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A PROGRAM FOR ECONOMIC RECOVERY AND CLEAN ENERGY TRANSITION IN CALIFORNIA

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Endorsements

The following unions have endorsed this report and its findings:

- Alameda Labor Council
- American Federation of State, County, and Municipal Employees Council 57
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- American Federation of State, County, and Municipal Employees United Domestic Workers
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- California Federation of Teachers
- Communication Workers of America District 9
- International Federation of Professional and Technical Engineers Local 21
- Service Employees International Union California
- Service Employees International Union Local 721
- Service Employees International Union Local 1021
- Service Employees International Union Nurse Alliance of California
- Service Employees International Union United Service Workers West
- United Auto Workers Local 2865
- United Auto Workers Local 5810
- UNITE HERE Local 30
- United Steelworkers Local 5
- United Steelworkers Local 675
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SUMMARY OF STUDY

The COVID-19 pandemic generated severe public health and economic impacts in California, as with most everywhere else in the United States. However, as of this writing in May 2021, the public health dangers from COVID-19 have diminished dramatically, in California and throughout the U.S. more generally, due to the development and distribution of multiple vaccines that have demonstrated their effectiveness. The U.S. economy, and the California economy specifically, are moving toward a full reopening, with the U.S. economy having grown by 6.4 percent over the first three months of 2021.

Both at the national level and within California, the focus of economic policy should therefore start shifting to the question of how to advance a recovery that is strong, equitable and sustainable. This study presents a recovery program for California that will also build a durable foundation for an economically robust and ecologically sustainable longer-term growth trajectory. As we emerge from the pandemic experience, we can also regain focus on the reality that we have truly limited time to take decisive action around climate change. The State of California has long been a national and global leader in implementing robust climate stabilization policies. This includes the 2018 Executive Order B-55-18 by then Governor Jerry Brown. This measure committed the state to become carbon neutral no later than 2045 and to produce net negative emissions thereafter. Governor Newsom has built on this foundation through his 2020 Executive Order N-79-20. Among its provisions, this order establishes that, as of 2035, all new cars and passenger trucks sold in California are required to be zero-emissions vehicles. The program we present in this study is based on these climate and emissions-reduction goals that are already established in policy in the State of California. This study outlines an investment program through which the state can achieve these established goals.

As we show, designing a robust climate stabilization project for California that is able to achieve the state's established emissions reduction commitments is a realistic prospect. The climate stabilization project can also serve as a major engine of economic recovery and expanding economic opportunities throughout the state. This includes an increase of over 1 million jobs in the state through investment programs in energy efficiency, clean renewable energy, public infrastructure, land restoration and agriculture. We also develop a detailed just transition program for workers and communities in California that are currently dependent on the state's fossil fuel industries for their livelihoods. In particular, we focus here on conditions in Kern, Contra Costa, and Los Angeles Counties.

The study is divided into nine sections:

1. Pandemic, Economic Collapse, and Conditions for Recovery
2. California's Clean Energy Transition Project
3. Clean Energy Investments and Job Creation
4. Investment Programs for Manufacturing, Infrastructure, Land Restoration and Agriculture
5. Total Job Creation in California through Combined Investment Programs

6. Contraction of California's Fossil Fuel Industries and Just Transition for Fossil Fuel Workers
7. County-level Job Creation, Job Displacement, and Just Transition
8. Achieving a Zero Emissions California Economy by 2045
9. Financing California's Recovery and Sustainable Transition Programs

This summary first provides a brief overview of the entire study. It then presents a more detailed presentation highlighting our main statistical findings.

Recovery from the COVID-19 Recession. California experienced a severe recession in 2020 – 2021 resulting from the COVID-19 pandemic. Over the year between mid-March 2020 and mid-March 2021, fully 63 percent of the state's entire labor force had filed for unemployment insurance. That is, *nearly two-thirds of all people who held jobs in the state as of February 2020 had experienced lay-offs during the past year*. The state's hospitality and tourism industries were the hardest hit by the pandemic, accounting for over 40 percent of the state's total job losses. These industries will therefore also benefit disproportionately as the recovery gathers force over the spring and summer. The most immediate challenge will be to maintain a recovery that is capable of creating meaningful opportunities for the huge pool of unemployed and underemployed workers that emerged during the COVID-19 recession, as well as the millions of people, in California and elsewhere, who stopped seeking employment because conditions were so unfavorable.

More broadly, the basic goals of economic policy coming out of the COVID recession in California should be to achieve a recovery that is rapid, inclusive, and sustainable. Three of the crucial elements for delivering such a recovery will be: 1) permanently expanding the provision of high-quality universal health care; 2) ending disparities in employment opportunities; and 3) advancing a climate stabilization program capable of achieving the state's CO_2 emissions targets. The focus of this study is the climate stabilization program. But we also give attention to the pressing issues regarding health insurance provision and unequal conditions in the state's labor market.

Clean Energy Investments and Job Creation. California's emissions reduction targets—to cut CO_2 emissions by 50 percent as of 2030 and to reach net zero emissions by 2045—are in close alignment with the global emissions reduction goals set out by the Intergovernmental Panel on Climate Change (IPCC) in 2018. We show how these 2030 and 2045 emissions reduction targets can be accomplished in California through phasing out the consumption of oil, coal, and natural gas to generate energy in the state, since burning fossil fuels to produce energy is, by far, the primary source of CO_2 emissions, and thereby, the single greatest factor causing climate change. The project we propose is to build a clean energy infrastructure to replace the existing fossil fuel-dominant infrastructure. The clean energy infrastructure will require large-scale investments to, first, dramatically raise energy efficiency standards in the state and, second, to equally dramatically expand the supply of clean renewable energy supplies, including solar and wind primarily, with supplemental supplies from low-emissions bioenergy, geothermal and small-scale hydro power. We show how this climate stabilization program for California can also serve as a major new engine of job creation and economic well-being throughout the state, both in the short- and longer run. We have scaled the clean energy investment project at about $76 billion per year on average between 2021 – 2030.

This would equal roughly 2.1 percent of what we estimate will be the state's average GDP between 2021 – 2030.

We estimate this level of investment will generate roughly 418,000 jobs throughout the state's economy. New job opportunities will open for, among other occupations, carpenters, machinists, welders, electronic equipment assemblers, environmental scientists, administrative assistants, accountants, truck drivers, roofers and agricultural laborers. Investments in public transportation—a major component of the energy efficiency investment program—will produce public-sector jobs for drivers and managerial staff. The quality of these jobs—including wages, benefits, and levels of unionization—vary by sector. In general, it will be critical to raise job quality standards as the number of jobs available expands. Raising unionization rates, as well as expanding job training programs will all be crucial for raising overall job quality levels. Local hire provisions and related measures will also need to be implemented to ensure equitable access by race and gender to the expanding job opportunities.

While focusing on the clean energy investment to reduce California's CO_2 emissions by 50 percent as of 2030, we do also examine how the state can achieve its longer-term goal of becoming a zero-emissions economy by 2045. As we show, the basic features of the investment program between 2031 – 2045 can be extended from the 2021 – 2030 framework. But, in fact, the scale of the investment spending required to achieve the 2045 zero-emissions target can be somewhat more modest, averaging about 1.3 percent of the state's GDP between 2031 – 2045, as opposed to the 2.1 percent of GDP figure for 2021 – 2030.

Upgrading California's Economic Base through Manufacturing, Infrastructure, Land Restoration and Agriculture Investments. California's economy would receive an additional major boost, in terms of both short-run stimulus and longer-term productivity, by undertaking large-scale investments—at about $62 billion per year, or 1.7 percent of the state's GDP—in these areas. This investment program is based on the proposed national THRIVE Agenda, a bill introduced into the the U.S. Congress in February 2021 by Senator Edward Markey and Congresswoman Debbie Dingell to "Transform, Heal, and Renew by Investing in a Vibrant Economy." To date, the THRIVE Agenda has been endorsed by more than 100 members of Congress and hundreds of major union, racial justice and climate organizations. We estimate that these investments will generate about 626,000 jobs throughout the state, in a wide range of occupations. In the manufacturing/infrastructure areas, over 30 percent of all employment will be in transportation and moving material, and another roughly 24 percent will be in the construction industry, including jobs for pipelayers, electricians, and supervisors. Jobs will also expand for water treatment plant operators, freight movers, teachers, recreation workers, administrative assistants, and bookkeeping clerks. With land restoration/agriculture, the largest expansion of employment will be for farmers, farm managers, and agricultural workers.

Public Sector Job Creation. A robust public sector is critical to ensure safe and effective build out of clean energy, manufacturing and infrastructure upgrades across the state. Jobs in public sector employment tend to be good jobs with higher-than-average unionization rates. Of the direct jobs created by clean energy investment, about 8,500 will be in the public sector—just under 4 percent of the 216,000 total direct jobs created. About 14 percent of the 626,000 jobs created through manufacturing, infrastructure, land restoration and agricultural investments will be in various areas of public employment. In total, about

96,000 of the 1 million total new jobs created by these combined investment programs will be in the public sector, or about 9.6 percent of total job creation. In these new investment areas, local hire provisions and related measures will need to be implemented to ensure equitable access by race and gender to the expanding job opportunities.

Overall job creation through combined investment programs. When we bring together the combined investment programs in the areas of energy efficiency and renewable energy, along with public infrastructure/manufacturing and land restoration/agriculture, total spending in California comes to an average of $138 billion per year, equal to about 3.8 percent of average annual GDP between 2021 – 2030. This level of job creation would generate about 1 million jobs within California, with about 6 percent of the total employment expansion being public sector jobs. This higher level of job creation will then be sustained through the full decade, as long as the budgetary levels for the range of investment programs are maintained. The expansion in job opportunities will equal more than 5 percent of California's 2019 labor force. It will be critical to ensure that these are good-quality jobs, in terms of compensation, benefits, access to union representation, and training opportunities as needed.

