Can Clean Energy Replace California Oil Production?

Petroleum cutbacks and the California economy

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Report by Synapse Energy Economics, Inc.

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Acknowledgements

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Above image: View from Griffith Observatory in Los Angeles by Levi Jones, courtesy of Unsplash.

Cover image: Pump jack mining crude oil at sunset by Zbynek Burival, courtesy of Unsplash.

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Summary

California has taken important initiatives to reduce greenhouse gas emissions, often leading the nation in efforts to decrease the use of oil and other fossil fuels. Less obvious, but also important, is California's role as an oil producer. Although the state is a net oil importer, in-state crude oil production is enough to fill about one-third of the state's refinery capacity.[1] How much of a contribution to climate protection can California make by limiting its oil output? And what will be the impacts on the state economy—both of oil cutbacks, and of alternative energy that replaces oil?

This report calculates the job losses from reducing oil output, and the offsetting job gains from alternative energy investments that could begin to replace oil use. It also estimates the value of reduced carbon emissions resulting from California's oil cutbacks.

California currently produces about 0.5 percent of world crude oil output, or about 5 percent of U.S. output. The state's peak year for oil production was 1985. Since then it has been gradually declining, both in absolute terms and as a share of national or global output. Seven counties in southern California account for 99 percent of the state's oil production: above all is Kern County, with 71 percent of the state total, followed by Los Angeles

Image 1: Oil well pumping next to residential units in Signal Hill in Long Beach (David McNew/News/Getty Images).

[1] California crude oil was 31 percent of the total crude input to the state's refineries in 2017, down from almost 38 percent in 2014. California Energy Commission, "Oil Supply Sources to California Refineries," http://www.energy.ca.gov/almanac/petroleum_data/statistics/crude_oil_receipts.html.

County with 11 percent, and smaller amounts from Monterey, Fresno, Ventura, Orange, and Santa Barbara Counties. Oil production and refining represents less than 1 percent of state GDP, and less than 0.2 percent of employment. Even in Kern County, the oil industry accounts for less than 2 percent of employment.

To evaluate the impacts of cutting back oil production, we compare two scenarios. A baseline scenario—referred to as business-as-usual or BAU—assumes continuation of current trends, including the gradual decline in California oil production, and no new policies. In contrast, a policy scenario assumes that no new drilling will be permitted, and that oil production within 2500 feet of homes, schools, and hospitals will be phased out. This results in a much more rapid reduction in oil output. The policy scenario also assumes new construction of solar power, sufficient to replace the oil cutbacks, and use of the increased solar energy to fuel electric vehicles.

As shown in Figure 1, the state as a whole gains about 5,000 full-time equivalent (FTE) jobs per year from the policy scenario. A loss of just over 11,000 jobs per year in oil drilling, production, and refining (including indirect and induced jobs created by the oil industry) is balanced by a nearly identical number of new jobs due to increased investment in solar power. In addition, consumers spend their substantial savings from reduced fuel costs as they convert from gasoline to electric vehicles. This creates an average of almost 5,000 jobs per year. Kern County gains an average of more than 1,500 jobs per year, Los Angeles County has a smaller net gain, and the other five top oil-producing counties, as a group, gain about 3,000 jobs per year.

A loss of just over 11,000 oil-related jobs, combining drilling, extraction, and refining, is offset by a nearly identical number of solar industry jobs, plus almost 5,000 jobs due to respending of consumer fuel savings.

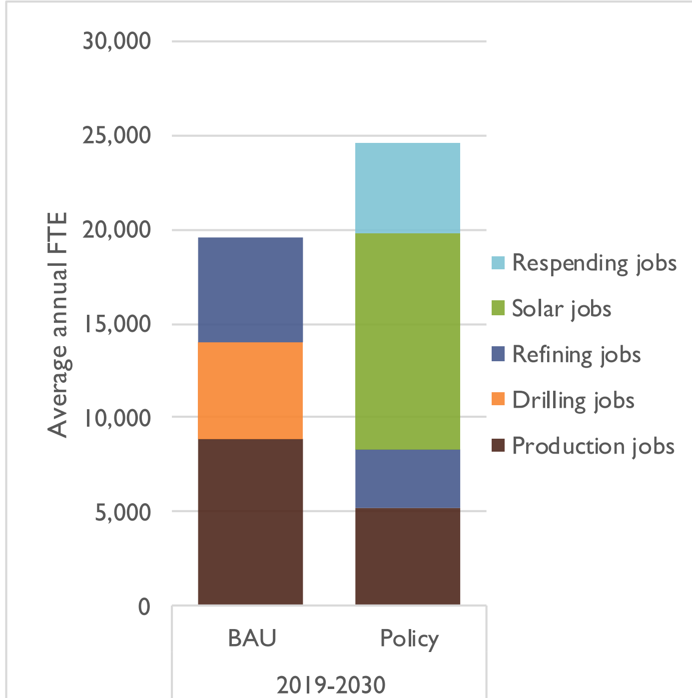

Figure 1. Average annual employment changes for BAU and policy cases, state-wide, 2019–2030

Oil cutbacks bring substantial environmental benefits in addition to job benefits. By 2030, the oil cutbacks result in a reduction of greenhouse gas emissions of 9.7 to 48.4 million metric tons per year. The broad range of estimates reflects uncertainty about how much of California's oil cutbacks will be replaced by increased output from other oil producers. Using conventional valuation of emission savings (the Obama administration's estimates of the social cost of carbon), the greenhouse gas emission reduction in 2030 alone would be worth more than $500 million at the low end, and more than $2.8 billion at the high end.

The environmental benefits of cutting back oil production extend beyond the greenhouse gas reductions. Oil exploration, production, and refining result in numerous local environmental impacts, including production of large volumes of wastewater, many air pollutants, and harmful effects on land use. In addition, the large-scale conversion from gasoline to electric vehicles envisioned in the policy scenario reduces tailpipe emissions, an important source of pollution in many urban areas.

Oil production: California, the nation, and the world

California oil production reached a peak in 1985, the last year of high world oil prices following the 1970s oil crises. From that year's peak of 1.08 million barrels per day, it has declined almost steadily to 0.48 million barrels per day in 2017, less than half the peak level. Production has declined, on average, by 2.5 percent per year since 1985.

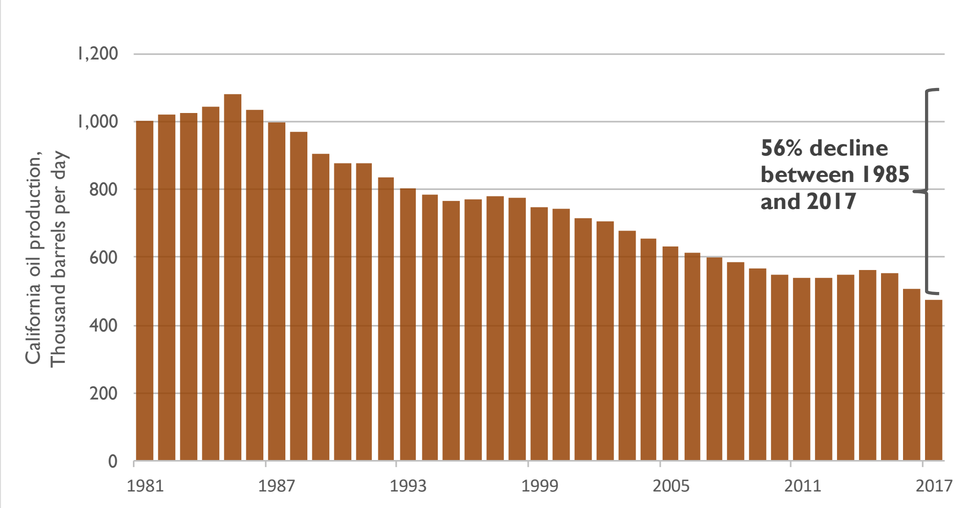

Figure 2. California oil production, 1981–2017

World production, meanwhile, has been gradually increasing. It rose from almost 80 million barrels per day in 2001 to almost 100 million barrels per day in 2017. As a result, California's share of world production has drifted downward from nearly 1 percent in 2001 to about 0.5 percent today. As an oil producer, California is now roughly comparable to Argentina, the world's 28th highest-producing country.[2]

