oil, 78.6 percent, is estimated as the ratio of (1) total diesel, 3,864,595,242 gallons, less "dyed diesel" (diesel fuel that is included for tax-exempt use such as in agriculture, mining, and other types of nonroad activity), 826,976,521 gallons; that subtotal equals 3,037,618,721 gallons, to (2) total diesel just shown. Total diesel is calculated as sum of finished diesel (a category that includes renewable diesel and dyed diesel), 3,697,070,574 gallons, and biodiesel, 167,524,668 gallons. All of the above figures are for 2016 and are from the California Energy Commission Final Staff Report "Transportation Fuel Supply Outlook, 2017," Table 3 (p. 38).

Where electricity generation is given in GWh, that amount is converted to trillions of Btus by dividing by 100. (1 GWh = 10^6 kWh, and 1 kWh is assumed to require burning 10^4 Btus of fossil fuel. A GWh thus requires burning 10^{10} Btu, which is 1/100 of one trillion.)

Net electricity imports are given in the EIA spreadsheet for California as the Btu equivalent of the electricity generated rather than as the Btus required to generate the electricity. To convert from the former to the latter we multiplied the given figures by 10,000 (the average amount of Btus required to generate a kWh) divided by 3,412 (the Btu equivalent of a kWh).

Note that the arithmetic sum of the eight entries in Table A2, 6,704.9 trillion Btu, is slightly greater than the 6,645.9 trillion Btu figure that we derived earlier in the appendix and that we use in this report to represent California's fossil fuel use in 2016. The discrepancy, 59 trillion Btu, probably arises from one or more of our approximation techniques. It is less than 1 percent of the total.

Over the four decades as a whole [1975–2016], California's consumption of fossil fuel–derived electricity actually increased by 56 percent. But during the same period, the state's population grew by 82 percent. As a result, per capita *fossil fuel power generation decreased by 14 percent. Moreover, state GDP more than quadrupled during the period. Per dollar of economic output, California's consumption of fossil fuel–generated electricity fell by 62 percent from 1975 to 2016.*

To begin, we estimated that in 1975, 120,310 GWh of electricity were generated from fossil fuel power stations in California or imported from neighboring states, as follows: 49,400 GWh from in-state oil-fired plants, 29,190 GWh from in-state gas-fired plants, and 41,720 GWh imported. (The GWh figures were calculated by dividing the Btu figures for 1975 given for those categories in "Table CT2, Primary Energy Consumption Estimates, 1960–2016, California," by 10,000.) Note that 1975 entries for coal-fired generation and imports from Canada and Mexico were zero or empty.

The corresponding figure (California electricity from fossil fuels) for 2016 was 187,919 GWh. That is calculated as the sum (before rounding) of GWh from in-state coal (319), in-state gas (97,074), in-state other gas (1,427), in-state petroleum (176)—the in-state subtotal is 98,995 GWh—and imports of 88,924 GWh, of which 79,780 GWh are from other states and 9,144 are from Canada or Mexico. The in-state figures are from the EIA's California State Electricity Summary for 2016, Table 5, "Electric Power Industry Generation by Primary Energy Source, 1990 Through 2016," https://www.eia.gov/electricity/state/california/state_tables.php. The state and country imports are taken from the **Fuel** tab of the spreadsheet for this report and are summarized in Table A2, above, in the entry "Out-of-state electricity."

The 2016 figure, 187,919 GWh, is 56 percent greater than the 1975 figure, 120,310 GWh.

California (and U.S.) population data are presented in the **VMT** + **Pop** tab of the spreadsheet for the report. The population of California was 21,537,849 in 1975 and 39,296,476 in 2016, from Federal Reserve Economic Data, "Resident Population in California, Annual, Not Seasonally Adjusted," https://fred.stlouisfed.org, data series: CAPOP. The population increase is 82 percent. The per capita change in fossil fuel electricity generation for California is then 1.56 divided by 1.82, which is 0.86, implying a 14 percent per capita decrease. Similarly, the per-GDP change in California's fossil fuel electricity is calculated as 1.56 divided by the 2016-to-1975 ratio of (constant-dollar) GDP, which was given earlier as 4.16. The figure 1.56/4.16 is 0.38, implying a 62 percent per-GDP decrease,

Fossil fuel–generated electricity for the 49 states increased [from 1975 to 2016] by 87 percent . . . fossil fuel electricity per capita was up 28 percent . . . and fossil fuel electricity per unit of economic activity decreased by 38 percent.

Every edition of the EIA's *Monthly Energy Review* includes monthly and annual tabulations of U.S. electricity generation from coal, petroleum, natural gas, and (since 1989) other gases. The national totals are 1,441,660 GWh for 1975 and 2,654,468 GWh for 2016. From these figures we deducted the respective California figures of 120,310 GWh for 1975 and 187,919 GWh for 2016. (The latter deduction is somewhat overstated by including imports from Canada and Mexico and treating them all as fossil fuel–derived; the result is to understate the 49 states' fossil fuel electricity for 2016 and, hence, to understate their rate of growth from 1975, a year in which cross-national imports were nil.)