Just Transition for Fossil Fuel-Dependent Workers and Communities. About 112,000 people are employed in California in fossil fuel-based industries, amounting to about 0.6 percent the state's total workforce in 2019. The total job figure includes oil and gas extraction operations, as well as support activities for all oil and gas projects, and other ancillary sectors, such as fossil fuel-based power generation. Workers in the state's fossil fuel-based industries will therefore experience job losses as the state dramatically reduces consumption of these CO_2-generating energy sources. We estimate that about 3,200 workers per year will be displaced in these industries in California between 2021 – 2030 while another roughly 2,500 will voluntarily retire each year. It is critical that all of these workers receive pension guarantees, health care coverage, re-employment guarantees along with wage subsidies to insure they will not experience income losses, along with retraining and relocation support, as needed. Enacting a generous just transition program for the displaced fossil fuel-based industry workers is especially important. At present, average compensation for these workers is around $130,000. This pay level is well above the roughly $85,000 received by workers in California's current clean energy sectors. We estimate that the costs of a generous just transition package for all fossil fuel industry-based workers experiencing layoffs would come to about $470 million per year. This is equal to about 0.02 percent (two one-hundredths of one percent) of the state's average GDP between 2021 – 2030.

Three counties in California—Kern, Contra Costa, and Los Angeles—account for roughly half of all employment in the state's fossil fuel-based industries. Kern County, in particular, will face the most significant proportional impacts from the phase-down of the state's fossil fuel industries. We therefore present a focused discussion on providing community transition support for Kern County. We note here that some initial-stage activities are already underway in Kern to move the area away from its current level of fossil fuel-based industry dependency and to build there a clean energy production infrastructure.

Financing a Sustainable Recovery. Of the $138 billion per year in combined investment and just transition programs that we present here, we assume that roughly half of total spending, about $70 billion per year, will be provided by private investors, while the other half is supplied by public spending. Private investments in the clean energy areas in particular will be incentivized by the federal and statewide regulatory environment. These include the state's commitment to operate with 100 percent renewable energy to generate electricity by 2045 and the requirement that, by 2035, all new cars sold in the state will be zero-emissions vehicles. A significant share, if not the majority of the approximately $70 billion per year, is likely to come from a version of the the Biden Administration's proposed American Jobs Plan, focused on infrastructure and clean energy investments. The State of California could then provide the additional funding, as needed. We show, for example, that if the state government issues $30 billion in bonds in the current low-interest rate environment, the debt servicing burden will also be low, i.e. in the range of 0.3 percent of the state's annual general revenues. It follows that even if the federal government's funding through the final version of the Biden American Jobs Plan comes in at a relatively low figure, the State of California could still provide the additional financing through issuing bonds in the current low-interest rate environment without imposing a major burden on the state's overall budget.

The program developed here for economic recovery and a clean energy transition in California demonstrates the viability of the state's existing commitment to cut CO_2 emissions in the state by 50 percent as of 2030 and to become a zero emissions economy by 2045. We also show how California can achieve these critical climate stabilization goals while also greatly expanding good-quality employment prospects, raising average living standards, and increasing opportunities for women and people of color throughout the state.

STUDY HIGHLIGHTS

1. THE PANDEMIC, ECONOMIC COLLAPSE, AND CONDITIONS FOR RECOVERY

- California experienced a severe recession resulting from the COVID pandemic, but has moved into an initial phase of economic recovery.
- Major factors that will influence the viability of the economic recovery will include:
    - Completing the state's vaccination program;
    - The extent of the federal government's short-term stimulus support;
    - The extent of a longer-term public-sector led investment project, including both federal and state-level support, to advance the clean energy transition;
    - Large-scale complementary investments in manufacturing, infrastructure, land restoration and agriculture.

2. CALIFORNIA'S CLEAN ENERGY TRANSITION PROJECT

50 Percent Emissions Reduction

- About 72 percent of all energy consumed in California comes from combusting oil and natural gas. High-emissions bioenergy contributes 3.7 percent and coal provides a negligible 0.4 percent.
- We develop a clean energy transition project to achieve, by 2030, a 50 percent reduction in CO_2 emissions in California relative to the 2018 emissions level.
    - Emissions in California in 2018 were at about 390 million metric tons after including emissions produced by bioenergy sources as well as oil, natural gas and the emissions level as of 2030 will therefore need to be no more than roughly 195 million tons.[1]
    - Oil, natural gas and high-emissions bioenergy consumption will all be reduced by 50 percent, and coal will be fully phased out.

Major Areas of Clean Energy Investments

- ***Energy Efficiency.*** Dramatically improving energy efficiency standards in California's stock of buildings, automobiles and public transportation systems, and industrial production processes.
- ***Clean Renewable Energy.*** Dramatically expanding the supply of clean renewable energy sources—including solar, wind, low-emissions bioenergy (energy from burning wood and crops, and crop residues), geothermal, and small-scale hydro power—available at competitive prices to all sectors of California's economy.
- ***Total Investment Expenditures.*** The level of investment needed to achieve California's energy goals will average roughly $76 billion per year between 2021 – 2030.
    - This estimate assumes that California's economic growth proceeds at an average rate of 2.5 percent per year.

- Clean energy investments will need to equal about 2.1 percent of California's annual GDP.
- The average annual clean energy investment level of 2.1 percent of GDP means that nearly 98 percent of California's overall economic activity will be directly engaged in activities *other than* clean energy investments.

Clean Energy Investments Will Deliver Lower Energy Costs

- Raising efficiency standards enable consumers to spend less for a given amount of energy services.
- The costs of wind, solar, geothermal, and hydro power are all presently roughly equal to or lower than those for fossil fuels and nuclear energy.
- The average California household should be able to save nearly 40 percent on their overall annual energy bill. This would be after they have paid off their initial up-front efficiency investments, to purchase, for example, a zero-emissions vehicle or an electric heat pump to replace an aging heating-and-cooling system. They could achieve greater savings still through being able to to forego owning a car because of improved public transportation service.

3. CLEAN ENERGY INVESTMENTS AND JOB CREATION

- Investing an average of $76 billion per year in clean energy projects in California over 2021 – 2030 will generate an average of about 418,000 jobs per year in the state.
- New job opportunities will be created in a wide range of areas, including construction, sales, management, manufacturing, engineering, and office support.
- Current average total compensation in these occupations mostly range between $70,000 – $95,000 per year.
- Rapid employment growth in these areas, combined with a supportive environment for organizing, should create increased opportunities to raise unionization rates and expand job opportunities for people of color and women.
- Higher unionization rates should promote gains in compensation and better working conditions in the affected industries.
- Good-quality worker training programs will be needed to ensure that a wide range of workers will have access to the jobs created by clean energy investments, including people of color and women, and that the newly employed workers can perform their jobs effectively.

4. INVESTMENT PROGRAMS FOR MANUFACTURING, INFRASTRUCTURE, LAND RESTORATION AND AGRICULTURE

- California's economy would receive a major boost both in terms of short-run stimulus and longer-term gains in employment, productivity, and environmental sustainability through investments in manufacturing, infrastructure, agriculture and land restoration.

- In 2018, the American Society of Civil Engineers (ASCE) gave an overall grade of C- to California's public infrastructure.
- We propose a $62 billion per year program, equal to about 1.7 percent of California's GDP.
- The program is derived from the THRIVE Agenda—a bill introduced into the U.S. Congress in February 2021 to "Transform, Heal, and Renew by Investing in a Vibrant Economy. The THRIVE Agenda has been endorsed by more than 100 members of Congress.
- Major areas of focus include universal broadband access; expansion and upgrading of public buildings, including schools and university campuses; water management; repairing leaky gas pipelines; closing orphaned oil and gas wells; regenerative agriculture; farmland conservation and resources for marginalized farmers.
- We estimate that investing in these areas will generate 626,000 jobs per year in California.
- Major areas of job expansion will be in transportation, construction, education, farming, forestry, and conservation workers.

5. TOTAL JOB CREATION IN CALIFORNIA THROUGH COMBINED INVESTMENT PROGRAMS

- Our annual average job estimates for 2021 – 2030 include:
  - 418,000 jobs per year through $76 billion in spending on energy efficiency and clean renewable energy;
  - 626,000 jobs per year through investing $62 billion in manufacturing/infrastructure and land restoration/agriculture.
- The total employment creation through clean energy, manufacturing/infrastructure and land restoration/agriculture will total to approximately 1 million jobs.
- Net job creation will average about 5.4 percent of California's workforce as of 2019.

6. CONTRACTION OF CALIFORNIA'S FOSSIL FUEL INDUSTRIES AND JUST TRANSITION FOR FOSSIL FUEL WORKERS

- About 112,000 workers in California are presently employed in the state's fossil fuel-based and bioenergy industries.
- Employment in these industries will fall by about 58,000 jobs by 2030, as the oil, natural gas and bioenergy industries contract by half and coal is fully shut down.
- We consider two phase-down patterns between 2021 – 2030 for these industries:
  - *Steady contraction*, in which employment losses proceed evenly, by about 5,800 jobs per year;
  - *Episodic contraction,* in which all employment losses occur in three separate years, 2021, 2026, and 2030.
- Under the steady contraction scenario, about 3,200 workers per year will become displaced, after accounting for about 2,500 workers per year retiring voluntarily.

- Under the episodic contraction scenario, about 12,500 workers will become displaced in 2021, 2026, and 2030, with no job losses occurring in intervening years.
- For both the steady and episodic contraction scenarios, we develop just transition programs for all fossil fuel-based industry workers. The program includes:
  - Pension guarantees for all workers;
  - Re-employment and income-level guarantees for all displaced workers;
  - Retraining and relocation support as needed;
  - Glide-path income support for workers between 60 – 64 under the episodic contraction scenario.
- We estimate the average costs of the just transition programs as:
  - *Steady contraction:* $470 million per year;
  - *Episodic contraction:* $830 million per year.
  - The costs of an episodic contraction are roughly 80 percent higher, primarily to provide glide-path support for laid-off workers between 60 – 64. These costs are unnecessary under a steady contraction.
- Total just transition costs would equal about one one-hundredth of one percent of California's average GDP under the steady contraction scenario and two one-hundredths of one percent under the episodic contraction scenario.