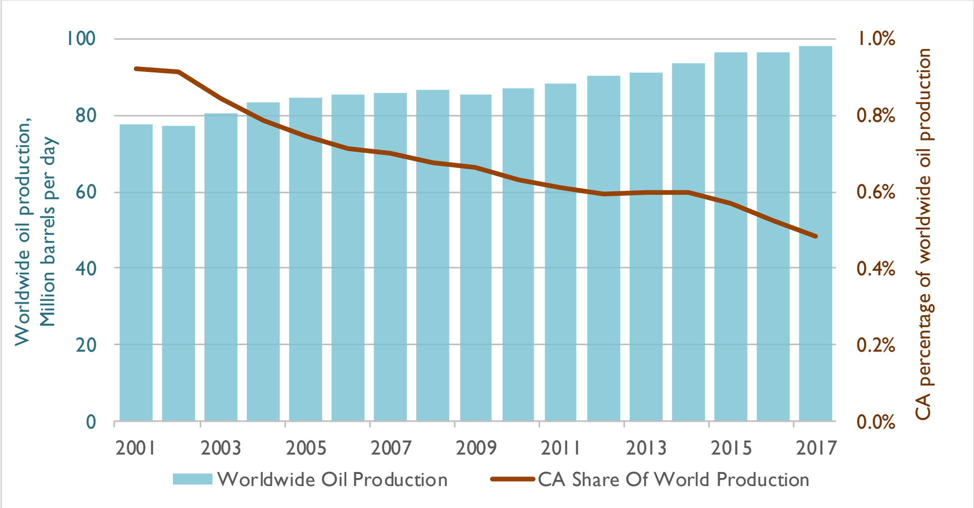

Figure 3. California share of world oil production, 2001–2017

[2] U.S. Energy Information Administration, "International Energy Statistics: Production of Crude Oil including Lease Condensate." Accessed July 25, 2018.

U.S. oil production started declining after 1985, in step with California, until the fracking boom began in 2009. Fracking has led to a rapid increase in U.S., but not California, production in recent years.

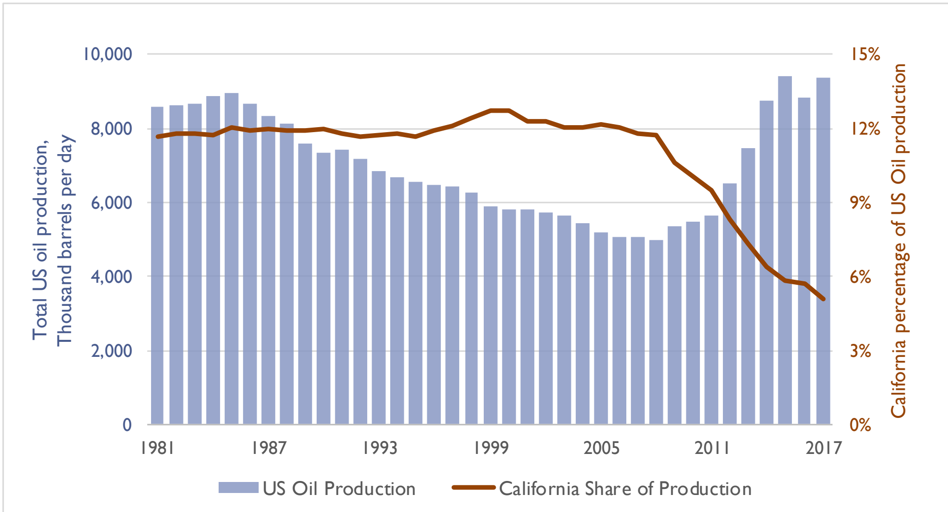

Figure 4. California share of U.S. oil production, 1981–2017

Image 2: Urban oilfield adjacent to homes in the Windsor Hills area of Los Angeles (AP Photo/Reed Saxon).

County lines

California oil production is concentrated in seven counties in the southern half of the state. As of 2017, 71 percent of state production came from Kern County, and 11 percent from Los Angeles County. The seven counties highlighted on the map account for 99 percent of state production

7 counties have 99 % of California oil production

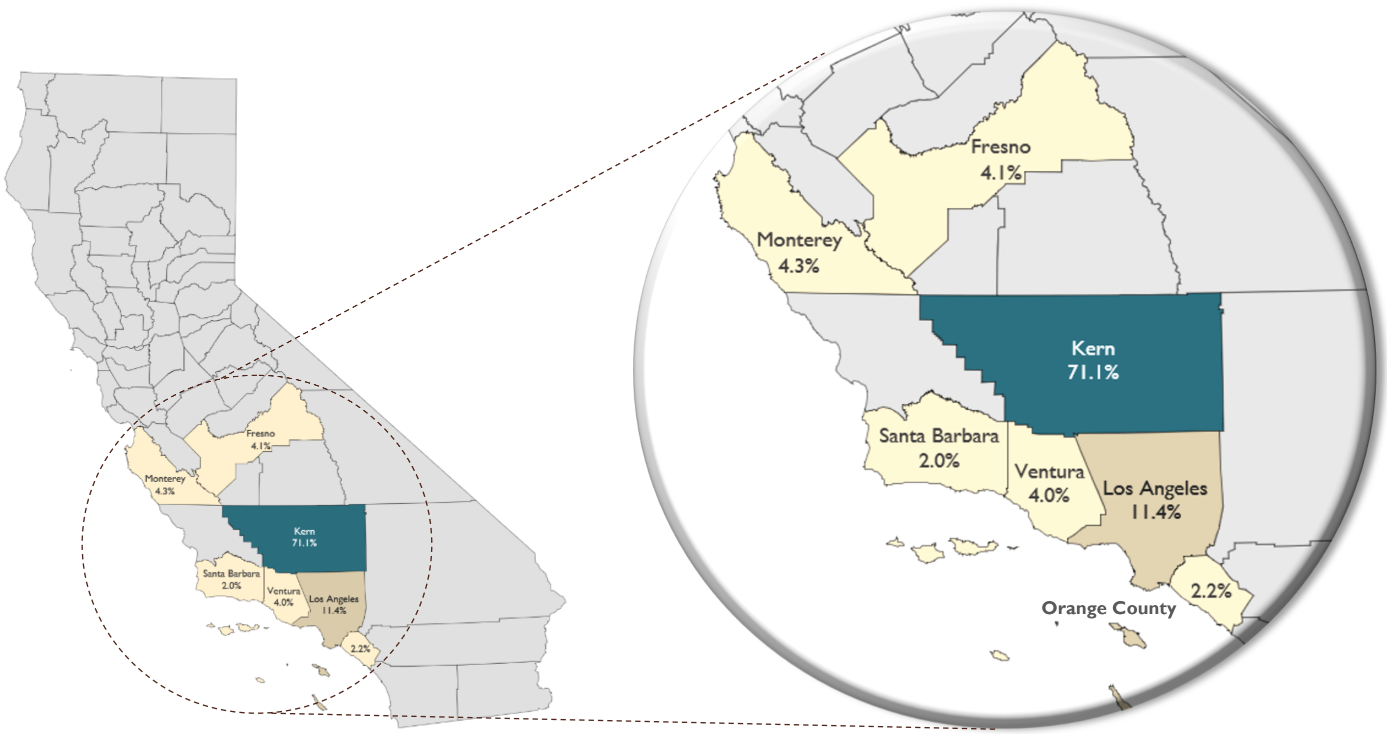

Figure 5. Map of California detailing counties that collectively contribute 99 percent of state oil production

Data Source: California Division of Oil, Gas, & Geothermal Resources. Well search data. https://secure.conservation.ca.gov/WellSearch. Accessed June 11, 2018.

Note: Oil production data includes offshore production in California waters. The California State Lands Commission put a moratorium on new oil and gas leases after a 1969 oil spill in federal waters off Santa Barbara County, and in 1994, the California legislature prohibited new oil and gas leases off California's coast. There are a number of leases that pre-date the moratorium, and offshore production is substantial in Los Angeles and Orange counties. (California State Lands Commission. Oil and Gas. Available at http://www.slc.ca.gov/Info/Oil_Gas.html.)