The resulting figures for fossil fuel generation by the 49 states are 1,321,350 GWh in 1975 and 2,466,549 GWh in 2016. The implied increase over the period is 87 percent. Per capita increases were calculated by factoring in U.S. population

of 215,973,000 in 1975 and 323,405,935 in 2016, sourced from Federal Reserve Economic Data, "Resident Population in United States, Annual, Not Seasonally Adjusted," https://fred.stlouisfed.org, data series: POPTOTUSA647NWDB, and subtracting the corresponding California population figures given above to calculate the population of the 49 states. The per-GDP change in the 49 states' fossil fuel electricity was calculated as 1.87 divided by the 49 states' 2016-to-1975 ratio of (constant-dollar) GDP, which was given earlier as 2.99. The resuting figure is 0.62, implying a 38 percent decrease in fossil fuel electricity per GDP for the 49 states.

If from 1975 to 2016 the other 49 states had reduced their consumption of fossil fuel–generated electricity relative to GDP at California's rate of 62 percent instead of the actual 38 percent, the U.S. economy today would be consuming nearly one trillion fewer kilowatt-hours a year from coal, oil, and gas.

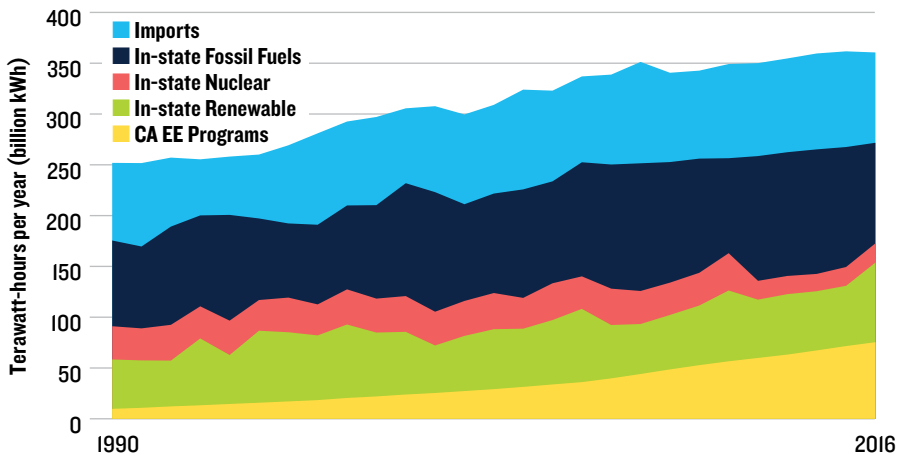
As shown in the prior paragraph (expressed in GWh), the 49 states other than California generated 2,467 TWh from fossil fuels in 2016. California's use of fossil fuel electricity per million dollars of GDP in that year was 37.6 percent of its 1975 rate, while the analogous percentage for the other 49 states was 62.4 percent. To extrapolate California's 1975–2016 reduction rate in kWh/GDP to the rest of the country, we multiply the 49 states' fossil fuel generation of 2,467 TWh by 0.376/0.624, yielding 1,485 TWh (before rounding). That figure is less than 2,467 TWh by 982 TWh, or nearly 1,000 TWh (one trillion kWh).

The unsaved electricity [of 982 TWh] each year equals the theoretical output of around 320 medium-size (500 MW capacity) coal-fired generating plants.

A 500 megawatt power plant operating at a capacity factor of 70 percent generates approximately 3 TWh a year (calculated as 500 MW x 8,760 hours per year x 0.7, which is 3,066,000 MWh). Dividing that figure into 982 TWh yields the figure of 320 generating units in the text. Note that 3 TWh of electricity savings is known in energy circles as a "Rosenfeld" as a tribute to the late physicist Arthur Rosenfeld, founder of UC Berkeley's Center for Building Science in 1975 and longtime member of the California Energy Commission, who pioneered and advanced energy efficiency measures and policies.

Data sources for graph of California electricity, 1990–2016

FIGURE A2: CALIFORNIA'S ELECTRICITY SOURCES, 1990–2016



The graph at left (a larger version appears in the main text as Figure 3) is derived in the **Electricity** tab of the spreadsheet for this report.

In-state fossil fuels are totals of kWh generated from coal, natural gas, other gas, and petroleum, compiled from the EIA's California State Electricity Summary for 2016, Table 5, "Electric Power Industry Generation by Primary Energy Source, 1990 Through 2016," https://www.eia.gov/electricity/state/california/state_tables.php.

Imports are taken from the **Fuel** tab of the spreadsheet for this report and are summarized in the entry Out-of-state electricity in the preceding table, "California Fossil Fuel Use, 2016."

In-state nuclear is from same source as in-state fossil fuels. *In-state renewables* are also from that source and comprise the following categories: geothermal, hydroelectric, nuclear, other biomass, pumped storage, solar, wind and wood.