7. COUNTY-LEVEL JOB CREATION, JOB DISPLACEMENT, AND JUST TRANSITION

- Three counties in California will account for roughly half of all statewide job losses due to the state's fossil fuel industry contraction:
  - *Kern County*, in which 13,651 workers account for 3.2 percent of countywide employment.
  - *Contra Costa County*, in which 12,972 workers account for 2.2 percent of countywide employment.
  - *Los Angeles County*, in which 29,003 workers account for 0.4 percent of countywide employment.
- For these three counties, we estimate job creation through the combined investment programs and job displacement through the fossil fuel industry contraction.
  - For Kern and Contra Costa Counties, employment creation through the investment programs will be about 30,000 jobs that will be sustained over the full investment period. Job displacements will be about 400 workers per year.
  - For Los Angeles County, employment creation will be about 320,000 jobs while an average of about 800 workers will be displaced.
- We examine clean energy transition and fossil fuel contraction developments and prospects for Kern County as well as review comparable transition experiences in other U.S. regions as well as in Germany's Ruhr Valley.

8. ACHIEVING A ZERO EMISSIONS CALIFORNIA ECONOMY BY 2045

- California can become a zero emissions economy by 2045 through continuing the clean energy investment program set out first between 2021 – 2030.
- California will be able to also absorb significant amounts of the existing stock of CO_2 in the atmosphere through programs to support organic agriculture and afforestation. This will move California into becoming a net negative emissions source.
- Average clean energy investments would need to equal about 1.3 percent of state GDP per year over 2031 – 2045.
- Job creation through these clean energy investments will average about 320,000 jobs per year.
- Just transition support for displaced workers over 2031 – 2045 will amount to an average of about $160 million per year. We estimate this amount will be well below 0.01 percent (one one-hundredth of one percent) of California's average GDP between 2031 – 2045.

9. FINANCING CALIFORNIA'S RECOVERY AND SUSTAINABLE TRANSITION PROGRAMS

- Total costs of the combined investment and just transition programs average to $138 billion per year, equal to about 3.8 percent of California's average GDP between 2021 – 2030.
- We assume roughly half of total spending, about $70 billion per year, is provided by private investors, and the other half is supplied by public funding.
    - This results through private investors contributing about 90 percent of clean energy investments funds, with public programs leveraging 10 percent of total clean energy investments to incentivize and supplement private investors.
- The Biden Administration's proposed American Jobs Plan, if enacted, is likely to provide in the range of $40 billion per year for clean energy and infrastructure investments in California. This would cover about 60 percent of the total $70 billion public funding requirement for the combined programs proposed here.
- The Congressional THRIVE Agenda would provide about $100 billion per year for the clean energy, infrastructure/manufacturing and land restoration/agriculture programs we describe in Sections 2 and 4. This would exceed by $30 billion per year the $70 billion combined public spending level proposed here.
- The State of California can borrow for capital expenditures to supplement federal funding for the combined investment and just transition programs.
    - As of 5/6/21, yields on California state and municipal bonds ranged between about 0.4 and 2.3 percent.
    - If the State of California borrows at 2 percent interest, interest payments on $30 billion of debt would amount to $600 million per year.
    - This would equal about 0.3 percent of the state's 2022 general revenue funds.
    - In a continuing low interest rate environment, the state could, if needed, borrow more than $40 billion per year without the debt-servicing costs creating a major burden on its overall budget.

1. THE PANDEMIC, ECONOMIC COLLAPSE, AND CONDITIONS FOR RECOVERY

The Pandemic in California

The State of California, like the rest of the United States, experienced an historically unprecedented public health and economic crisis that began when the COVID-19 pandemic emerged full force in mid-March 2020.

However, as of this writing in May 2021, the public health dangers from COVID-19 have diminished dramatically, in California and throughout the U.S. more generally, due to the development and distribution of multiple vaccines that have demonstrated their effectiveness. The U.S. economy, and the California economy specifically, are moving toward a full reopening, with the U.S. economy having grown by 6.4 percent over the first three months of 2021.[2] A report from CBS News from May 7 summarizes this situation as follows:

> Coronavirus cases and deaths across the country have plummeted to the lowest point in months as reopenings soar. In some areas that were once overwhelmed by COVID-19, like California, vaccinations are up and cases are down.
>
> Los Angeles County now has the fewest restrictions since the pandemic began. Just four months ago, hospitals were overwhelmed. In early January, L.A. County averaged more than 16,000 cases a day. On Wednesday, there were less than 300 — a 98% drop. California now has the lowest rate in the nation of new COVID-19 cases. San Francisco could be on the verge of herd immunity. "It means that hopefully, we'll be the city that keeps on easing our restrictions," said Dr. Monica Gandhi, a professor at the University of California, San Francisco. Almost three-quarters of adults in the city have received at least one dose. "Even though we're opening up and mingling, our cases are still staying low. That's what vaccination immunity to a pathogen does," Gandhi said. "It's working. And it's going to work in the rest of the country too."[3]

Some specific state-focused indicators of the markedly improving situation are as follows[4]:

- ***New Infections:*** Between July 1, 2020 and January 14, 2021, the new infection rate in California rose from 16.9 cases to 111.9 cases per 100,000 people, a nearly 7-fold increase. But as of May 8, new infections had dropped to 4.9 cases per 100,000. This is the lowest figure for new infections since the year prior, in mid-May 2020.
- ***Death rate:*** As of July 1, 2020, the 7-day average daily number of deaths was 62.9 people. As of January 28, 2021, it had spiked to 546.1 people, a nearly 9-fold increase in the state's 7-day average daily death rate. As of May 7, the 7-day average overall death rate had fallen back 65.6 people.
- ***Intensive Care Unit Capacity:*** As of November 9, 2020, 68 percent of the state's roughly 8,000 intensive care unit beds were being utilized. This figure spiked to 91 percent as of January 20, 2021. As of May 8, the usage of intensive care beds had fallen

back to 70 percent. The COVID Act Now site concludes that "this suggests there is likely enough capacity to absorb a wave of new COVID infections."

- ***Vaccine distribution:*** As of May 8, 51.1 percent of California's population had received at least a first vaccine shot, and 34.3 percent had received the second shot as well. California's rate of vaccination distribution ranks 19th among the 50 U.S. states.

In short, public health conditions have been improving significantly since vaccinations have become widely distributed throughout the state. This, in turn, is enabling the state's economy to reopen more fully.

At the same time, it is important to be clear as to the severity of the public health and economic crisis California experienced over the 13 months between March 2020 and March 2021. This information is critical for understanding what policy initiatives need to be prioritized for advancing a viable statewide recovery program. We focus here on job losses, disproportionate impacts by race and income levels, and uncertainties over the prospects for recovery.

Statewide Job Losses

As with the U.S. economy overall, employment conditions in California experienced a severe deterioration resulting from the COVID pandemic. As one clear measure of this, we show in Table 1.1 figures on job losses in California during the 13 months from mid-March 2020 to mid-March 2021. Specifically, we report on initial unemployment insurance claims by workers in California from March 21, 2020 until March 13, 2021. As Table 1.1 shows, the number of people in the state who lost their jobs and filed to receive unemployment insurance over this period totals to 12.3 million. This figure amounts to more than 63 percent of California's workforce as of February 2020.

For comparison, we show in the second column of Table 1.1 the figures over the comparable time period for 2019 – 2020, i.e. March 23, 2019 until March 14, 2020. As we see,

TABLE 1.1
Job Losses in California and U.S. During COVID-19 Pandemic and One Year Prior

Initial Unemployment Insurance Claims:
Weekly Figures Covering March 21, 2020 – March 13, 2021 and March 23, 2019 – March 14, 2020

	3/21/20 – 3/13/21 Figures	3/23/19 – 3/4/20 Figures
Figures for California		
1. Number of people filing initial unemployment insurance claims	12,335,014	2,110,810
2. Number of claims as share of February labor force	63.4%	10.8%
Figures for U.S.		
3. Number of people filing initial unemployment insurance claims	81,890,000	11,262,000
4. Number of claims as share of February labor force	49.8%	6.9%

Sources: https://fred.stlouisfed.org/series/CAICLAIMS; https://fred.stlouisfed.org/series/ICSA.

total initial unemployment claims over this 13-month period a year ago totaled to 2.1 million, equal to 10.8 percent of California's workforce at that time. In other words, job losses from the onset of COVID to March 2021 jumped *nearly 6-fold* over the same time period in the previous year.

We also report the comparable figures for the U.S. overall in rows 3 and 4. As we see, the figures for California are more severe than the overall U.S. economy. With the overall U.S. economy, job losses between March 21, 2020 and March 13, 2021 totaled to 49.8 percent of the U.S. labor force, while over the same time period a year ago, that figure was at 6.9 percent.

Industry-Specific Contractions and Job Losses

We can obtain a more detailed perspective on California's recession by examining data on changes in employment level by industry, combining figures for January and February 2021 with comparable figures for January/February 2020, i.e. the months immediately preceding the onset of the pandemic. We report these figures in Tables 1.2 and 1.3.

The first set of figures in Table 1.2 presents job losses *within* each industry, both for California and the U.S. overall. The second set of figures in Table 1.3 shows the contributions, industry-by-industry, to California's *overall* decline in employment as of January/February 2021 relative to those months in 2020. In the second set of figures, we incorporate the size of each industry in terms of employment prior to the crisis. This allows us to measure the relative contribution of each industry to overall job losses based on both 1) the size of the industry; and 2) the industry's job loss rate. Here again, we compare the figures for California with those for the U.S. overall.[5]

TABLE 1.2
Job Losses within Industries, California and U.S. Percentages
Figures are employment figures, not seasonally adjusted, from January/February 2020 to January/February 2021

California: *Decline in state employment = 9.7%*		**United States:** *Decline in national employment = 5.9%*	
Leisure and hospitality	-36.6%	Leisure and hospitality	-20.9%
Other services	-24.6%	Mining and logging	-12.6%
Mining and logging	-14.4%	Information	-7.7%
Information	-10.9%	Other services	-7.4%
Government	-8.1%	Government	-5.5%
Manufacturing	-6.3%	Education and health services	-5.2%
Professional and business services	-5.3%	Manufacturing	-4.3%
Education and health services	-4.8%	Professional and business services	-3.4%
Financial activities	-4.5%	Construction	-3.1%
Trade, transportation, and utilities	-3.5%	Trade, transportation, and utilities	-2.7%
Construction	-3.0%	Financial Activities	-0.8%

Sources: U.S. Labor Department.