Oil jobs in California

The oil industry is only a small part of the California economy. In 2016, the state's $2.6 trillion economy included $17 billion in oil refining, $6 billion in oil and gas extraction, and $1 billion in support activities for the oil industry—a total of only 0.9 percent of state GDP.[3] In that year, oil extraction, drilling and refining accounted for less than 21,000 of the state's 14,288,000 jobs, or less than 0.2 percent of total employment. Similarly, Los Angeles County had less than 6,000 oil jobs, out of its total of 3,782,000 jobs, again less than 0.2 percent. Even Kern County, by far the most oil-dependent county, had less than 4,900 oil jobs out of a total of 252,000, or less than 2.0 percent.[4]

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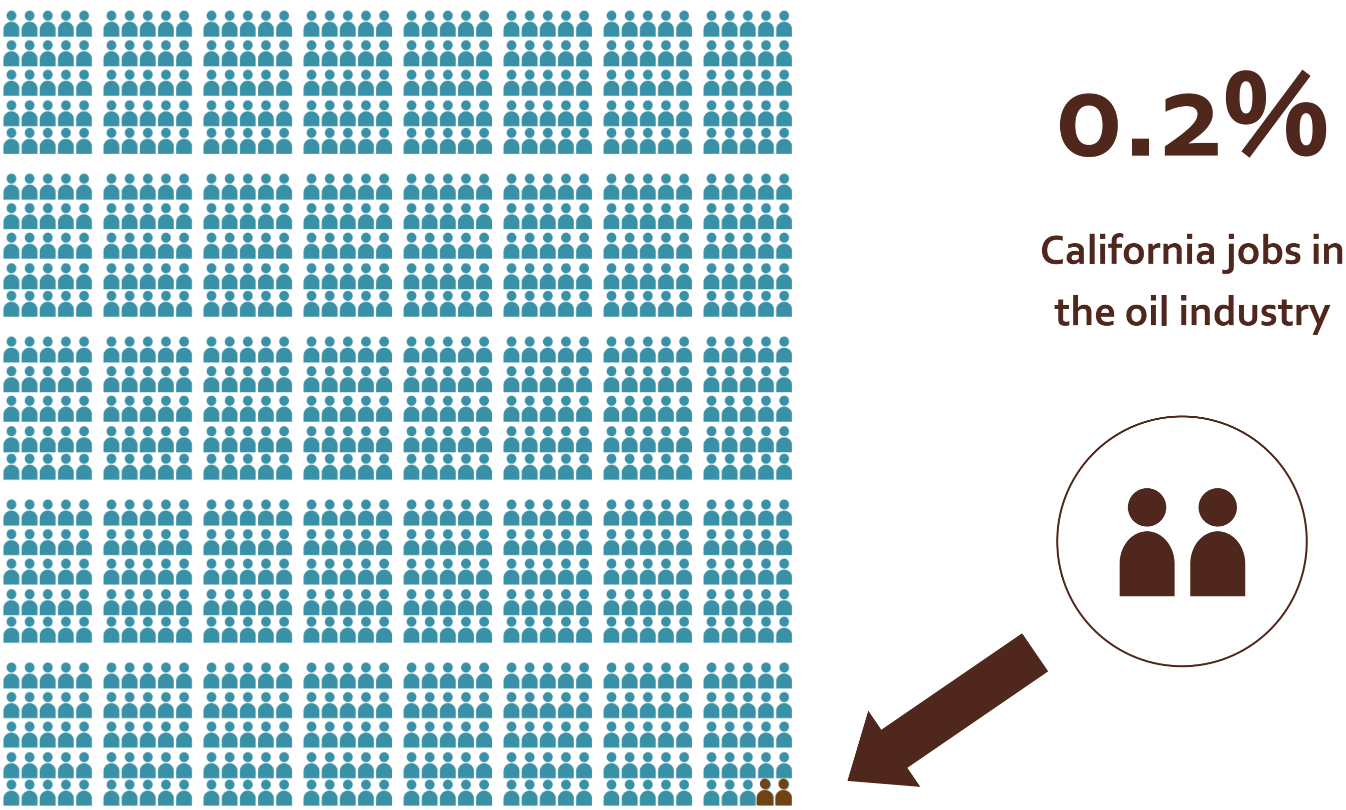


[3] Bureau of Economic Analysis, Annual Gross Domestic Product (GDP) by State. Available at https://www.bea.gov/regional/downloadzip.cfm.

[4] State of California Employment Development Department. Quarterly Census of Employment and Wages. Accessed June 29, 2018. Available at: www.labormarketinfo.edd.ca.gov/qcew/CEW-Select.asp.

Baseline and policy scenarios

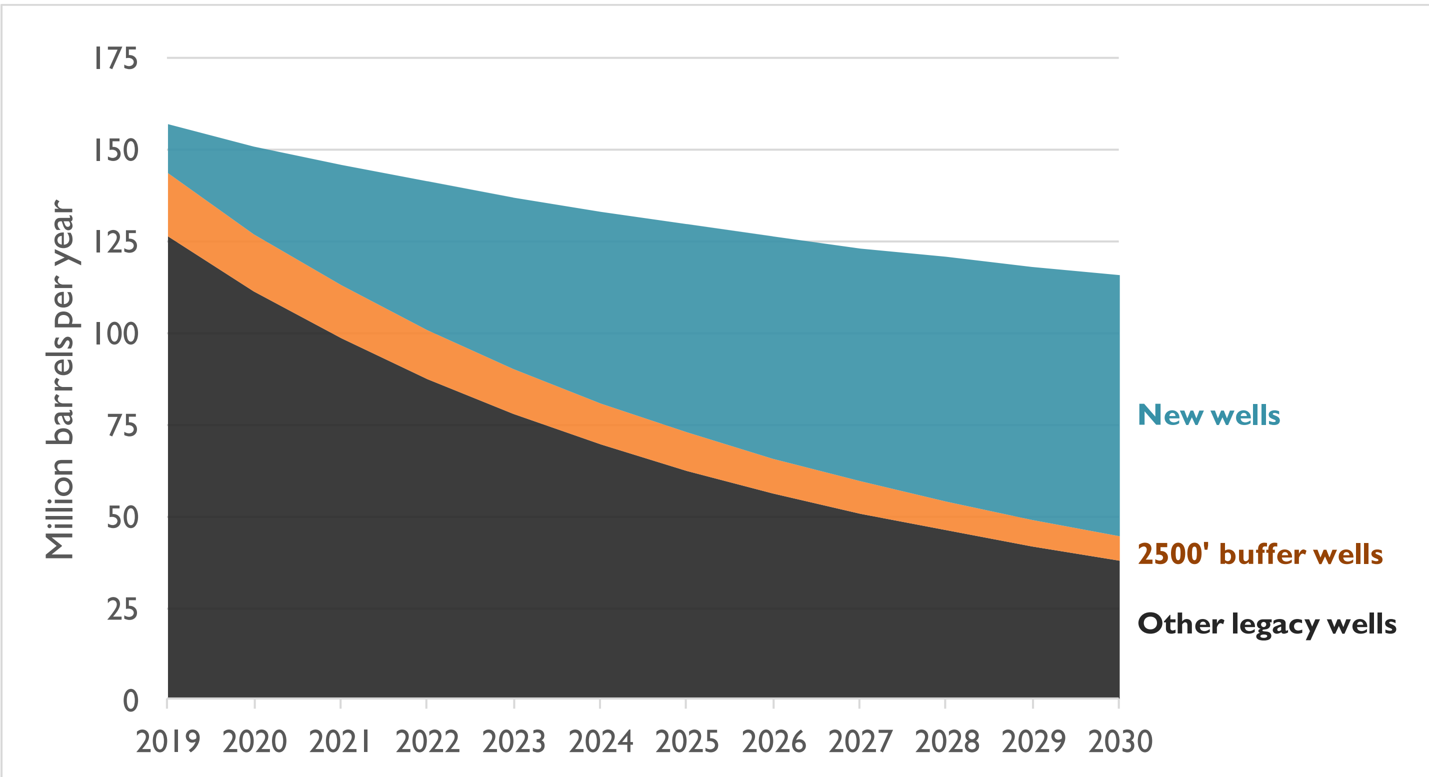


Figure 6. Projected California oil production, business-as-usual case, 2019–2030
Source: Oil Change International analysis.

In this analysis, we estimate the employment impacts of reducing oil drilling, production, and refining, while at the same time ramping up renewable solar photovoltaic supply to meet current demand for miles travelled with electric vehicles. A baseline scenario projects the expected oil output and resulting employment in the absence of new policies. A separate policy scenario makes comparable projections, assuming two important policies to reduce California oil output, and enough solar power to replace the oil reductions. The difference between the two scenarios represents the expected effect of the policy changes.