California energy efficiency programs are from a spreadsheet, "102018 Committed Elec Savings by Category 1975–2016," prepared by staff of the Demand Analysis Office of the California Energy Commission (CEC), which sums, for each year, the electricity generation avoided in that year because of reductions in electricity demand attributed to three sets of CEC programs: buildings standards; appliance standards; and programs that incentivize, subsidize, or otherwise support energy efficiency investments in California. For example, the 2016 figures are: building standards, 17,986 GWh; appliance standards, 33,000 GWh; and programs, 19,802 GWh. The subtotal, 70,789 GWh, is then increased by 6.58 percent to reflect estimated electricity losses from delivery, a figure drawn from CEC's "System Efficiency Report," 2017, Table 1, based on

statewide data from 2009–2014. The 2016 total savings figure is then 75,447 GWh. The vector of annual figures may be found in the **Electricity** tab of the spreadsheet supporting this report. The CEC's own graph of those figures may be found in the CEC report "Tracking Progress: Energy Efficiency," https://www.energy.ca.gov/renewables/tracking_progress/documents/energy_efficiency.pdf.

The 1990–2016 growth in "delivered efficiency" . . . exceeds the increases in renewables, imports, and in-state fossil electricity combined.

The increase in electricity generation avoided by government-directed energy efficiency programs from 1990 to 2016 was 65.7 TWh. Over the same period, the respective increases in renewables, imports, and in-state fossil electricity were 29.8 TWh, 12.5 TWh, and 14.6 TWh, which total 56.9 TWh. These figures may be found in the **Electricity** tab of the spreadsheet supporting this report.

If we aggregate renewables with electricity saved from California state efficiency programs, the combined total accounted for about 43 percent of total state electricity supply in 2016, up from just over 23 percent in 1990.

Counting electricity avoided by state government energy efficiency programs, California electricity supply in 2016 totaled 361.3 TWh and was derived as follows: in-state renewables, 78.4 TWh; government energy efficiency programs, 75.5 TWh; in-state nuclear, 18.9 TWh; in-state fossil, 99.0 TWh; imports (which we count in this report as fossil fuels), 88.9 TWh; and other, 0.7 TWh. The first two categories together accounted for 153.8 TWh, or 42.6 percent of the total. These figures and corresponding figures for each year to 1990 may be found in the **Electricity** tab of the spreadsheet supporting this report.

Half of this nearly 20-point increase [in renewables' and efficiency's combined share of California's electricity provision] occurred from 2010 to 2016 . . . From 2008 to 2016, electricity from renewables and state efficiency programs rose 60 and 70 percent, respectively.

The share of total California electricity supply (with state government efficiency programs counted in both numerator and denominator) was 23.2 percent in 1990, 32.5 percent in 2010, and 42.6 percent in 2016. These figures, along with the figures supporting the 60 percent and 70 percent rises for renewables and efficiency, are shown in the **Electricity** tab of the spreadsheet supporting this report.

Data sources for graph of California wind and solar electricity

This graph, Figure 8 of our report, is drawn from the EIA's California State Electricity Summary for 2016, Table 5, "Electric Power Industry Generation by Primary Energy Source, 1990 Through 2016," https://www.eia.gov/electricity/state/california/state_tables.php.

From 1975 to 2016, gasoline use grew faster in California than in the rest of the United States, by 45 percent versus 39 percent. However, when we look at fossil fuel consumption for passenger vehicles on a per capita basis or per unit of GDP, we see that the growth from 1975 to 2016 was smaller in California than in the other 49 states.

California gasoline consumption in each year was calculated from the annual Btu figures for Motor Gasoline Including Fuel Ethanol from the EIA spreadsheet "State Profile and Energy Estimates," described earlier in this appendix, under the headings "Fossil Fuel Consumption, California." The spreadsheet is available at https://www.eia.gov/state/seds/data.php?incfile=/state/seds/sep_use/total/use_tot_CAcb.html&sid=CA. We converted those Btu figures to gallons using the figure of 5,222,000 Btu per gallon of gasoline taken from *Monthly Energy Review*, Table A2, "Approximate Heat Content of Petroleum Production, Imports, and Exports."

U.S. gasoline consumption in barrels per day was taken from *Monthly Energy Review*, Table 3.5 (**Annual** tab), "Petroleum Products Supplied by Type." We converted the figures to annual Btus using number of days in leap years and conventional years, and using the figure of 5,222,000 Btus per gallon of gasoline. Consumption by the 49 states was calculated as the difference between the figures for California and the United States as a whole. The California and 49 states figures for the years 1975–2016 were then normalized by both population and GDP. These figures are presented in the **Gasoline** tab of the spreadsheet underlying this report.

VEHICLE MILES TRAVELED (VMT)

California

VMT for California was compiled as follows:

- Data for 1970–2011 are from a Web file, https://public.tableau.com/profile/roy.fleshman#!/vizhome/SolvingforSafetySampler/Overview, maintained by Roy Fleshman, an analyst with the California Dept of Transportation (Caltrans), provided to the authors in November 2018.