TABLE 1.3

Share of Total Job Losses by Industry, California and U.S. Percentages

Figures are employment figures, not seasonally adjusted, from January/February 2020 to January/February 2021

California: *Decline in state employment = 9.7%*			**United States:** *Decline in national employment = 5.9%*		
	% of state employment	Industry job loss as percentage points of total state employment loss		% of U.S. employment	Industry job loss as percentage points of total state employment loss
Leisure and hospitality	11.5%	-4.2%	Leisure and hospitality	10.8%	-2.2%
Government	15.0%	-1.2%	Government	15.2%	-0.8%
Education and health services	16.4%	-0.8%	Education and health services	16.3%	-0.8%
Professional and business services	15.6%	-0.8%	Trade, transportation, and utilities	18.4%	-0.5%
Other services	3.3%	-0.8%	Professional and business services	14.0%	-0.5%
Trade, transportation, and utilities	17.4%	-0.6%	Manufacturing	8.4%	-0.4%
Manufacturing	7.5%	-0.5%	Other services	3.9%	-0.3%
Information	3.3%	-0.4%	Information	1.9%	-0.1%
Construction	5.0%	-0.2%	Construction	4.8%	-0.1%
Financial activities	4.8%	-0.2%	Mining and logging	0.4%	-0.1%
Mining and logging	0.1%	0.0%	Financial activities	5.8%	0.0%

Sources: U.S. Labor Department.

As we see first, in Table 1.2, the employment level declines for all 11 of the economic sectors listed. California's employment crisis was clearly widespread over this period. At the same time, the extent of decline varied greatly by industry. The most heavily impacted industry was leisure and hospitality. Here the employment decline was nearly 37 percent between January/February 2021 relative to the 2020 level. Employment in "other services"—including auto repair and nail salons—also fell severely, declining by nearly 25 percent. All of the remaining 9 industries experienced job losses of between 3.0 and 14.4 percent. Overall, state employment in California fell by 9.7 percent in January/February 2021 relative to these months in 2020. By this measure again, California's heavy job losses due to the COVID pandemic over this year were also sharper than those for the U.S. overall. For the U.S. overall, the employment decline was 5.9 percent in January/February 2021 relative to January/February 2020.

In Table 1.3, we see that, after taking account of the relative size of each of the industries in California's economy, the leisure and hospitality industry remains as the largest source of overall employment losses. Thus, job losses in leisure and hospitality accounted for 4.2 percentage points of the state's overall 9.7 percent level of job loss—i.e. the contraction of the leisure and hospitality industry accounted for about 43 percent of California's overall job losses. Government employment was the other sector of the economy that accounted for over 1 percentage point of the state's overall 9.7 percent employment decline, at 1.2 percent of the overall 9.7 percent decline. Combined, job losses in leisure/hospitality and government totalled to 55 percent of statewide job losses over the COVID pandemic year. Jobs in various service sectors also contributed substantially to the overall employment decline, with education and health services, professional and business services, and "other services" each accounting for 0.8 percentage points of the overall 9.7 percent employment contraction.

Disparities by Race, Ethnicity and Income

There were large disparities in the impact of the pandemic in California based on race, ethnicity and income. Such disparities based on race and ethnicity are evident from the figures we present in Table 1.4, as reported by the California Department of Public Health. As the table shows, California's Latinx population, the state's largest cohort at 38.9 percent of overall population, experienced COVID-19 infection rates 159 percent higher than whites and death rates nearly 42 percent higher than whites. The state's African American population, accounting for 6.0 percent of overall population, experienced infection rates 27 percent higher than whites and death rates that were 24 percent higher. The state's cohort of Native Hawaiian and other Pacific Islanders is relatively small, at 0.3 percent of statewide population. But their infection and death rates were more severe than those of any other racial or ethnic group, with an infection rate 232 percent higher than whites and a death rate 107 percent higher than whites. The state's large Asian population, totaling over 15 percent of statewide population, had infection and death rates that were lower than whites—with infection rates nearly 20 percent lower and death rates nearly 9 percent lower. The state's American Indian or Alaskan Native population, at 0.5 percent of the total population, had a more mixed relative experience, with an infection rate 21 percent higher than whites but a death rate 15 percent lower.

TABLE 1.4
Differential Impact of COVID-19 in California by Race and Ethnicity

	% of California population	Number of Infections		Death Rates	
		Infections per 100,000 people	Infections relative to white population	Deaths per 100,000 people	Death rate relative to white population
Latinx	38.9%	10,414	+159.4%	179.4	+41.8%
White	36.6%	4,015	---	126.5	---
Asian	15.4%	3,233	-19.5%	115.8	-8.5%
African American	6.0%	5,110	+27.3%	157.5	+24.3%
American Indian or Alaska Native	0.5%	4,863	+21.1%	107.5	-15.0%
Native Hawaiian and other Pacific Islander	0.3%	13,318	+231.7%	262.5	+107.5%

Note: Table does not include 2.2 percent of population identified as "multi-race" and additional "other" cohort which is uncounted by U.S. census.
Source: https://www.cdph.ca.gov/Programs/CID/DCDC/Pages/COVID-19/Race-Ethnicity.aspx.

Overall, the experience with the COVID pandemic for California's Latinx, African American and Native Hawaiian/Pacific Islander populations was significantly more severe than those for the state's white and Asian populations.

With respect to disparities by income, the data for Los Angeles County during the early stages of the pandemic are illustrative. According to these figures, as of May 2020, in areas where more than 30 percent of residents live in poverty, 303 people per 100,000 residents were infected, compared with 156 people per 100,000 in areas where less than 10 percent live in poverty. Residents of those low-income communities were also more likely to die of the virus, at a rate of 15 deaths per 100,0000 residents, twice the rate of people in the wealthier areas.[6] Similar infection-rate disparities between low- and high-income zip codes occurred across the U.S.[7] Further, a study for Western Massachusetts found that workers earning less than $20 per hour were 2-3 times more likely than those earning above $40 per hour to lack access to protective measures.[8]

These findings are even more significant since lower income workers were also much less likely to be able to work from home during the pandemic. According to the U.S. Bureau of Labor Statistics, only 6.6 percent of full-time workers in the lowest quartile of earnings were able to work remotely in their primary place of employment, while 55.5 percent of those in the highest quartile of earnings have been able to work remotely.[9] Since the intersection between low- income workers and communities of color is high, these communities have faced much higher levels of risk from COVID throughout all phases of the pandemic.[10]

Prospects for Recovery

The California economy clearly began to experience a recovery from the COVID recession over the Spring of 2021. At the same time, both the overall strength of the recovery and the extent to which the gains will be equitably shared, remain uncertain. Some major factors that will influence the robustness of the recovery include the following:

1. Federal- and state-level stimulus programs. In December 2020, while Donald Trump was still in office, the U.S. Congress enacted the COVID-19 Economic Relief Bill, budgeted at $900 billion overall, equal to about 4.2 percent of current U.S. GDP. This was followed up in March 2021 by the passage of the Biden Administration's American Rescue Plan. This was a much larger $1.9 trillion measure, equal to 8.9 percent of GDP, which aimed to provide further economic stimulus support. According to Governor Newsom and the California Legislative Analyst's Office, California should be receiving between $60 – 70 billion from the December 2020 bill and another $180 billion from the March 2021 bill.[11] Assuming a total level of support at $250 billion, that would amount to 8.1 percent of California's 2019 GDP.

In addition to these federal programs, Governor Newsom and the state legislature agreed on February 17 to implement a $9.6 billion state-level stimulus program. Its major provisions include $600 in cash support for low-income households; $2 billion in grants for small businesses; and $400 million for child-care support.[12] As a follow-up, Governor Newsom proposed in May a second stimulus program for the state. This second stimulus program would include an additional round of $600 direct payments, to be provided to those who will not have received a payment through the February stimulus program. In combination, the first- and second-round individual payments should provide support for two-thirds of Californians. Newsom's second round proposal also includes an additional $500 payment for families with children, along with $5 billion in total funds to assist renters and $2 billion to subsidize utility bills.[13]

2. Uncertainties in Economic Outlook. The federal- and state-level stimulus programs that have already been enacted will provide a significant boost to California's economic recovery. The recovery will receive additional major support if the Biden Administration's American Jobs Plan at the federal level and Governor Newsom's current proposal for a second round of stimulus support are voted into law.

But California's recovery out of the deep COVID-induced recession still faces major challenges and uncertainties even after accounting for these various forms of government support. These challenges and uncertainties are reflected in the "Economic Outlook" section of the *Governor's Budget Summary for 2021 – 2022*, which was published in January 2021.[14] The baseline projection in the outlook estimates that "businesses are expected to continue to operate at limited capacity into 2021." It also projects that, overall, nonfarm employment for California is not expected to return to its pre-pandemic level until 2025. Even under the Outlook's "Optimistic Scenario," employment in California would only return to its pre-pandemic level "within three years," i.e. some time in 2024. According to this report, achieving the Optimistic Scenario's result would become more likely with the passage of the Biden Administration's American Rescue Plan as well as Governor Newsom's two rounds of additional stimulus support. Thus, according to this January 2021 projection, California's recovery is likely to be slow even under the "Optimistic Scenario"—i.e. even with major forms of stimulus support already in place, and with further support likely to be forthcoming.