Baseline scenario: Continuing slow decline in oil output

California oil production has been gradually declining since 1985. Even in the absence of new policies designed to lower output, it seems likely that the decline would continue. Detailed research by Oil Change International (OCI) confirms this in a recent study projecting California production trends through 2030.[5] For 17 categories of wells, the OCI study projects the number of new wells

[5] Trout 2018. "The Sky's Limit California: Why the Paris Climate Goals Demand that California Lead in a Managed Decline of Oil Extraction," Oil Change International. Available at http://priceofoil.org/2018/05/22/skys-limit-california-oil-production-paris-climate-goals/.

and the rate of decline in production from old and new wells, based on extrapolations from historical California well data.[6] In general, oil wells reach their peak output soon after drilling, followed by gradual decline over the rest of their lifetimes. The OCI study integrates research by Kyle Ferrar at FracTracker Alliance. Ferrar used GIS analysis to identify existing oil wells that are within 2500 feet of residences, schools, or hospitals (referred to as "2500' Buffer Wells" below).

Based on OCI's mid-case projections,[7] the state's oil production is likely to decline from 157 million barrels in 2019 to 116 million barrels in 2030, even without any new policies. This would represent an average annual decrease of 2.7 percent, or a cumulative reduction of 26 percent from 2019 through 2030.

Image 3: Oil rig operating in the Culver City neighborhood of Los Angeles (David McNew/News/Getty Images). Over the last fifteen years, urban residents have seen previously unprofitable wells reopen in their neighborhoods, prompting concerns about noise, smells, and possible environmental hazards.

Policy scenario: Less oil, more solar power

Two widely discussed policy proposals would reduce future oil production: banning new production wells, for instance by refusing to issue any new drilling permits; and phasing out oil production within 2500 feet of homes, schools and hospitals. Production from new oil wells, the large blue area in Figure 6, is of increasing importance over time. New oil wells are projected to account for half of the state's baseline production by 2027. Production from existing oil wells that are within the 2500-foot buffer zone, the orange area in the graph, is a smaller but still important category linked to significant public health impacts.

If production from both new wells and 2500-foot buffer wells was eliminated,[8] the remaining output from California oil wells – "other legacy wells," the black area in Figure 6 – would fall by more than 10 percent per year. This would bring a cumulative reduction of 70 percent from 2019 to 2030.

We address employment impacts of these scenarios using IMPLAN, the best known and most widely used model of employment impacts. Specifically, we analyze the jobs gained and lost, relative to the baseline scenario, from five policy-related changes:

1. an end to drilling new oil wells[9]
2. a phaseout of wells with the 2500-foot buffer zone
3. a cutback in southern California refinery output, equal to the reduction in California oil output
4. the replacement of oil cutbacks with new solar PV to fuel electric vehicles, powering the same number of vehicle-miles that the oil cutbacks could have supported
5. consumer savings from the lowered cost of fuel, when switching to electric vehicles

[6] Thanks to Kelly Trout for sharing her detailed results with us.

[7] OCI's mid-case is midway between projections based on high oil prices and those based on low oil prices.

[8] This assumes an immediate end to production in the 2500-foot buffer zone. OCI also explores a scenario with a 5-year phase-out of buffer zone production.

[9] We assume an end to all new drilling. This may overstate the impacts of the policy scenario, since some drilling is for underground injection control (UIC) wells, not new production. UIC wells may be for enhanced oil recovery at existing wells, or for disposal of wastewater. For 2012 – 2017, DOGGR data show that UIC wells accounted for an average of 27 percent of drilling permits in California (personal communication, Kelly Trout).

IMPLAN, like other similar models, calculates three categories of employment resulting from any change in spending:

- **Direct employment:** direct employment, such as jobs in oil extraction created when more oil is produced
- **Indirect employment:** such as jobs in industries that supply services, materials, and equipment to oil producers
- **Induced employment:** the jobs created throughout the economy by consumer spending that results from increases in direct and indirect employment

Image 4: Electric vehicle plugged into a charging station in a parking lot in Los Angeles (AP Photo/Richard Vogel).

In most of the following discussion, we combine direct, indirect, and induced jobs resulting from a policy change.To elaborate on the five categories listed above, we assume that:

1. Direct jobs in drilling are proportional to the number of wells drilled.[10]

2. Direct jobs in oil extraction are proportional to the quantity of oil produced.

3. All California oil production goes to southern California refineries and is not replaced by out-of-state or foreign crude oil when California production is reduced.[11]

4. All the oil cutbacks (the difference between baseline and policy oil output) would have been used to make gasoline. More precisely speaking (since refineries always produce a mix of gasoline and other products), we assume a reduction in gasoline output equivalent to the reduction in the state's crude oil output.

5. The cost to consumers of new electric vehicles, net of federal and state incentives, is equal to the cost of comparable new conventional vehicles.[12]

[10] IMPLAN's 2016 data set implies a very high number of workers in oil and gas drilling. For our calculations, we have recalibrated the model's assumed labor-intensity of the drilling industry so that it matches the actual level of employment in oil drilling in California in 2016, as reported in the state employment census (State of California Employment Development Department. Quarterly Census of Employment and Wages).

[11] Combining separate calculation of the impacts of cutbacks in both oil production and refinery activity would involve double-counting. Refinery activity has large indirect impacts on petroleum production (extraction). So, if the targeted level of extraction cutbacks has already been included, the indirect effects of refinery cutbacks will double-count losses in extraction jobs. To avoid this problem, we have removed IMPLAN's indirect impacts of refinery activity on oil extraction; other indirect impacts remain unchanged. We have also cut the induced employment impacts from refineries, in proportion to the reduction in direct plus indirect refinery jobs.

[12] We also ignore gas stations, gasoline transportation, and related employment, assuming that cutbacks in these sectors are offset by equivalent increases in employment in electric utilities and vehicle charging infrastructure.

Shutting down oil wells creates another category of employment, in remediation of the closed well sites. We have omitted calculation of employment in oilfield remediation, an important but temporary source of jobs when cutting back on oil production.[13]

State vs. county employment

Each scenario and employment calculation can be carried out at two geographical levels.

- A statewide estimate includes jobs throughout California, regardless of where oil production changes and where jobs are created within the state.
- County-level estimates include only the in-county job changes, such as job losses in Kern County due to reduced production in that county.

The county-level calculation omits changes in cross-county jobs, such as decreases in Los Angeles employment due to oil production cutbacks in Kern County (or vice versa), which are included in the statewide calculation. The county-level calculation also omits indirect and induced employment outside the seven major oil-producing counties.[14]

Our employment calculations include estimates for the state and for the seven top-producing counties.

How much PV is needed?

Oil is primarily used for transportation. Suppose that all the California oil cutbacks in the policy scenario were

Image 5: Installing solar PV on roof (Big Stock).

reductions in fuel for light-duty vehicles (cars and light trucks). Then it is easy to find the amount of solar power needed to support the same amount of transportation in electric vehicles. The national average fuel economy of cars and light trucks on the road in 2017 was 23.5 mpg.[15] Since there are 42 gallons in a barrel of oil, one barrel supports an average of 987 vehicle-miles of travel. The average efficiency of the best-selling electric vehicles in the United States today is about 30 kwh per 100 miles.[16] Thus 296 kwh of electricity would be needed for 987 vehicle-miles of travel, the same amount produced by a barrel of oil.

The policy scenario for California oil reduction—no new wells and no production in the 2500-foot buffer zone—would save 78.1 million barrels of oil in 2030 (see Figure 11 on page 17). The electric-vehicle equivalent, multiplying 296 kwh per barrel by the number of barrels, is 23,100 GWh in 2030. To reach this target, California would need a cumulative 8.8 GW of new solar capacity

[13] Remediation activities would make a relatively small contribution to employment in the policy scenario. Some observers have estimated that remediation may produce almost as much employment as operation of a well - for one year after closure. In their analysis of the economic impacts of restricting oil and gas extraction in the city of Los Angeles, David Rigby and Michael Shin estimate that there would be direct employment losses of 269 full time equivalent workers associated with implementing a 2500′ setback ordinance, while remediation activities at the affected sites could result in single-year direct employment gains of 215, for a net loss of 54 in the year that remediation occurs. Their analysis finds that annual total job losses (direct, indirect, and induced employment) associated with the policy would be 535, while remediation activities could result in single year total employment increases of 356 jobs, for a net job loss of 179 during the year that sites are remediated. (Rigby, David and Michael Shin 2017. "The Oil and Gas Extraction Sector in the City of Los Angeles.")

[14] To avoid spurious calculations involving Bay Area refineries, we constrain the refinery calculations to the seven oil-producing counties (i.e. to Los Angeles and Kern Counties, the only two oil-producing counties that have refineries). We also assume that the increased adoption of electric vehicles, and related fuel savings, is restricted to the seven counties, distributed in proportion to population.