- Data for 2012–2015 are from a worksheet tab, Table 7Q: "Collisions, Victims, Vehicle Miles of Travel, Motor Vehicle Registration, Population, and Mileage Death Rate 1933–2015" contained in an Excel spreadsheet, "Section (7) Seven, 2015," maintained by Caltrans and available at https://www.chp.ca.gov/programs-services/services-information/switrs-internet-statewide-integrated-traffic-records-system/switrs-2015-report. Note that this data series agrees very closely with the data series in the preceding bullet in the many years with overlapping data.
- The total for 2016 was calculated by applying to the 2015 figure the percentage increase for 2015–2016 given in a file maintained by Caltrans, VMTHIST1.pdf, showing "Historical Monthly Vehicle Miles of Travel, 1972–2016," covering VMT on California state highways, provided by Roy Fleshman of Caltrans.

VMT for the United States as a whole was compiled from a spreadsheet, "Historical Vehicle Miles Traveled Report (ANA7)," downloaded by the authors in May 2017 via https://www.fhwa.dot.gov/policyinformation/travel_monitoring/historicvmt.xlsx.

Over the four-decade period covered here, federal Corporate Average Fuel Economy (CAFE) mandates helped lift miles-per-gallon averages by 80 percent in California and 70 percent in the rest of the country.

In the **Gasoline** tab of the spreadsheet underlying this report, we divided each year's VMT by the number of gallons consumed in that year, for both California and the 49 states. These calculations show that from 1975 to 2016, average mpg increased from 12.9 to 23.5 in California, a gain of 82 percent, and from 13.0 to 22.0 in the other 49 states, a gain of 69 percent.

In 1975, for every 100 units of fossil fuels that California required to produce a dollar's worth of economic output, the rest of the country required 130 units. By 2016, the ratio of U.S. fossil fuel use per GDP relative to California had ballooned to 175.

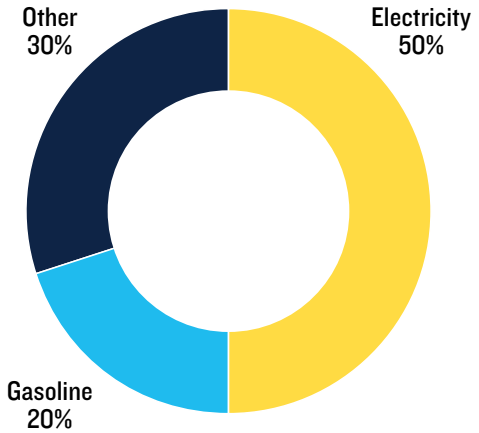
Refer to Table A1, above. In 1975, California required an average of 9,562 Btu of fossil fuels to produce a dollar's worth of GDP, while in the same year, the 49 states required 12,394 Btu to produce the same amount of GDP; the ratio of the second figure to the first is 1.30. In 2016, the California figure was 2,836 Btu per dollar, while the 49-state figure was 4,976; the ratio of the second figure to the first is 1.75.

Because the United States as a whole didn't act as aggressively as California to reduce economic dependence on fossil fuels, we missed a chance to wipe out the carbon emissions equivalent of our entire fleet of automobiles.

This statement has already been sourced in this appendix, but here we embellish the derivation slightly. The burning of gasoline by U.S. passenger vehicles (automobiles and light trucks) and, secondarily, by recreational vehicles such as boats and all-terrain vehicles, caused the emission of 1,075 million metric tons of carbon dioxide in 2016. Petroleum refining to produce that gasoline added an additional 169 million metric tons, according to the Carbon Tax Center's carbon-tax spreadsheet. The combined figure, 1,244 million metric tons of CO_2 associated with gasoline, is within 4 percent of the 1,199 million metric tons in our hypothetical calculation.

We now allocate California's fossil fuel savings into three broad categories: electricity, gasoline, and "other." This material was deemed too detailed for the main text, but technical-minded readers may find it of interest. Note that the figures in the next several paragraphs are derived and presented in the **Distillation** tab of the spreadsheet underlying this report.

FIGURE A3: WHERE CALIFORNIA CUT ITS FOSSIL FUEL USE (RELATIVE TO THE OTHER 49 STATES)



Electricity: Earlier in this appendix we noted that California consumed 120.3 TWh of fossil fuel electricity in 1975 and 187.9 TWh in 2016. Converting these figures to Btus (at an assumed rate of 10,000 Btu/kWh) and factoring the more than fourfold growth in GDP (the multiple of 4.16 from 1975 to 2016 California GDP is shown in Table A1), California's 2016 electricity fossil fuel requirement per dollar of GDP was only 0.3757 times as great as its requirement in 1975.

For the other 49 states, the corresponding figures are: 1975 fossil fuel electricity, 1,321.3 TWh; 2016 fossil fuel electricity, 2,466.5 TWh, GDP growth multiple, 2.99. For the 49 states, the 2016 electricity fossil fuel requirement per dollar of GDP was only 0.6240 times as great as its requirement in 1975.