The Outlook further emphasizes that "climate change and extreme weather events continue to be a risk to California," including the impact of wildfires, rising sea levels and droughts. Indeed, on May 10, Governor Newsom declared a drought emergency in 41 of the state's counties, now covering 30 percent of the state's population. According to the *Los Angeles Times*, Newsom's emergency proclamation is anticipating that "the drought is expected to lead to a heightened fire season in a state that blasted records last year; decrease available water for agriculture, and present threats for fish and wildlife habitats."[15]

An Accelerated, Inclusive, and Sustainable Recovery Path

The most basic goals of economic policy coming out of the COVID recession in California are to achieve a recovery that is rapid, inclusive, and sustainable. Three of the crucial elements for delivering such a recovery will be: 1) permanently expanding the provision of high-quality universal health care; 2) ending disparities in employment opportunities; and 3) advancing a climate stabilization program capable of achieving the state's CO_2 emissions targets. Of course, the primary focus of this study is the climate stabilization program. But it will be useful here to also give some initial, if brief, attention to the pressing issues regarding health care delivery and unequal conditions in the state's labor market. We will then also integrate consideration of these issues in our discussions of employment creation through investments in energy efficiency/renewable energy, infrastructure/manufacturing, and land restoration/agriculture.

Universal health coverage. The need to transition the public health system, in California and more generally throughout the United States, became transparently clear during the COVID-19 pandemic. Indeed, the successes thus far of the national COVID vaccine program demonstrate the extent to which health care delivery organized to meet human needs can advance public health far more effectively than a system driven by the imperatives of corporate profitability. A single-payer Medicare for All type system is the most effective model for delivering universal high-quality health care on a sustained basis. The health economist Peter Arno and physician Peter Caper recently explained this point as follows:

> The development and distribution of the vaccines have features of a single-payer approach to health care that set the program apart from business as usual in our private market-oriented health care system. Vaccines are not usually profitable for pharmaceutical companies. It was therefore necessary for the federal government to subsidize the development and distribution of the Covid19 vaccines, mainly through Operation Warp Speed. As a result of these subsidies, none of us have to pay to receive the vaccine. Moreover, there are no documentation requirements to show eligibility and no disputes with insurance companies before or after vaccination. According to guidelines from the Centers for Medicaid and Medicare Services (CMS), "Vaccine doses purchased with U.S. taxpayer dollars will be given to the American people at no cost." Additionally, providers "may not seek any reimbursement, including through balance billing, from a vaccine recipient." We will all be covered automatically with no out-of-pocket costs. The national vaccination program has all the features of a single-payer health care system including no copays, no premiums, no insurance company blocking payment, and universal, affordable healthcare for all. The vaccine is being treated as a public good, not a private commodity, and its priority process is determined by medical need, not by ability to pay.[16]

Of course, there are a large number of challenging issues to address in transforming the U.S. health insurance infrastructure, or the infrastructure for California alone, into a Medicare for All type single-payer system. Examining these issues is well beyond the scope of this study. However, two of the authors of this study (Pollin and Wicks-Lim) have, in fact, produced in-depth studies on these questions, both for California specifically and for the U.S. overall.[17]

Inclusive job creation. The need for the recovery to be both accelerated as well as inclusive was well documented in a May 2021 report by Alissa Anderson of the California Budget and Policy Center. Anderson writes as follows:

> With COVID-19 cases plummeting and vaccine distribution expanding, businesses are picking up hiring. This is bringing hope that California has turned the corner on the pandemic and is setting a path forward for an economic recovery to finally take hold. But as the state begins to emerge from the recession, lawmakers must keep in mind that their policy choices will determine whether the recovery is inclusive of all people and builds toward an economy that works for everyone. The economic crisis amplified long-standing economic and health inequities, hitting Black, Latinx, and other Californians of color, as well as women, immigrants, and workers paid low wages much harder. These inequities will not disappear as the economy recovers unless lawmakers dismantle racist, sexist, and anti-immigrant barriers to opportunity and make investments that allow all Californians to share in the state's prosperity.[18]

Anderson points out that, even with strong employment gains in the state in February and March 2021, the level of employment remains at 1.5 million jobs fewer than in February 2020. She further notes that if the pace of employment growth remains at the rate of the most recent February and March figures, it would still take an additional 18 months just to return to the state's pre-COVID employment level. In addition, the largest ongoing gaps in employment in California are in low-paying industries. As Anderson writes:

> Some of the lowest-paying industries still had massive job shortfalls in March: 90% of the arts, entertainment, and recreation jobs that California lost were still gone, as were 61% of the accommodation and food service jobs, and 68% of the "other services" jobs, which include jobs at barber shops, hair salons, and nail salons. Rehiring in these sectors could take time, and it's possible that not all of the jobs that were lost will come back. For example, to the extent that office workers continue to work remotely after the pandemic ends, restaurants and other businesses near office buildings or downtown hubs may see fewer customers and won't need as many employees as they did prior to the pandemic. Similarly, if companies continue to hold remote meetings and conferences, hotels and other businesses serving business travelers may not need to rehire as many workers.

Anderson also points out that the percentages of Black and Latinx Californians that are unemployed or underemployed remains much higher than those for whites and Asians. One year into the recession, unemployment and underemployment was 58 percent higher for Black workers relative to whites and 34 percent higher for Latinx workers relative to whites.

Investment programs, health care and job creation. The major scale investment programs on which this study focuses in its upcoming sections—investments in energy efficiency, renewable energy, infrastructure, manufacturing, land restoration and agriculture—are capable of establishing a strong foundation for an economic recovery that is both robust in the short-term and sustainable over the longer-term. As such, these investment programs are also capable of nurturing the conditions throughout California or delivering transformational gains in the areas of both health care and employment equity.

2. CALIFORNIA'S CLEAN ENERGY TRANSITION PROJECT

Even under current pandemic conditions, we cannot forget that we have truly limited time to take decisive action around climate change. In October 2018, the Intergovernmental Panel on Climate Change (IPCC), the most world's most authoritative body for supporting and disseminating research on climate change, concluded that the world must reduce carbon dioxide emissions by 45 percent as of 2030—9 years from now—and reach net zero emissions by 2050, in order to retain a reasonable chance of moving onto a viable global climate stabilization path.[19] This means that, within the next 30 years, we must totally supplant our current fossil fuel-dominant energy system with one based on the combination of high efficiency and clean renewable energy sources, especially solar and wind power that gets converted into electricity.

Costs of Climate Change in California

To frame our discussion on advancing a viable climate stabilization project for California, it will be useful to review the costs of climate change that the state has already experienced in recent years. In fact, for decades, California has been experiencing a range of impacts including through wildfires, droughts, floods, heat waves, and air pollution. These effects of climate change have become more frequent and severe over time. The costs to California's economy and the well-being of the state's residents have risen correspondingly.

Estimates vary between researchers as to as to the magnitude of these costs. This is not surprising, given that the range of impacts are large and diverse. Moreover, not all the impacts can be readily quantified in dollar terms, including, for example, the public health effects of breathing air that has been polluted by intense wildfires. Nevertheless, it is useful to review some of the main evidence available on this question.

One useful source for the overall costs of climate change in California has been developed by the National Centers for Environmental Information (NCEI), a branch of the National Oceanic and Atmospheric Administration. NCEI has produced a database of what it terms "billion-dollar disaster events" throughout the United States. According to the NCEI database, California experienced 39 such billion-dollar disaster events between 1970 – 2020, including 16 major wildfires, 12 droughts, 4 floods, 4 severe storms, and 3 freeze disaster events. NCEI estimates that the damages from these events total to $235 billion. It is especially significant that, of this total damage since 1980, NCEI estimates that more than half has resulted from the 16 disaster events that have occurred since 2013.

Beyond these broad figures, some of the more specific findings associated with the various types of climate-related disasters in California are as follows.

Wildfires

The frequency and size of wildfires in California have increased rapidly as a result of rising average temperatures in the state. This pattern will continue as long as average temperatures also rise.[20] Thus, the 2020 wildfire season was the most destructive on record, during which 10.2 million acres burned. This figure more than doubled the previous annual record set in 2018, in which 4.1 million acres burned. Five of the six largest wildfires on record in California burned during August and September of 2020. The August Complex was the largest California wildfire. This began as 37 separate wildfires within the Mendocino National Forest that were set off after storms caused more than 10,000 lightning strikes across Northern California. Approximately 10,500 structures were damaged or destroyed across California during this one episode.[21]

Alternative estimates that aim to quantify these damages in recent years do vary, but are broadly consistent in terms of orders of magnitude. Some key estimates are as follows:

- From 2001-2016, wildfires cost utilities over $700 million in damages to electricity transmission and distribution infrastructure.[22]
- California's emergency firefighting costs totaled to $1.3 billion in 2020 alone.[23]
- The cleanup of the debris from the 2018 Camp Fire, which leveled the town of Paradise, cost about $2 billion, much of it paid by the federal government.[24]
- Long-term exposure to wildfire smoke generated an estimated $76 billion to $136 billion per year in health costs across the contiguous United States from 2008 to 2012, with some of the most significant impacts in northern California.[25]
- A 2020 study found that overall wildfire damages in 2018 totaled to $148.5 billion, including $28 billion in capital losses, $32 billion in health costs and $89 billion in indirect losses.[26]

Droughts

Climate change has altered factors fundamental to food production and rural livelihoods in the Southwest, particularly the shortage of water caused by droughts in California.[27] As temperatures continue warming, heat waves are more frequent, and precipitation has become increasingly variable. California is increasingly experiencing the impacts of droughts. For example, peak runoff in the Sacramento River now occurs nearly a month earlier than in the first half of the twentieth century and glaciers in the Sierra Nevada have lost an average of 70 percent of their area since the start of the 20th century.[28]

A 2014 study by Griffin and Anchukaitis concluded that California's drought between 2012 – 2104 was the most severe *in at least the past 1,200 years*.[29] This drought, which continued until 2016, is estimated to have caused 21,000 job losses. In 2015 alone, the drought caused the fallowing of 540,000 acres of land, at a cost of $900 million in gross crop revenue. Throughout the entire period from late 2011 – 2017, the drought caused $5 billion or more in damage to the state's agriculture industry and affected water supplies, fisheries, and infrastructure. NCEI estimates that total economic losses in the region due to the drought were in the range of $64 billion.[30]