[15] U.S. Energy Information Administration, Annual Energy Outlook 2018, Light-Duty Vehicle Miles per Gallon by Technology Type, Table 41.

[16] U.S Department of Energy, "All-Electric Vehicles." https://www.fueleconomy.gov/feg/evtech.shtml.

by 2030 if relying exclusively on utility-scale solar power, or 13.2 GW of new capacity by 2030 if relying on distributed solar.[17]

For comparison, California had a total of 21.1 GW of installed solar capacity at the end of 2017.[18] Replacing the oil cutbacks with the equivalent amount of electric vehicle fuel would require a cumulative 42 percent increase in current PV capacity by 2030 with utility-scale solar, or a 63 percent increase with distributed solar.

Assuming solar capacity is installed at a steady rate from 2019 through 2030, the policy scenario would require adding 730 MW of utility scale solar or 1100 MW of distributed solar each year.[19] In our calculations, these projected solar investments are distributed by county in proportion to each county's loss of oil production under the policy scenario.

Costs and productivity

The jobs produced through increased solar installations depend on capital expenditure and operations and maintenance (O&M) costs for solar power. The well-known, dramatic declines in the cost of solar power will continue to reduce investment requirements, and therefore jobs as well, through 2030, according to the National Renewable Energy Laboratory (NREL):

- For distributed solar power:[20]
    - Capital expenditures, $2,660/kW in 2017, are projected to drop to $1,620/kW by 2030.
    - O&M expenses, $21/kW-yr in 2017, are likely to decline to $7/kW-yr by 2030.
- For utility scale solar:[21]
    - Capital investment is expected to fall from $1,915/kW in 2017 to $945/kW in 2030.
    - O&M costs, $13/kW-yr in 2017, may fall to $10/kW-yr in 2030.

As a result of plummeting solar costs over the forecast period, the cumulative cost of installing the additional solar power is less than the costs of drilling new wells in the BAU scenario. With drilling costs of $1.88 million per well,[22] the total cost for new wells in the BAU scenario is $36 million. In comparison, the cumulative cost for the equivalent solar capacity is $27 million for distributed solar, or $12 million for utility-scale solar.

IMPLAN provides a single-year snapshot of the economy, in this case for 2016. It does not incorporate changes over time in productivity. Rapid decreases in solar power costs imply rapidly rising productivity: the same amount of solar capacity is being produced by fewer workers over time. Something similar is happening in the oil industry, although at a slower pace: from 1987 to 2017, productivity per worker rose by 2.5 percent per year in oil and gas extraction, and by 2.3 percent per year in refineries.[23] Our future projections assume the continuation of these trends, so that slightly fewer workers are needed each year to produce the same amount of oil.

Another issue involves changes in consumer costs over time. The transition from gasoline to electricity saves

[17] This calculation assumes that capacity factors (defined as actual output, divided by theoretical output if producing at maximum capacity in every hour of every day) for solar photovoltaic panels in southern California are 30 percent for utility-scale installations and 20 percent for distributed (individual rooftop) systems. (See Pat Knight et. al., 2018. Clean Energy for Los Angeles, Synapse Energy Economics, Inc.).

[18] Solar Energy Industries Association, 2018. Top 10 Solar States 2017. Available at https://www.seia.org/sites/default/files/2018-03/SEIA_Top10_Solar_States_2017.pdf.

[19] This schedule does not match the projected oil cutbacks on a year-by-year basis. However, it reaches 100 percent replacement of oil cutbacks by 2030.

[20] National Renewable Energy Laboratory, 2018. Cost Reduction Roadmap for Residential Solar. The forecasts used are based on the less aggressive pathway representing a conservative estimate based on technologies and business practice shifts within the new construction market. Costs are presented in 2017 dollars. Available at https://www.nrel.gov/docs/fy18osti/70748.pdf.

[21] National Renewable Energy Laboratory, 2017. Annual Technology Baseline Cost and Performance Summary. Available at https://atb.nrel.gov/electricity/2017/summary.html. The forecast is the ATB Mid Scenario and based on current market conditions.

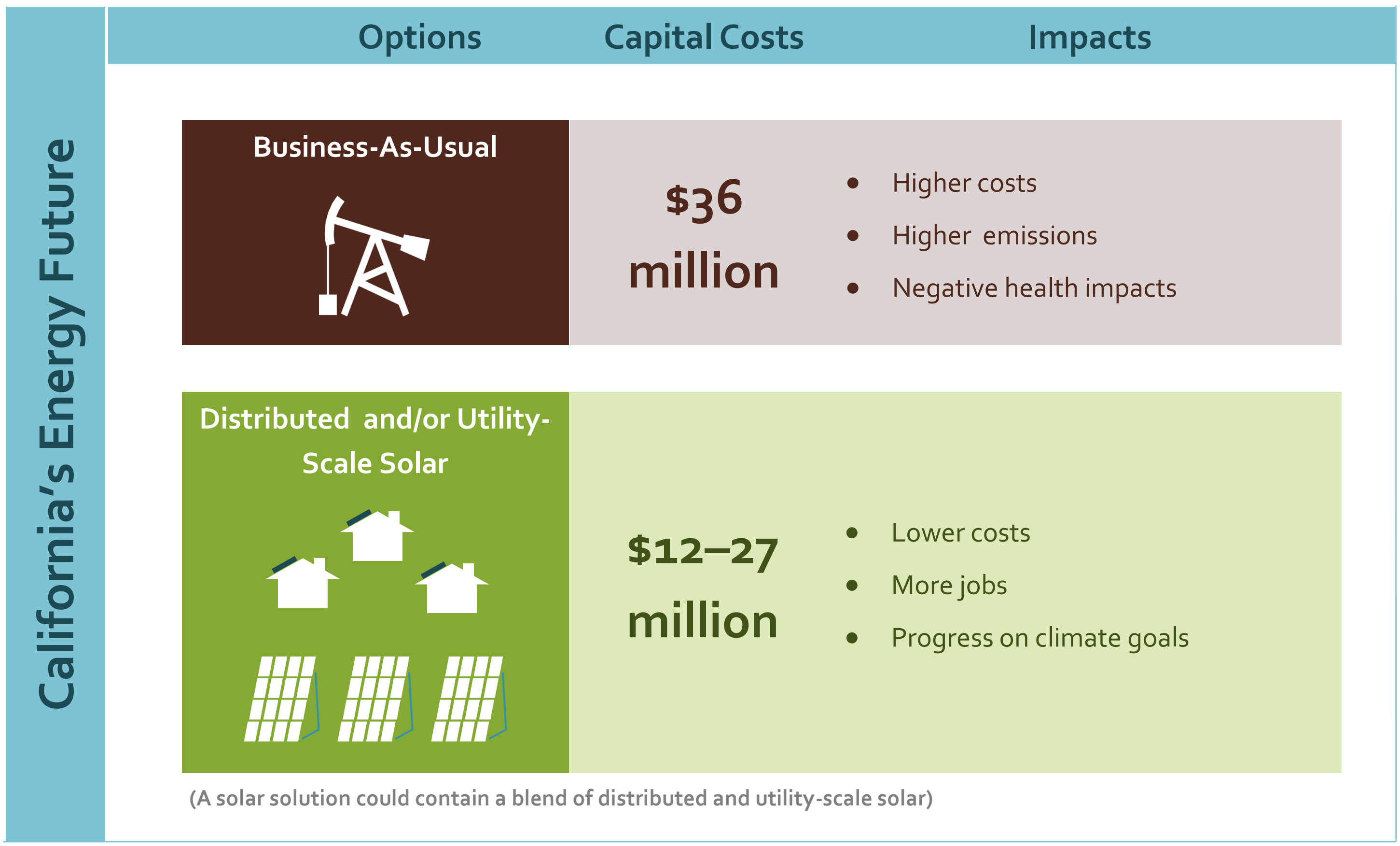
[22] This is the ratio of IMPLAN total drilling costs to the number of new wells drilled in 2016.

[23] Bureau of Labor Statistics, 2018. "Productivity and Costs by Industry: Manufacturing and Mining Industries – 2017." Available at: https://www.bls.gov/news.release/pdf/prin.pdf. We assume that the rate of productivity increase in oil extraction applies to drilling as well.

money for drivers due to the lower fuel cost of charging electric vehicles. These savings result in additional consumer spending that would cause a further increase in jobs.