If the 1975–2016 fossil fuel electricity-to-GDP multiple for the 49 states had been the same as California's 0.3757, then the 49 states' consumption of fossil fuel electricity in 2016 would have been 0.3757/0.6240 multiplied by 2,466.5 TWh, which equals 1,484.9 TWh. This hypothetical figure is less than the actual (2,466.5 TWh) by 981.6 TWh. Applying our assumed Btu/kWh rate of 10,000, the missed fossil fuel savings in electricity was **9.82 quads**.

Gasoline: The analogous process for gasoline yields an estimate of missed fossil fuel savings of 3.97 quads. Here are the underlying figures: The 49 states consumed 15.96 quads of gasoline in 2016. On a Btu/GDP basis, this figure was 1,103 Btu of gasoline per dollar of GDP, which was 0.466 times as great as the 1975 figure of 2,367. California outpaced the 49 states somewhat; its Btu/GDP ratio for 2016, 788 Btu of gasoline per dollar of GDP, being 0.350 times as great as its 1975 ratio of 2,251. If the 1975–2016 gasoline-to-GDP multiple for the 49 states had been the same as California's, 0.350, then the 49 states' consumption of gasoline in 2016 would have been 0.350/0.466 x 15.96 quads, or 11.99 quads. This hypothetical figure is less than the actual (15.96 quads) by **3.97 quads**.

Other: For this calculation, we define as "Other" all fossil fuel Btus not accounted for by electricity or gasoline. For the 49 states, this category consumed 31.40 quads in 2016, which equates to 2,169 Btu per dollar of GDP. This Btu/GDP ratio was 0.297 times as great as the 1975 figure of 7,296. In this category as well as electricity and gasoline, California outpaced the 49 states, with its Btu/GDP ratio for 2016, 1,247 Btu per dollar of GDP, being 0.241 times as great as its 1975 ratio of 5,176. If the 1975–2016 "Other Btu"-to-GDP multiple for the 49 states had been the same as California's, 0.241, then the 49 states' consumption of fossil fuels for uses other than electricity or gasoline in 2016 would have been 0.241/0.297 x 31.40 quads, or 25.43 quads (before rounding). This hypothetical figures is less than the actual (31.40 quads) by **5.97 quads**.

These three missed fossil fuel savings for the 49 states—9.82 quads in generating electricity, 3.97 quads in gasoline, and 5.97 quads in other fuel uses—underlie the doughnut graph at the top of this section. The percentages implied by these missed savings—50 percent in the electricity sector, 20 percent in gasoline, and 30 percent in other uses—can be viewed as the shares of California's fossil fuel savings resulting from that state's outpacing the other 49 states in reducing the dependence of its economic activity on fossil fuels.

It is true that the sum of the three figures in this discussion, 19.76 quads, is greater than the figure of 18.82 quads used in the body of the report to represent the fossil fuel savings that the United States would have realized in 2016 if the entire country had downsized its dependence on fossil fuels relative to GDP at the same rate as California. The discrepancy between the two figures is around 5 percent, which is not small. But the anomaly does not undermine the essential finding of this report: that the failure of the other 49 states to match California's progress in cutting dependence on fossil fuels since 1975 is causing the United States today to be emitting 25 percent more carbon pollution than if it had followed California's lead.

Over the past four decades California has already reduced its fossil fuel consumption per unit of GDP by a compound rate of 2.9 percent per year. For the other 49 states, the compounded annual reduction rate was 2.2 percent.

In 1975 California's economy consumed 9,562 Btus of fossil fuels for each (2009 constant) dollar of GDP. In 2016 the analogous number of Btus was 2,836. The ratio of the latter figure to the former is 0.2966. Exponentiating that to the reciprocal of 41 (the number of intervening years), i.e., $0.2966^{(1/41)}$, yields 0.9708. Subtracting 1 from that figure yields **–2.92 percent**. A parallel calculation for the 49 states, using 12,394 Btus in 1975 and 4,976 Btus in 2016, yields a compounded annual rate of change of **–2.20 percent**.

California's economy today is effectively one-third larger than it would have been if the state's ratio of economic activity to fossil fuel use had grown only at the rate of the United States. This dividend equates to almost $700 billion in increased economic activity in California in 2016—an amount in the same ballpark as the entire domestic product of Pennsylvania or Ohio.

California's GDP in 2016 was $2,620 billion, according to official state data referenced in the GDP section of this appendix, above. In that year, the state produced 1.75 times as much economic output per Btu as the rest of the country, whereas in 1975 the analogous ratio was only 1.30. Had the ratio remained at its 1975 level, California GDP in 2016 would have been only 1.30/1.75 as great as the actual amount. The missed economic output would have been $684 billion (0.45/1.75 x $2,620 billion). For comparison, 2017 state economic data maintained by the statistics portal Statista.com (https://www.statista.com/statistics/248023/us-gross-domestic-product-gdp-by-state/) show Pennsylvania with $752 billion of GDP and Ohio with $649 billion.