Heat Waves

Exposure to hotter temperatures and heat waves has led to wide-ranging impacts in California, including loss of work and crops, and heat-associated deaths and illnesses.[31] In the unprecedented 2006 heat wave, extremely high temperatures occurred day and night for more than two weeks. Compared to non-heat wave summer days, it is estimated that the event led to an additional 600 deaths, 16,000 emergency room visits, and 1,100 hospitalizations throughout California.[32]

Record-breaking heat extremes were sustained for most of the five-year period 2012 – 2017 throughout much of the Southwest.[33] These extreme temperatures returned in 2020. Death Valley recorded a temperature of 130^0 in August 2020. If this figure is verified, it would represent the warmest August temperature on record and the third warmest temperature for any month across the U.S. Los Angeles County recorded a record high of 121^0 during this same heat wave. This heat wave caused major crop and livestock losses across the West and Central states due to both the persistent heat and increasingly dry conditions. The combined drought and heat also led to vegetation drying out across the West, which in turn was a major factor contributing to the severity of the California wildfires. NCEI estimates the event cost $4.5 billion in damages throughout the region.[34]

Air Pollution

The sources that produce greenhouse gases—including primarily methane and nitrous oxide along with CO_2—also release pollutants into the atmosphere, including particulate matter and volatile organic compounds as well as various nitrous oxides. A major 2008 study of San Joaquin Valley and the South Coast Basin found the annual public health costs of air pollution in these areas were estimated at $1,250-$1,600 per person, or $28 billion a year. These costs include direct healthcare provision and reduced activity, including hospital admissions and emergency room visits, school absences, and lost days of work.[35]

Actions to reduce greenhouse gas emissions will correspondingly reduce air pollution levels and the negative health impacts from pollution. A recent detailed analysis suggests that reducing greenhouse gas emissions in California by 80 percent below 1990 levels would produce a 55 percent reduction in air pollution mortality rates relative to 2010 levels.[36]

The Current Policy Setting

The State of California has committed itself to achieving state-wide emissions reduction targets fully consistent with the IPCC goals. Thus, in 2018, California enacted two major directives to bring its energy policies in line with the IPCC's 2018 targets. They are:

1. **Decarbonizing electricity.** Senate Bill (SB) 100 calls for California to completely decarbonize the electricity system by 2045, building on the state's existing goal of reducing all greenhouse gas emissions to 40 percent below 1990 levels by 2030.[37]
2. **Carbon neutrality by 2045.** Executive Order B-55-18 set the more ambitious term goal of the state becoming carbon neutral no later than 2045, with net negative emissions thereafter.[38]

These 2018 initiatives in California had been preceded by a series of critical measures that have established the state as a global leader in advancing a viable climate stabilization project. Thus, in 2006, the California legislature enacted the Global Warming Solutions Act (AB32). This established a greenhouse gas emissions reduction target, which was for California to return to its 1990 level of overall emissions by 2020. This was the first measure enacted throughout the Western Hemisphere that established an economywide emissions reduction target. In practice, the Global Warming Solutions Act was relatively modest in its goals relative to the 2018 initiatives and the IPCC's 2018 targets. It meant that California would have to cut its emissions by about 10 percent, from its 2006 level of 480 million metric tons to the 1990 level of 431 tons. In fact, emissions in California fell below 431 million metric tons by 2016 and have remained below that level as of the most recent 2018 figures. This is while the state pursues the much more ambitious targets it set out in 2018.

Even before passing the 2006 Global Warming Solutions Act, California had been implementing a range of policies to advance emissions reduction and climate stabilization in the state. Some of the major initiatives include the following:

Cap and Trade. Launched in 2013 and enforced by the California Air Resources Board, California's Cap-and-Trade program is the first multi-sector cap-and-trade program in the U.S., regulating around 450 businesses responsible for approximately 85 percent of California's total greenhouse gas emissions.[39] The cap-and-trade regulations applied first to electric power plants, industrial plants, and importers of electricity into the state which emit over 25,000 tons of CO_2 equivalent per year. In January 2015, the program was extended to include distributors of transportation fuels and natural gas.

Fuel Efficiency Standards. California has played a leading role in setting fuel efficiency standards for automobiles and trucks throughout the U.S. This is because, under the federal Clean Air Act, California is permitted to establish its own standards and other U.S. states are permitted to follow the California standard. The current standards for 2017-2025 for cars and light-duty trucks is 54.5 miles per gallon average across the fleet by 2025.[40] In October 2020, California introduced a more stringent standard, that by 2035, all new cars and passenger trucks sold in California will be required to be zero-emissions electric vehicles. However, it remains unclear what the overall emissions goal will be under this new standard, since existing vehicles running on fossil fuels will be permitted to continue running.[41]

Renewable Portfolio Standards. California's Renewables Portfolio Standard was established by legislation enacted in 2002. In 2018, California updated its standard, requiring 100 percent of electricity sales in the state to come from renewable energy and zero carbon resources by 2045. Interim targets include 50 percent from eligible renewables by Dec. 31, 2026 and 60 percent from eligible renewables by Dec. 31, 2030.[42]

Energy Efficiency Standards. California operates with several statewide standards, with the State Energy Resources Conservation and Development Commission establishing annual targets. The most comprehensive target is SB350, enacted in 2015, which requires that by 2030, electricity and natural gas sold to retail customers be provided at an efficiency level twice as high as the 2015 efficiency standard. [43]

Net Metering. Net metering is an arrangement whereby direct on-site producers of renewable energy can sell their excess electricity supply to utilities at an established price. For example, residential owners of solar panels can sell the excess electricity generated by the panels during periods of high sunlight to a utility, and thereby receive credit from the utility cover their costs during periods when the solar panels do not generate sufficient electricity to fully power their homes. California has operated with net metering laws since 1996. They apply to virtually all utilities in the state and renewable technologies, including geothermal, ocean thermal, tidal, wind and wave energy along with solar.[44]

Financial Subsidies and Incentives. California offers a wide range of incentives and subsidies in support of clean energy investments.[45] These include funding for local governments, small businesses and individuals to purchase electric vehicles.[46] The state also offers a range of private credit financing subsidies through so-called Property Assessed Clean Energy Financing, or "PACE financing".[47] Under typical PACE financing arrangements, property owners borrow from a local government or bank to finance clean energy investments. The amount borrowed is then repaid via a special assessment on property taxes or another locally collected tax or bill. The security of the tax collection mechanism reduces the risk to the private lender, which enables the financing costs of loan to be reduced. The state also offers a variety of renewable energy tax incentives, including sales and use tax exclusions and property tax exclusions.

Since becoming California's governor in January 2019, Gavin Newsom has enacted measures that have strengthened the existing policy framework aimed at achieving the state's emissions reduction targets. These measures include two significant executive orders:

1. **Zero-emissions vehicles by 2035.** Introduced in September 2020, Executive Order N-79-20, establishes that, as of 2035, all new cars and passenger trucks sold in California will be required to be zero-emissions vehicles. The California Air Resources Board and other state agencies will develop this order. The Board will also develop similar regulations to be applied, as of 2045, to the sale of new medium- and heavy-duty trucks in the state.[48]

   This executive order also gives strong, if less specified, support for California's clean energy transition project in these areas:

   - To expedite regulatory processes to repurpose and transition upstream and downstream oil production facilities, while supporting community participation, labor standards, and protection of public health, safety and the environment;
   - To manage and expedite the responsible closure and remediation of former oil extraction sites as the state transitions to a carbon-neutral economy;
   - To strictly enforce bonding requirements and other regulations to ensure oil extraction operators are responsible for the proper closure and remediation of their sites.

2. **30 x 30 Land Use Plan.**[49] Introduced in October 2020, Executive Order N-82-20, the "30 x 30" Land Use Plan for the state, establishes the goal of conserving 30 percent of the state's land and coastal water by 2030. The aim here is to reduce CO_2 in the state's atmosphere through expanding the stock of plants and forests, and to increase the organic content of soils. This will result because plants, trees and soil with high organic content all naturally absorb CO_2—i.e. they are all natural 'carbon capture' technologies.[50] The 30 x 30 measure also aims to reduce the risks of wildfires and protect the state's biodiversity.

Overall then, California's policy infrastructure is uniquely well-positioned to support transition to a zero emissions economy by 2045. Still, the full range of measures will need to be scaled up dramatically in order to meet the challenge of transforming the state's entire energy infrastructure, which, as we review below, remains to date dominated by fossil fuels.

Energy Sources and CO_2 Emissions for California

In this section, we review the sources of energy supply and demand in California, as well as the factors generating CO_2 emissions in the state. This discussion will provide necessary background for advancing a viable framework for reaching the state's emission reduction goals for 2030 and 2045.

Table 2.1 shows California's energy consumption profile both in terms of sources and uses of energy. In this table and throughout the study, we measure all energy sources uniformly in terms of British Thermal Units (BTUs). A BTU represents the amount of thermal energy necessary to raise the temperature of one pound of pure liquid water by one degree Fahrenheit from the temperature at which water has its greatest density (39 degrees Fahrenheit). Burning a wood match to its end generates about 1 BTU of energy. We will present figures on energy production and consumption, as appropriate, in terms of both trillion and quadrillion BTUs, referring to the acronyms T-BTUs and Q-BTUs respectively.

As one measure of how much energy is provided by 1 Q-BTU of energy, as we see in Table 2.1, total energy consumption in California in 2018 was 7,966.6 trillion BTUs, or approximately 8.0 Q-BTUs. This means that, roughly, 1 Q-BTU would be able to provide for California, at its 2018 consumption level, all the energy consumed for all purposes for a month and a half.