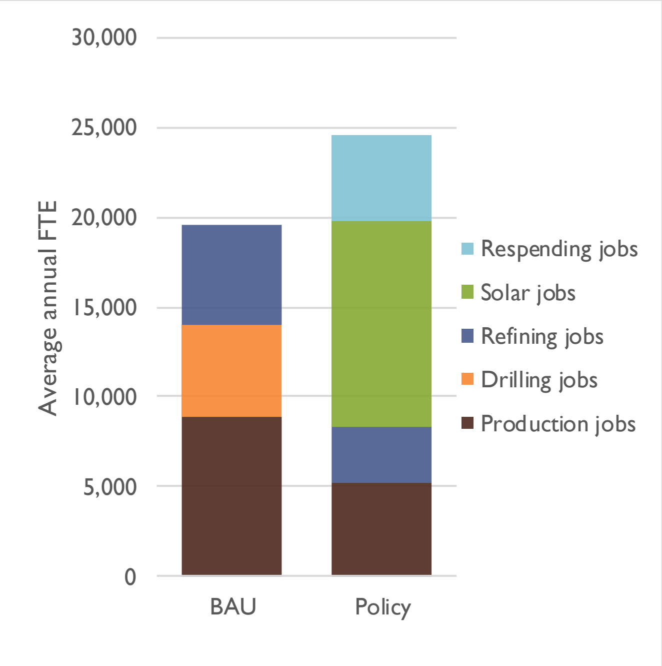
The difference between the amount spent on gasoline vs. electricity to drive the same number of vehicle-miles in a year is based on forecasts of gasoline and electricity prices. Starting from recent California prices, both are projected to increase at similar average rates through 2030: 2.15 percent per year for electricity, and 2.3 percent per year for gasoline (both in constant dollars, corrected for inflation).[24]

The result is a substantial gap: by 2030, gasoline spending of $970 million is replaced by electricity spending of $390 million, leaving $580 million for additional consumer spending in that year alone.



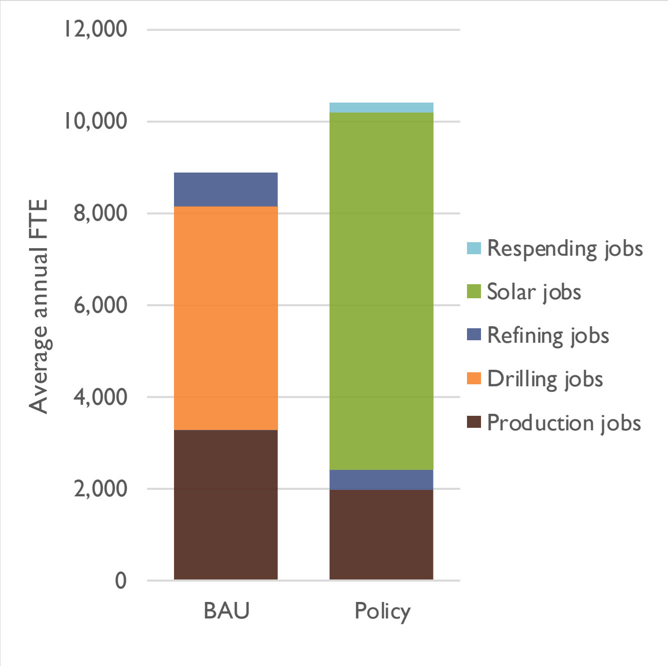
[24] Electricity price escalation is based on an E3 report, Investigating a Higher Renewables Portfolio Standard in California (2014). Gasoline price escalation is a national average projected by U.S. EIA's Annual Energy Outlook 2018.

Employment impacts



California		2019-2030	
Average annual FTEs	*BAU*	*Policy*	*Job difference*
Oil	19,590	8,299	(11,290)
Solar	0	11,448	11,448
Respending	0	4,829	4,829
Total jobs	**19,590**	**24,576**	**4,987**

Figure 7. Average annual employment changes for BAU and policy cases, state-wide, 2019–2030



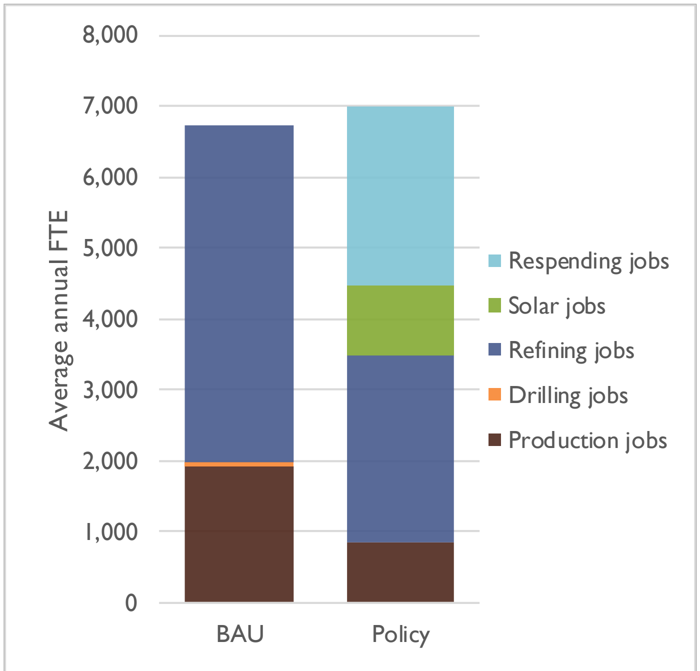
Kern		2019-2030	
Average annual FTEs	*BAU*	*Policy*	*Difference*
Oil	8,855	2,383	(6,473)
Solar	0	7,798	7,798
Respending	0	197	197
Total jobs	**8,855**	**10,378**	**1,523**

Figure 8. Average annual employment changes for BAU and policy cases, Kern County, 2019–2030

At the statewide level, the policy scenario creates an annual average of about 5,000 more full-time equivalent (FTE) jobs than the baseline scenario.[25] A loss of just over 11,000 oil-related jobs—combining drilling, extraction, and refining—is offset by a nearly identical increase in the number of solar industry jobs, plus almost 5,000 jobs due to respending of consumer fuel savings.

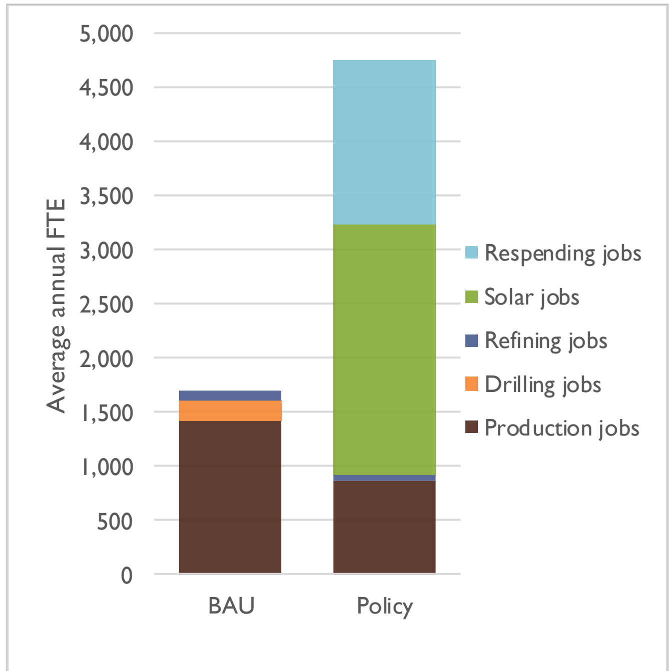
We also examine the results by county. The combined results for the seven oil-producing counties are close but not identical to the state totals. In a statewide analysis, a fraction of the indirect and induced jobs created by oil or solar power spending are located outside the seven-county area.

[25] All figures in this section are annual averages over the 12-year forecast period, 2019–2030. For results in job-years, multiply by 12. All job figures in this section combine direct, indirect, and induced jobs from the specified activities.



Los Angeles County	2019-2030		
Average annual FTEs	*BAU*	*Policy*	*Difference*
Oil	6,731	3,489	(3,241)
Solar	0	980	980
Respending	0	2,513	2,513
Total jobs	**6,731**	**6,983**	**252**

Figure 9. Average annual employment changes for BAU and policy cases, Los Angeles County, 2019–2030



5-county	2019-2030		
Average annual FTEs	*BAU*	*Policy*	*Difference*
Oil	1,712	925	(787)
Solar	0	2,320	2,320
Respending	0	1,511	1,511
Total jobs	**1,712**	**4,755**	**3,043**

Figure 10. Average annual employment changes for BAU and policy cases, five counties, 2019–2030

Kern County, the center of California oil production, gains an annual average of more than 1,500 jobs under the policy scenario. Although the county is hit by oil production cutbacks in the policy scenario and loses a fraction of its small refining industry, new solar investments are allocated in proportion to oil cutbacks. These investments provide more jobs than the county loses in oil.