Even if all 50 states had matched California's 1975–2016 rate of progress in reducing fossil fuel use relative to GDP, nationwide consumption of fossil fuels would have fallen from 1990 (a common baseline year) to 2016 at an average annual rate of just 0.73 percent.

As noted in the text and derived earlier in this appendix, U.S. fossil fuel consumption in 2016 of 78.7 quads would have been 18.8 quads less if the 49 states had matched California's downward trajectory of fossil fuels used per economic output from 1975 to 2016. The resulting (hypothetical) U.S. consumption, 59.9 quads, is 17.3 percent less than actual 1990 fossil fuel use of 72.33 quads, before rounding. Reverse-compounded over the 26-year interval from 1990 to 2016, that decrease equates to an average annual reduction of 0.73 percent (2016 figures were calculated by the authors; 1990 figures are from *Monthly Energy Review*).

Going forward, the United States will have to reduce its fossil fuel dependence more than three times as fast as that hypothetical rate for our country to meet its Paris climate commitment.

U.S. CO_2 emissions in 2018 from burning fossil fuels were about 5,028 million metric tons (a preliminary figure calculated by applying 2016–2018 estimates of changes in emissions compiled by Carbon Brief to the Carbon Tax Center spreadsheet cited earlier in this appendix). The U.S. Paris commitment for 2025 was 4,250 million metric tons (calculated as 27 percent less than U.S. 2005 emissions of 5,822 million metric tons, from the CTC spreadsheet). The implied 2018–2025 reduction is 15.5 percent, which equates to a compounded annual reduction rate of 2.37 percent. That figure is 3.2 times as great as the hypothetical annual reduction rate of 0.73 percent just noted (if all 50 states had matched California's downward trajectory of fossil fuels used per economic output from 1975 to 2016). More details of these calculations are in the **Paris** tab of the spreadsheet underlying this report.

ENDNOTES

1 See, for example, Chapman University, Center for Demographics and Policy, *California, Greenhouse Gas Regulation, and Climate Change*, 2018, www.newgeography.com/files/California GHG Regulation Final.pdf, which argues that "California's prioritization of climate change policies have [sic] resulted in disparate and damaging social and economic impacts for most Californians."

2 This report compares California with the rest of the United States considered as a single entity. While that entity includes the District of Columbia, we use the expression "the other 49 states" as shorthand.

3 The share of California's population living in urban areas in 2010 was 95 percent, versus 81 percent for the United States as a whole, according to census data compiled by Iowa State University's Iowa Community Indicators Program. Figures for 1970 were 91 percent (California) and 74 percent (United States). In both years, California trailed only the District of Columbia in its percentage of urban population.

4 The classic text on "inherently green" cities is David Owen, *Green Metropolis: Why Living Smaller, Living Closer, and Driving Less Are the Keys to Sustainability*, (New York: Riverhead Books 2009), https://www.penguinrandomhouse.com/books/302948/green-metropolis-by-david-owen/9781594484841/.

5 "California Takes Population Lead; but New York Is Still Ahead in Number of Civilians, Census Bureau Says," *New York Times,* September 1, 1964, https://www.nytimes.com/1964/09/01/archives/california-takes-population-lead-but-new-york-is-still-ahead-in.html.

6 In this report we measure and discuss California's and the other 49 states' fossil fuel use as total Btus (British thermal units) from coal, oil, and natural gas combined.

7 Toward the end of this report we note that, had the entire country followed California's trajectory in reducing fossil fuel use relative to GDP, total national use of fossil fuels would have fallen by an average of 0.73 percent per year from 1990 to 2016. Actual use of fossil fuels *grew* instead by an average of 0.32 percent per year, a rate 1.05 percentage points greater than the negative 0.73 percent hypothetical rate.

8 See, for example, Anant Sudarshan and James L. Sweeney, "Deconstructing the Rosenfeld Curve," Precourt Energy Efficiency Center, Stanford University, 2008, www.peec.stanford.edu/research/deconstructing-rosenfeld-curve.

9 Our 56 percent figure likely overstates the true increase in California's fossil fuel electric generation, since, as noted, our calculations assume that all imported electricity was generated with fossil fuels. California's per capita and per GDP fossil fuel generation almost certainly declined more than our percentages in the text as well, for the same reason.

10 See appendix for derivation of that figure.

11 U.S. electricity generation in 2016 from coal, 1,239 TWh, was 777 TWh below its 2007 peak of 2,016 TWh. See any edition of U.S. Energy Information Administration, *Monthly Energy Review*, Table 7.2a ("Electricity Net Generation").

12 In 2017, Japan generated 1,020 TWh from all sources, per *BP Statistical Review of World Energy 2018*, 67th ed., June 2018, p. 46, www.bp.com/content/dam/bp/business-sites/en/global/corporate/pdfs/energy-economics/statistical-review/bp-stats-review-2018-full-report.pdf.

13 We say "nearly" because the ostensible 20-point increase from 1990 to 2016 was only 19.4 percentage points, before rounding.