TABLE 2.1
California State Energy Consumption by Sector and Energy Source, 2018
Figures are T-BTUs

	Buildings						
	Residential	Commercial	All buildings	Industrial	Transportation	TOTAL	% of TOTAL
1. Total	**1,439.2**	**1,509.2**	**2,948.4**	**1,848.2**	**3,170.0**	**7,966.6**	**100.0%**
2. % of Total	**18.1%**	**18.9%**	**37.0%**	**23.2%**	**39.8%**	**100.0%**	**---**
3. Petroleum	24.9	82.9	107.8	423.1	2,981.9	3,512.9	44.1%
4. Natural gas	659.5	543.8	1,203.3	957.5	46.7	2,207.5	27.7%
5. Solar	175.1	141.1	316.2	64.8	0.7	381.7	4.8%
6. Bioenergy	44.8	51.7	96.5	60.8	136.3	296.9	3.7%
7. Hydro	83.6	108.7	192.3	46.6	0.7	239.7	3.0%
8. Nuclear	66.4	86.3	152.8	37.1	0.6	190.4	2.4%
9. Wind	44.5	57.9	102.4	24.8	0.4	127.6	1.6%
10. Geothermal	37.4	48.8	86.2	21.9	0.3	108.4	1.4%
11. Coal	0	0	0	33.3	0	33.3	0.4%
12. Electricity imported from other U.S. states	--	--	--	--	--	865.7	10.9%

Notes: Electricity use is distributed within each energy source and sector. Electricity figures include losses distributed by source and sector. Electricity imported from other U.S. states is only reported as an aggregate figure across sectors.

Source: https://www.eia.gov/state/?sid=CA.

Moving into the specifics of Table 2.1, we see in rows 1 and 2 how total energy consumption is divided between the sectors of California's economy. As we see, about 40 percent is used for all forms of transportation, 37 percent is for all buildings, and the remaining 23 percent is for industrial activity.

In rows 3 – 11 of Table 2.1, we see how the state's energy supply is broken down by energy sources. These figures include energy consumed as electricity, with electricity use distributed within each sector and source. The figures for electricity consumption include energy losses resulting from generating electricity, as we discuss further below.

As we see in row 3, petroleum is the most heavily utilized energy source in California, providing about 44 percent of all the state's energy supply. About 85 percent of oil is used for transportation in California, with 12 percent used in industrial operations and the remaining 3 percent for buildings. Natural gas is the next largest energy source in California, at about 28 percent of all supply, and with 54 percent used for buildings and 43 percent for industrial activity. Nuclear energy is a modest contributor to the state's overall energy supply, at 2.4 percent. Nuclear energy is used to generate electricity, which then is used primarily in buildings (80 percent) but also in industry (20 percent). Coal has been almost completely phased out as an energy source in California.

Among renewable energy sources, solar is already a significant contributor to the state's overall energy supply, accounting for nearly 5 percent of total supply, with 83 percent of solar being consumed in buildings and most of the rest for industrial activity. While the contribution of solar is currently negligible in transportation, that will certainly be changing as the presence of electric vehicles in the state expands. After solar, the most heavily consumed renewable energy source in California is bioenergy, at 3.7 percent of the state's energy supply. However, as we discuss below, bioenergy is not necessarily a clean renewable energy source. Within a 30-year cycle, emissions levels from wood and other plant-based raw materials are comparable to coal when burned directly, and to petroleum when converted into liquid biofuels. Bioenergy can become a low-emissions energy source. But this requires that the raw materials for producing energy are either waste products, such as waste grease or agricultural wastes such as corn stover, or cheaply and rapidly growing plants such as switchgrass, and that these raw materials are refined into biofuels by relying on clean renewable energy sources. We assume that such low-emissions bioenergy sources can develop in California between 2021 – 2030.[51]

Hydro power provides about 3 percent of California's total energy supply, while wind and geothermal power also combine for a total of 3 percent. Overall then, clean renewable energy sources, including solar, hydro, wind and geothermal, account for nearly 11 percent of California's overall energy supply. This is the highest proportion of clean energy among all U.S. states. It provides a solid initial foundation for the major expansion in clean renewable supply that will be needed in order for California to achieve its emissions reduction goals.

Electricity Supply and Demand

To further clarify the profile of energy consumption in California, we show data in Tables 2.2 and 2.3 on the uses and sources of electricity in the state. Electricity, of course, is unique in that it is an intermediate energy source, relying on several primary sources—including natural gas, solar, biomass, hydro, and nuclear energy as its primary sources in California — for its generation. It is also unique in that, as Table 2.2 shows, nearly half of all energy consumed is lost in the conversion process from the primary energy sources to electricity supply, while the other half is channeled into energy that is consumed. One evident way to raise energy efficiency, in California and elsewhere, would therefore entail reducing the percentage of energy losses through electricity use.[52]

Overall, as Table 2.2 shows, electricity production requires 1,611 T-BTUs of California's total energy consumption, amounting to roughly 20 percent of all energy produced in the state, while, as an energy source to final consumers in the state's building, transportation and industrial sectors, electricity provides only about 871 T-BTUs of end-use consumption, or 11 percent of the total energy consumed within the state.

Table 2.3 provides more detail on the sources of electricity supply and demand within California. As we see, natural gas is the primary source for electricity supply, accounting for 39 percent of total electricity generation. After natural gas, solar, and hydro provide about 15 percent respectively, nuclear is at 12 percent and wind is at 8 percent. The total for clean renewable energy sources, including wind and geothermal as well as solar and hydro, is at nearly 45 percent of the total. From these figures, it again becomes clear that California has already achieved substantial progress toward creating a net zero emissions economy, in particular, in its electricity sector. Nevertheless, the state will still have to make major additional advances, including in electricity generation, to achieve a 50 percent emissions cut by 2030 and to reach the net zero goal by 2045.

In terms of the specific uses of electricity in California. we see in Table 2.3 that the most prevalent use is for the operation of buildings, accounting for about 80 percent of all electricity demand. Industrial processes utilize the remaining 20 percent of all electricity. At present, electricity is not used to a measurable extent in transportation. But the share of electricity demand for transportation will, of course, need to rise sharply as the use of electricity-powered vehicles expands sharply. Governor Newsom's September 2020 Executive Order requiring all new car sales in California to be zero-emissions vehicles by 2035 will certainly support this transition.

TABLE 2.2
California State Total Electricity Consumption and Energy Losses in Electricity Generation, 2018

Total energy consumed in generating electricity	1,610.7 TBTUs *(20.2% of state energy consumption)*
Electricity end-use consumption	871.3 TBTUs (*10.9% of state energy consumption)*
Energy losses as share of energy consumed in generating electricity	45.9%

Source: https://www.eia.gov/state/?sid=CA.

TABLE 2.3
California End-Use Electricity Consumption, 2018
Figures are T-BTUs

	Buildings					
	Residential	Commercial	All buildings	Industrial	Transportation	TOTAL
Natural gas	119.9	155.8	275.6	66.9	1.0	343.5 *39.4% of total*
Solar	46.1	60.0	106.1	25.7	0.4	132.3 *15.2% of total*
Hydro	45.3	58.9	104.2	25.3	0.4	129.8 *14.9% of total*
Nuclear	36.0	46.8	82.8	20.1	0.3	103.2 *11.8% of total*
Wind	24.1	31.3	55.5	13.5	0.2	69.1 *7.9% of total*
Geothermal	20.1	26.1	46.2	11.2	0.2	57.6 *6.6% of total*
Bioenergy	12.4	16.1	28.6	6.9	0.1	35.6 *4.1% of total*
Petroleum	0.1	0.1	0.2	0.0	0.0	0.2 *0.0% of total*
Coal	0.0	0.0	0.0	0.0	0.0	0.0 *0.0% of total*
Total	304.0	395.1	699.2	169.6	2.6	871.3
Share of total (in %)	35%	45%	80%	20%	0%	100%

Source: https://www.eia.gov/state/?sid=CA.

What Is Clean Energy?

In this section, we consider the extent to which alternative energy sources and technologies can serve effectively to reduce CO_2 emissions in California by approximately 50 percent and to transform the state into a net zero emissions economy by 2045.

Natural Gas

We begin with natural gas, which, as we have seen, is the second-most heavily consumed energy source in California, and is the primary source in electricity generation. Here we focus on natural gas as a source of CO_2 and other greenhouse gas emissions.

There are large differences in the emissions levels resulting through burning oil, coal, and natural gas respectively, with natural gas generating about 40 percent fewer emissions for a given amount of energy produced than coal and 15 percent less than oil. It is therefore widely argued that natural gas can be a "bridge fuel" to a clean energy future.[53] Such claims do not withstand scrutiny.

To begin with, emissions from burning natural gas are still substantial, even if they are lower than coal and petroleum. As a straightforward matter, it is not possible to get to a net zero economy through increasing reliance on CO_2-emitting natural gas energy. But it is also imperative, in calculating the full emissions impact of natural gas, that we take account of the leakage of methane gas into the atmosphere that results through extracting natural gas through fracking. Recent research finds that when more than about 5 percent of the gas extracted leaks into the atmosphere through fracking, the impact eliminates any environmental benefit from burning natural gas relative to coal. Various studies have reported a wide range of estimates as to what leakage rates have actually been in the United States, as fracking operations have grown rapidly. A recent survey paper puts that range as between 0.18 and 11.7 percent for different specific sites in North Dakota, Utah, Colorado, Louisiana, Texas, Arkansas, and California.

It would be reasonable to assume that if fracking expands on a large scale in the U.S., or elsewhere, it is likely that leakage rates will fall closer to the higher-end figures of 12 percent, at least until serious controls could be established. This then would greatly diminish, if not eliminate altogether, any emission-reduction benefits from a coal-to-natural gas fuel switch.[54]

Nuclear Energy

As we have seen, nuclear energy is a relatively modest source of California's overall energy supply, providing 2.4 percent of the state's total energy consumption, and about 12 percent of the state's electricity generation. California's nuclear energy is produced at the Diablo Canyon power plant, which operates two reactors. These two reactors are scheduled to be shut down in 2024 and 2025 respectively. The question then becomes whether the state should permit any new nuclear power plant construction.