Los Angeles County has a small net gain in jobs, averaging about 250 per year. Los Angeles contains almost all of southern California's refineries, where the policy scenario leads to significant job cutbacks. New jobs in solar power (allocated in proportion to oil output cuts) are not enough to balance the oil production and refinery job losses. However, jobs created by respending of consumer fuel savings (allocated in proportion to population) leave Los Angeles with a small employment gain.

The other five oil-producing counties (Monterey, Fresno, Ventura, Orange, and Santa Barbara) are collectively winners, gaining an annual average of 3,000 jobs. Here, new solar jobs far outweigh losses in drilling and production; these counties have no refineries, and thus do not lose refining jobs. Jobs created by respending of fuel savings account for about half of their gains.

These results are encouraging, but they do not mean that everyone in the state wins from oil cutback policies. Although total energy-related jobs increase under the policy scenario, some workers in the oil industry will be displaced. A "just transition" for oil workers, including income support, retraining opportunities, and retirement with dignity for older workers, is a vitally important part of policies that cut back on oil production.[26]

Kern County, the center of California oil production, gains an annual average of more than 1,500 jobs under the policy scenario.

Image 6: Oil crew in Coyote fields, California. The New York Public Library Digital Collections, 1860 - 1920 (Wikimedia Commons).

[26] See the 2018 Oil Change International report, among many others. From a broader perspective, the workers displaced by oil cutbacks are a small proportion of the huge number of workers who lose jobs every year. Everyone deserves better employment insurance and retraining opportunities, regardless of the reasons for their job losses, along the lines provided in many European countries.

Benefits of emission reduction

Greenhouse gas reductions

Proposals to cut back California oil production have arisen, in part, from the effort to reduce greenhouse gas emissions and meet climate targets. Reductions in oil output, on the scale envisioned under the policy scenario, will avoid millions of tons of carbon dioxide (CO2) emissions each year. Using the most common approach to valuation of these emissions, the environmental benefits are worth hundreds of millions of dollars per year, reaching $0.6 billion to $2.8 billion per year by 2030.

We explore three scenarios for CO2 reductions. Our policy scenario, assuming complete replacement of oil cutbacks with renewable energy, leads to the greatest reduction. Alternatively, if oil cutbacks are not replaced by clean energy, how much would be replaced by oil production increases in the rest of the world? Our second and third scenarios are based on different answers to that question.

The calculation of avoided CO2 emissions rests on two numerical results from research by Peter Erickson and Michael Lazarus at the Stockholm Environment Institute.[27] First, they examine the lifecycle CO2 emissions per barrel of oil. Combustion of a barrel of oil yields 400 kg of CO2. For many oil producers, including Saudi Arabia, lifecycle emissions are around 500 kg per barrel, including extraction, transportation, and refining as well as combustion emissions. California, however, relies on energy- and emissions-intensive methods of extraction of oil, resulting in average lifecycle emissions of around 620 kg per barrel.[28]

Image 7: Trust (Lauren Lulu Taylor/Unsplash).

Second, they estimate the global reduction in oil production that results when one producer, such as California, cuts back on its output—and does not replace it with other energy sources. The consensus is that other producers would replace some but not all of the reduction in output. Several analysts have estimated that the global reduction in oil consumption would be between 20 percent and 60 percent of a unilateral cut in—or conversely, the rest of the world would replace 40 to 80 percent of California's cutbacks.[29]

[27] Erickson and Lazarus, 2018. "How limiting oil production could help California meet its climate goals." Available at https://www.sei.org/publications/limiting-oil-production-california/.

[28] Personal communication from Peter Erickson, June 2018.

[29] For citations to this literature, see Erickson and Lazarus 2018. The world oil market is an oligopoly, where unpredictable strategic decisions by leading producers such as Saudi Arabia, Russia, and the United States may be more important than price elasticity-driven calculations by smaller producers. Still, there are few analysts who predict 100 percent replacement of California's cutbacks.

We therefore consider high and low emission-reduction scenarios:

- The high emission-reduction case assumes that other producers replace 50 percent of California's cutbacks, and the replacement oil has lifecycle CO_2 emissions of 500 kg per barrel—e.g., the emissions expected if the replacement oil comes from Saudi Arabia.[30]
- The low emission-reduction case assumes that other producers replace 80 percent of California's cutbacks, with replacement oil emissions of 620 kg per barrel, equal to the California average.[31]

		2020	2025	2030
Gross effects of oil reduction: if replaced exclusively by renewable energy	Assumed California oil reduction, million bbl	39.8	66.9	78.1
	Avoided CO_2 emissions, million metric tons	24.7	41.5	48.4
	Social cost of carbon (SCC), 2017 $ / ton	$49	$54	$59
	SCC value of gross reduction, million 2017 $	**$1,210**	**$2,241**	**$2,856**
High emission-reduction case: 50% replacement, 500 kg CO_2 per barrel	Replacement production, million bbl	19.9	33.45	39.05
	CO_2 from replacement production, million metric tons	10.0	16.7	19.5
	Net CO_2 reduction, million metric tons	14.8	24.8	28.9
	SCC value of net reduction, million 2017 $	**$723**	**$1,338**	**$1,704**
Low emission-reduction case: 80% replacement, 620 kg CO_2 per barrel	Replacement production, million bbl	31.8	53.5	62.5
	CO_2 from replacement production, million metric tons	19.7	33.2	38.7
	Net CO_2 reduction, million metric tons	5.0	8.3	9.7
	SCC value of net reduction, million 2017 $	**$243**	**$449**	**$570**

Figure 11. Projected annual value of avoided CO_2 emissions under three replacement cases, 2020, 2025, and 2030

The reduction in California oil production projected under the policy scenario is roughly 40 million barrels in 2020, rising to 78 million barrels in 2030. The result is a gross reduction in CO_2 emissions of roughly 25 million tons in 2020, rising to 48 million tons by 2030. (See the top two lines of Figure 11.) The rest of the world replaces either (a) none of the cutbacks, in our solar-intensive policy scenario, (b) 50 percent of the California cutbacks, with oil having lower lifecycle emissions (high emission-reduction case) or (c) 80 percent of the California cutbacks, with oil having lifecycle emissions equal to in-state production (low emission-reduction case).

The net annual CO_2 reduction would be 48.4 million tons by 2030 in the policy scenario (last column of table), or 28.9 million tons in the high-reduction scenario, or 9.7 million tons in the low-reduction scenario. Reduction in refinery emissions would lead to a moderate additional increase, perhaps 0.7 – 3.7 million tons by 2030.[32]

[30] Some analysts refer to 50 percent replacement as the "central estimate," apparently based on Erickson and Lazarus (2018) and the research cited there. This estimate is close to their maximum-reduction case of 40 percent replacement of California oil cutbacks.

[31] This alternative assumes that the world oil industry could rapidly replace most of California's cutbacks. Even worse cases can be imagined. If 80 percent of California's oil cutbacks were replaced with Canadian oil sands production, with lifecycle emissions of about 725 kg per barrel (Erickson and Lazarus 2018), the net benefits would be roughly one-third of the low emission-reduction case benefits shown in the table.

[32] Average U.S. refinery emissions are 7.8g CO_2 per MJ of gasoline, higher than for other major refinery products (Amgad Elgowainy et al., 2014, "Energy Efficiency and Greenhouse Gas Emission Intensity of Petroleum Products at U.S. Refineries", Environmental Science & Technology 48, 7612-7624). At 6,120 MJ per barrel of oil, this implies 3.73 tons of CO_2 from the 2030 gross reduction of 78.1 million barrels, assuming it was all gasoline. The numbers in the text are based on net global reduction of 20 percent to 100 percent of the gross reduction.