14 Rob Nikolewski, "Regulators Vote to Shut Down Diablo Canyon, California's Last Nuclear Power Plant," *Los Angeles Times,* January 11, 2018, https://www.latimes.com/business/la-fi-diablo-canyon-nuclear-20180111-story.html.

15 This comparison, too, is conservative; efficiency savings are nearly always estimated in a policy context in which an error of optimism is considered a defect of the analysis, while an error of pessimism is termed "conservatism."

16 The 60 to 70 nuclear reactors contemplated would have been located every 10 miles along the coast. Richard Frank, "Celebrating Four Decades of Energy Innovation: The California Energy Commission at 40," *Legal Planet*, January 30, 2015, http://legal-planet.org/2015/01/30/celebrating-four-decades-of-energy-innovation-the-california-energy-commission-at-40/.

17 AB 1575 (1973–74).

18 California Energy Commission, "Title 20 Appliance Efficiency Program," https://www.energy.ca.gov/appliances/.

19 California Energy Commission, "Building Energy Efficiency Program—Past Building Energy Efficiency Standards," https://www.energy.ca.gov/title24/.

20 California Public Utilities Commission, "Regulating Energy Efficiency: A Primer on the CPUC's Energy Efficiency Programs," February 2016, http://www.cpuc.ca.gov/uploadedFiles/CPUC_Public_Website/Content/News_Room/Fact_Sheets/English/Regulating%20Energy%20Efficiency%200216.pdf.

21 Figure 6 is adapted from "Statewide Electricity Savings From Energy Efficiency," Figure 1 in California Energy Commission, "Tracking Progress: Energy Efficiency," 2018, https://www.energy.ca.gov/renewables/tracking_progress/documents/energy_efficiency.pdf. Data underlying that figure and extending further back in time were provided to the authors by CEC staff.

22 The efficiency figures in the text and Figure 6 add 6.6 percent to CEC's estimated end-use savings, to allow for electricity losses from delivery (California Public Utilities Commission, *System Efficiency Report, 2017*, Table 1), which puts the efficiency programs on the same footing as generation-based supply.

23 David Roberts, "Climate Change Policy Can Be Overwhelming. Here's a Guide to the Policies That Work," *Vox,* November 16, 2018, updated January 24, 2019, Figure 1, www.vox.com/energy-and-environment/2018/11/16/18096352/climate-change-clean-energy-policies-guide.

24 Standards-based approaches are sometimes criticized as "command and control"—an expression that might apply to detailed design standards, such as a mandate that refrigerators have 3 inches of fiberglass insulation on all sides. However, California efficiency standards are performance-based, requiring, for example, that refrigerators use no more than 700 kWh per year plus 30 kWh/year for each cubic foot of size above a threshold. Performance-based standards encourage market competition for the best and cheapest way to meet the prescribed level and lead to design concepts beyond the standard-writer's imagination. Indeed, this helps explain why most appliance cost increases due to standards have been zero or less. Performance-based standards also encourage continual improvement by demonstrating how far one can go before exhausting known efficiency options.

25 For example, the European Ecodesign Initiative was established in 2009 to oversee standards for the European Union. See European Commission, "Internal Market, Industry, Entrepreneurship and SMEs: Industry," http://ec.europa.eu/growth/industry/sustainability/ecodesign_en. Accessed March 26, 2019

26 David Goldstein, *Invisible Energy: Strategies to Rescue the Economy and Save the Planet* (Richmond, CA: Bay Tree Publishing, 2010).

27 Total U.S. solar electricity generation, largely from distributed and utility-scale solar photovoltaics but also from solar thermal plants, was 55 TWh in 2016 (U.S. Energy Information Administration, *Monthly Energy Review*, Table 7.2a, Electricity Net Generation).

28 California's Renewable Portfolio Standard was first adopted in 2002 through Senate Bill 1078 (SB 1078) It was authored by Senator Byron Sher and signed into law by Governor Gray Davis. It set a target of 20 percent renewables by 2017.

29 Go Solar California, "About the California Solar Initiative," www.gosolarcalifornia.org/about/csi.php. Accessed March 25, 2019.

30 See California Public Utilities Commission (CPUC), California Renewables Portfolio Standard (RPS), http://www.cpuc.ca.gov/rps_homepage/, for a summary of the successive increases in target levels and for links to the enabling legislation and program details.

31 Ibid. Retail electricity sellers met or exceeded CPUC's 2017 target of serving 27 percent of sales with renewable electricity, as did the state's three largest investor-owned utilities (36 percent), and for Community Choice Aggregators (50 percent).

32 For a useful discussion of the federal fuel economy standards and California GHG emission standards and their relationship see: https://oag.ca.gov/environment/clean-air/clean-cars. Accessed April 15, 2019.

33 The classic text on America's pro-agrarian, anti-urban bias is Dan Lazare's *America's Undeclared War: What's Killing Our Cities and How We Can Stop It* (San Diego: Harcourt, 2001), www.amazon.com/Americas-Undeclared-War-Killing-Cities/dp/0151005524.