The "social cost of carbon" and the value of greenhouse gas reductions

What is the value of the net emission reductions from California cutbacks? There is a lengthy debate about the so-called social cost of carbon (SCC), the dollar value per ton of avoided emissions. The best-known SCC estimates are those created by the Obama administration's Interagency Working Group (IWG). The most widely cited, among their four variants on the SCC, rises steadily from $49 in 2020 to $59 in 2030 (when converted to 2017 dollars).[33]

These numbers are far from being uncontroversial, and the true values of avoided climate damages could be much higher. An in-depth 2017 review by the National Academy of Sciences had scathing criticisms of the IWG methodology, recommending countless changes. Academic critiques have continued to appear since the first IWG estimates were published in 2010.[34] The IWG averaged results from three simple models, each of which simplistically extrapolates climate damages to temperatures outside our historical experience. The models include little or no recognition of the problem of tipping points and irreversible risks, one of the crucial dimensions of the climate crisis. They also ignore the problem of pricing "priceless" values (see sidebar). Extremely high values, many times greater than the IWG estimates, are not a certainty. But they also cannot be ruled out with much confidence. Nonetheless, there are no other estimates that are nearly as widely used at this point. Therefore the IWG values are used, despite their limitations, in Figure 11.

The bottom line for each case in Figure 11 applies the federal SCC to the net emission savings from the California oil

Are climate damages priceless?

Some damages caused by climate change, such as declines in crop yields due to droughts and heat waves, or loss of coastal property to sea-level rise and storm surges, have meaningful monetary values. Other damages, of at least equal importance, do not have price tags attached. What is the value of avoidable human deaths, of the extinction of an endangered species, of the loss of unique natural environments?

As the philosopher Immanuel Kant said long ago, some things have a price while others have a dignity. The all-too-common process of fabricating prices for priceless values dishonors the dignity of human life and the natural world. Since climate damages will include many priceless values, monetary measures such as the IWG's SCC estimates will inevitably fail to capture the full meaning of climate change.[35]

[33] These are the estimates with a 3 percent discount rate and median climate sensitivity (sometimes misleadingly called the "central estimate"), from the IWG's final (August 2016) SCC update. The values were published in 2007 dollars; they have been inflated to 2017 dollars using the Consumer Price Index.

[34] Among many others, see: National Academy of Sciences, Engineering and Medicine, 2017. *Valuing Climate Damages: Updating Estimation of the Social Cost of Carbon Dioxide*. Washington DC: National Academies Press, https://doi.org/10.17226/24651; Robert S. Pindyck, 2013. "Climate Change Policy: What Do the Models Tell Us?" *Journal of Economic Literature* 51, September 2013, 860-872 [the author's answer to the title question: "Very little"]; Frank Ackerman and Elizabeth A. Stanton (2012), "Climate Risks and Carbon Prices: Revising the Social Cost of Carbon", *Economics* e-journal 6; Martin L. Weitzman (2014), "Fat Tails and the Social Cost of Carbon," *American Economic Review* 104, 544 -546.

[35] See: Frank Ackerman and Lisa Heinzerling, 2004, *Priceless: On Knowing the Price of Everything and the Value of Nothing* (New York: The New Press); and Frank Ackerman, 2017, *Worst-Case Economics: Extreme Events in Climate and Finance* (London: Anthem Press).

cutbacks. By 2030, the SCC value of the reduced emissions is $570 million in the low emission-reduction case, and $1.7 billion in the high emission-reduction case. In the policy scenario, where the oil cutbacks are replaced exclusively by solar power, the (gross) emission reduction is worth more than $2.8 billion by 2030.

In short, the oil cutbacks implied by our policy scenario, blocking new oil wells and stopping oil production within the 2500-foot buffer zone, would cause net annual CO2 emission reductions worth hundreds of millions, if not billions, of dollars in 2030, using a straightforward application of the Obama-era federal SCC. And the value of the avoided emissions would only grow after 2030—both because the SCC rises over time, and because the net reduction in oil production due to the policy scenario would continue to expand.

Image 8. 2001 fire at Tosco refinery in Carson, CA (AP Photo/ Nick Ut).

Local environmental benefits

A cutback in oil production, and especially in new oil drilling, could reduce the multiple negative environmental impacts of exploration, drilling, extraction, transportation, and refining of oil. The benefits of reducing oil production include a decrease in contamination of soil, air, and water (and thereby a reduction in health hazards to humans and wildlife), reduction in safety risks for those working and living near oil fields and a decrease in the impacts from undesirable changes in land use such as erosion, deforestation, and wildlife habitat disruption.

The largest waste stream associated with the oil and gas industry is the quantity and quality of wastewater produced through the process of extraction. Drilling practices during exploration and extraction involve a combination of chemicals that are injected into wells which are eventually discharged back into the environment. These chemicals are known to include carcinogens, reproductive toxins, and endocrine disruptors.[36] Oil production cutbacks avoid numerous health impacts caused by chemical contamination within waterways and the soil. In addition to the contamination of water in the drilling phase, refineries also use large volumes of water for production and cooling and the resulting effluents enter the waterways, impacting humans, fish, and other wildlife.[37]

The process of exploration, drilling, and extraction results in significant local air contamination which leads to numerous human health hazards. This air contamination is a result of emissions from powering drilling equipment and machinery, well-pad construction, hydrocarbons escaping from wells, and the flaring of natural gas.[38] The toxins emitted through the oil production process include particulate matter, volatile organic compounds, and hazardous air pollutants including benzene, toluene, ethylbenzene, and xylenes. These air toxins result in numerous health related impacts: asthma, heart disease, low birth weight, and, in some cases, cancer (some of the air toxins are known to be human carcinogens).[39]

[36] Liberty Hill Foundation, 2015. "Drilling Down: Community Consequences of Expanded Oil Development in Los Angeles." Available at https://www.libertyhill.org/sites/libertyhillfoundation/files/Drilling%20Down%20Report_1.pdf.

[37] Epstein, P.R. and Selber, J., 2002. *Oil a Life Cycle Analysis of Its Health and Environmental Impacts*. The Center for Health and the Global Environment Harvard Medical School.

[38] Caswell M.F., 1993. "Balancing Energy and the Environment." In: Gilbert R.J. (eds) *The Environment of Oil. Studies in Industrial Organization*, vol 17. Springer, Dordrecht.

[39] Liberty Hill Foundation, 2015.

Oil production also leads to harmful changes in land use. Transportation of oil to refineries and then to gas stations and locations of consumption requires construction of pipelines, roads, and platforms. Additionally, oil exploration involves movement of heavy equipment, often requiring clearing of land for roads and platforms.[40] Other land-use impacts from exploration, extraction, and drilling processes include construction of oil wells, creation of waste pits for solid waste disposal, and inland oil spills. The entire oil production process results in significant surface disturbances, deforestation, erosion, and harm to wildlife through habitat disruption and interference with the migratory patterns of bird and animals.[41]

Cutback in the production of oil would also help in the avoidance of the safety risks to oil industry workers and those living near the oil fields. The ever-present risk of explosions and fires can lead to injuries and fatalities during exploration, extraction, and refining. The handling of heavy pipes and other equipment as well as the exposure to chemicals, gases, and noise also create significant safety and health risks. The Bureau of Labor Statistics reports 1,485 fatalities nationwide between 2003 and 2016 associated with oil and gas extraction industry alone—an average of more than 100 per year.[42]

A large-scale switch from gasoline to electric vehicles, as envisioned in our policy scenario, would lead to a reduction in tailpipe emissions—a major source of health hazards. In 2013, transportation contributed more than half of all emissions of carbon monoxide and nitrogen oxides, and almost a quarter of hydrocarbon emissions; air toxics emitted from cars and trucks account for an estimated half of all cancers caused by air pollution.[43]

In short, the damages associated with oil production extend well beyond oil's lifecycle greenhouse gas emissions. There is no simple way to monetize these damages, comparable to the SCC. Nonetheless, it is important to remember these additional environmental benefits from reducing oil production.

[40] Epstein PR, Selber J. 2002. Oil: A Life Cycle Analysis of Its Health and Environmental Impacts. Boston: Center Health Glob. Environ., Harv. Med. Sch.

[41] U.S. EPA and Sector Strategies 2008. An Assessment of Environmental Implications of Oil and Gas Production, Sept. 2008 Working Draft. Available at https://archive.epa.gov/sectors/web/pdf/oil-gas-report.pdf.

[42] Bureau of Labor Statistics, 2016, "Census of Fatal Occupational Injuries Charts, 1992-2016." Available at https://www.bls.gov/iif/oshwc/cfoi/cfch0015.pdf.

[43] Union of Concerned Scientists, 2014, "Vehicles, Air Pollution, and Human Health." Available at https://www.ucsusa.org/clean-vehicles/vehicles-air-pollution-and-human-health.