34 See appendix.

35 David Roberts, "Climate Change Policy Can Be Overwhelming." See endnote 23.

36 *New York Times* journalist Keith Bradsher reported on this arrangement in *High and Mighty—S.U.V.'s: The World's Most Dangerous Vehicles and How They Got That Way* (New York: Public Affairs, 2002), www.nytimes.com/2002/11/26/books/books-of-the-times-when-is-a-car-a-truck-if-uncle-sam-says-so.html. Ironically, during the drafting of this report the *New York Times* was reporting that the U.S. "is hurriedly clearing the way for oil exploration" in the Alaska National Wildlife Refuge. See Henry Fountain and Steve Eder, "In the Blink of an Eye, a Hunt for Oil Threatens Pristine Alaska," *New York Times,* December 3, 2018, www.nytimes.com/2018/12/03/us/oil-drilling-arctic-national-wildlife-refuge.html.

37 As pointed out not only by Bradsher but also by *The New Republic*'s Gregg Easterbrook in his review of Bradsher's book, the rise of SUVs can be seen as a classic case of path dependence, with both social validation and a road-danger "arms race" coercing Americans into abandoning sedans for sport-utility vehicles and pickups. Gregg Easterbrook, "Axle of Evil: America's Twisted Love Affair With Sociopathic Cars," *The New Republic*, January 20, 2003, www.newrepublic.com/article/axle-evil.

38 California Air Resources Board, "Sustainable Communities & Climate Protection Program," https://ww2.arb.ca.gov/index.php/our-work/programs/sustainable-communities-climate-protection-program.

39 Emma Fitzsimmons, "Why the West Coast Is Suddenly Beating the East Coast on Transportation," *New York Times*, January 1, 2019, www.nytimes.com/2019/01/01/nyregion/transportation-east-coast-vs-west-coast.html.

40 California Air Resources Board, "Low Emission Vehicle Program," https://ww2.arb.ca.gov/our-work/programs/low-emission-vehicle-program. Accessed December 2018.

41 California Air Resources Board, "The Zero Emission Vehicle (ZEV) Regulation," fact sheet, www.arb.ca.gov/msprog/zevprog/factsheets/zev_regulation_factsheet_082418.pdf. Accessed December 2018.

42 For a report on State Senator Scott Wiener's most recent legislative attempt, S.B. 50, see Angela Hart, "New California Bill Would Spur Housing Development Near Transit, Job Centers," *Politico*, December 4, 2018, www.politico.com/states/california/story/2018/12/04/new-california-bill-would-spur-housing-development-near-transit-job-centers-724751. For a discussion of a range of transportation alternatives, see Alyssa Walker, "When Electric Isn't Good Enough," *Curbed*, October 24, 2018, www.curbed.com/a/texas-california/electric-cars-climate-change-sacramento-california.

43 This may help visualize the relative percentages: Let's say both you and I start with 100 units of something; if your 100 units shrink by 60, you're left with 40, whereas if mine shrink by 70, I have just 30—one-fourth less than you. Here, the units are fossil fuels (actually, fossil fuels relative to GDP), you are the 49 states, and I'm California.

44 Japan's carbon dioxide emissions from burning fossil fuels in 2017 were 1,177 million metric tons, according to *BP Statistical Review of World Energy 2018*, p. 49.

45 S. David Freeman et al., *A Time to Choose: America's Energy Future*, Energy Policy Project of the Ford Foundation (Pensacola, FL: Ballinger, 1974), https://ieer.org/resource/books/a-time-to-choose-americas-energy-future/.

46 Wilson Clark, *Energy for Survival: The Alternative to Extinction* (New York: Anchor Books, 1975).

47 Amory B. Lovins, *Soft Energy Paths: Toward a Durable Peace*, Harper & Row, 1977, http://www.environmentandsociety.org/mml/soft-energy-paths-towards-durable-peace.

48 Amory B. Lovins, "Energy Strategy: The Road Not Taken?" *Foreign Affairs* 55, no. 1 (October 1976).

49 A quad is one quadrillion Btu—that is, a million billion Btu.

50 Calculated as 72.0 quads x 130/175, which yields 53.2.

51 Ratios of 2016 to 1975 GDP (all expressed in 2009 constant dollars) were 4.16 for California and 2.99 for the 49 states, as Table 1 earlier showed. In annualized terms, the respective growth rates were 3.54 percent in California, 2.71 percent in the rest of the United States.

52 Kieran Corcoran, "California's Economy Is Now The 5th Biggest in the World, and Has Overtaken the United Kingdom," *Business Insider*, May 5, 2018, www.businessinsider.com/california-economy-ranks-5th-in-the-world-beating-the-uk-2018-5.

53 Marco Sakai et al., "Thermodynamic Efficiency Gains and Their Role as a Key 'Engine of Economic Growth,'" *Energies* 12, no. 1 (January 2019): 110, www.mdpi.com/1996-1073/12/1/110.

54 See appendix for derivation of $700 billion figure and comparison with Pennsylvania and Ohio.