In terms of advancing a clean energy transition in California, nuclear energy provides the important benefit that it does not generate CO_2 emissions or air pollution of any kind while operating. At the same time, the processes for mining and refining uranium ore, making reactor fuel, and building nuclear power plants do all require large amounts of energy. But even if we put aside the emissions that result from building and operating nuclear plants, we still need to recognize the longstanding environmental and public safety issues associated with nuclear energy. These include:

- ***Radioactive wastes.*** These wastes include uranium mill tailings, spent reactor fuel, and other wastes, which according to the U.S. Energy Information Agency (EIA) "can remain radioactive and dangerous to human health for thousands of years" (EIA 2020b, p. 1).
- ***Storage of spent reactor fuel and power plant decommissioning.*** Spent reactor fuel assemblies are highly radioactive and must be stored in specially designed pools or specially designed storage containers. When a nuclear power plant stops operating, the decommissioning process involves safely removing the plant from service and reducing radioactivity to a level that permits other uses of the property.
- ***Political security.*** Nuclear energy can obviously be used to produce deadly weapons as well as electricity. Thus, the proliferation of nuclear energy production capacity creates dangers of this capacity being acquired by organizations - governments or otherwise - which would use that energy as instruments of war or terror.

- ***Nuclear reactor meltdowns.*** An uncontrolled nuclear reaction at a nuclear plant can result in widespread contamination of air and water with radioactivity for hundreds of miles around a reactor.

How to weigh the benefits to California of nuclear energy versus these environmental and public safety concerns is a critical challenge for determining the state's future energy trajectory. It will be useful to briefly consider some relevant recent history.

In 1979, the U.S. experienced a nuclear reactor meltdown at the Three Mile Island facility in Middletown, Pennsylvania. Despite this, support for maintaining nuclear energy production facilities continued. At least partially, the continued support for nuclear in the U.S. post-Three Mile Island can be explained by the fact that, at least in official assessments, the negative effects of the accident were relatively modest. Thus, the Pennsylvania Department of Health followed for 18 years the health outcomes of 30,000 people who lived within five miles of the reactor. This study found that these people experienced no negative health effects.[55]

No new construction of nuclear facilities occurred in the U.S. for 30 years after Three Mile Island. At the same time, existing facilities did continue operating, including at Diablo Canyon. In addition, as of 2007, new nuclear facilities were built in the United States in states other than California. Nuclear power facilities were also built elsewhere in the world, including in Japan, France, and China, in the years after Three Mile Island.

The nuclear industry expanded in these other countries even though, in 1986, a second major accident occurred in Chernobyl, in the former Soviet Union. Moreover, at Chernobyl, in contrast with Three Mile Island, there was no question as to the severity of the consequences of the meltdown. The Chernobyl accident released more radiation than the atomic bomb in Hiroshima. As a result, at least 20,000 children contracted thyroid cancer, among its public health impacts. The economic costs of addressing the full range of impacts, including decontamination and reclamation of the region, resettling 200,000 people, and providing health care for 7 million people exposed to radiation amounted to $700 billion over thirty years.[56]

More recently, in 2011, Japan experienced a nuclear accident at the Fukushima Daiichi power plant of comparable severity to Chernobyl. This meltdown resulted from the massive 9.0 Tohuku earthquake and tsunami. While the full effects of the Fukushima meltdown remain uncertain a decade subsequent to the disaster, the most recent estimate of the total costs of decommissioning the power plant and providing compensation to victims is $250 billion.[57]

Considering this evidence, it is clear that, over the long term, relying on nuclear energy will continue to carry major environmental, public health, safety, and political risks. The safer option is therefore for California to continue building its net zero emissions economy on a foundation of energy sources that are both clean and safe—i.e. solar, wind, geothermal, small-scale hydro, and low-emissions bioenergy.

Bioenergy

As we saw in Table 2.1, bioenergy—including solid biomass energy from burning wood and other raw materials as well as liquid biofuels, primarily corn ethanol—provides 3.7 percent of California's total energy supply. But, as noted above, it is critical to recognize that, unlike other renewable energy sources, bioenergy is not a clean energy source under most circumstances. This is, first of all, because burning solid biomass can generate significant emissions levels, depending on the raw materials used and the processes used for converting raw materials into energy. The emissions that result through burning wood are significantly greater than those produced by burning coal, and are far in excess of those produced through either oil or natural gas combustion. Despite this, in the official methodology for measuring CO_2 emissions used in the U.S. (and elsewhere), biomass is treated as a carbon-neutral energy source. This approach is based on the fact that when new crops of trees are planted and grown, they absorb CO_2 by the same amount as the CO_2 that is emitted when trees are burned.

However, this approach to accounting for biomass emissions has been widely refuted in the recent research literature.[58] The main consideration here is that trees require decades to regrow and thereby to absorb CO_2. By contrast, emissions generated by burning wood enter into the atmosphere immediately on combustion. Allowing that we are operating withn the emissions-reduction timeframe set out by the State of California itself, this means that we have only 10 years to reduce CO_2 emissions by 50 percent and 25 years to reach net zero emissions. As such, the decades-long process through which newly planted trees absorb CO_2 will not deliver carbon neutrality within a 25-year time frame, much less a 50 percent emissions reduction within 10 years.

This point was emphasized in a May 2020 letter to the Members of Congress by 200 leading environmental scientists. The letter states that:

> The scientific evidence does not support the burning of wood in place of fossil fuels as a climate solution. Current science finds that burning trees for energy produces even more CO_2 than burning coal, for equal electricity produced…and the considerable accumulated carbon debt from the delay in growing a replacement forest is not made up by planting trees or woods substitution.[59]

Other bioenergy sources include various liquid biofuels, including ethanol and biodiesel. These are produced from a range of feedstocks, including corn, sugarcane, waste grease, corn stover, and switchgrass. The emissions levels generated by these alternative feedstocks and refining techniques vary greatly. For example, over a 30-year cycle, emissions from burning corn ethanol are comparable to those from coal. However, major emissions reductions can be achieved with bioenergy through burning waste-grease biodiesel fuel, corn stover, or switchgrass-based ethanol. With either waste grease or corn stover, there are no production costs, including energy consumption, required to supply the bioenergy raw material. With switchgrass as the raw material, the production costs—including energy consumption—are minimal.[60] Even when including the refining and energy-generating processes, these bioenergy fuel sources can become low-emissions energy sources. However, to date, California does not either produce or consume low-emissions bioenergy to any significant extent.[61]

It is therefore critical for our discussion that we incorporate emissions from burning wood and consuming ethanol biofuels into our estimate of overall CO_2 emissions in California. In fact, emissions from biomass and biofuels vary widely.[62] As a rough approximation, we assume that emissions levels from bioenergy in California are, at present, at a midpoint level between burning coal and petroleum. But we will also include low-emissions bioenergy as among the clean renewable energy sources that can contribute toward transforming California into a net zero emissions economy.

Geoengineering

This includes a broad category of measures whose purpose is either to remove existing CO_2 or to inject cooling forces into the atmosphere to counteract the warming effects of CO_2 and other greenhouse gases. One broad category of removal technologies is carbon capture and sequestration (CCS). A category of cooling technologies is stratospheric aerosol injections (SAI).

CCS technologies aim to capture emitted carbon and transport it, usually through pipelines, to subsurface geological formations, where it would be stored permanently. One straightforward and natural variation on CCS is afforestation. This involves increasing forest cover or density in previously non-forested or deforested areas, with "reforestation"—the more commonly used term—as one component.

The general class of CCS technologies have not been proven at a commercial scale, despite decades of efforts to accomplish this. A major problem with most CCS technologies is the prospect for carbon leakages that would result under flawed transportation and storage systems. These dangers will only increase to the extent that CCS technologies are commercialized and operating under an incentive structure in which maintaining safety standards will reduce profits.

By contrast, afforestation is, of course, a natural and proven carbon removal technology. Roughly one-third of California's overall land area is presently covered by forest.[63] Thus, forest growth in California can provide a significant offset to the emissions generated through combusting fossil fuels and bioenergy to produce energy. As such, California can reach a net zero CO_2 emissions threshold by 2045 even while energy consumers in the state continue to rely on fossil fuels to a modest extent. We return to this point in Section 8, which focuses on the path for California to become a net zero emissions economy.

The idea of stratospheric aerosol injections builds from the results that followed from the volcanic eruption of Mount Pinatubo in the Philippines in 1991. The eruption led to a massive injection of ash and gas, which produced sulfate particles, or aerosols, which then rose into the stratosphere. The impact was to cool the earth's average temperature by about 0.6^0C for 15 months.[64] The technologies being researched now aim to artificially replicate the impact of the Mount Pinatubo eruption through deliberately injecting sulfate particles into the stratosphere. Some researchers contend that to do so would be a cost-effective method of counteracting the warming effects of greenhouse gases.

Lawrence et al. (2018) published an extensive review on the range of climate geoengineering technologies, including 201 literature references. Their overall conclusion from this review is that none of these technologies are presently at a point at which they can make a significant difference in reversing global warming. They conclude:

> Proposed climate geoengineering techniques cannot be relied on to be able to make significant contributions…towards counteracting climate change in the context of the Paris Agreement. Even if climate geoengineering techniques were actively pursued, and eventually worked as envisioned on global scales, they would very unlikely be implementable prior to the second half of the century….This would very likely be too late to sufficiently counteract the warming due to increasing levels of CO_2 and other climate forces to stay within the 1.5^0C temperature limit—and probably even the 2^0C limit—especially if mitigation efforts after 2030 do not substantially exceed the planned efforts of the next decade, (pp. 13-14).

Energy Efficiency and Clean Renewable Energy

Given these major problems with bioenergy, natural gas, nuclear energy and geoengineering, it follows, in advancing a program to cut emissions by 50 percent as of 2030 and to net zero emissions by 2045, that California should focus instead on the most cautious clean energy transition program, i.e. investing in technologies that are well understood, already operating at large-scale, and, without question, safe. In short, we focus here on investments that can dramatically raise energy efficiency standards and equally dramatically expand the supply of clean renewable energy sources.

Prospects for Energy Efficiency

Energy efficiency entails using less energy to achieve the same, or even higher, levels of energy services from the adoption of improved technologies and practices. Examples include insulating buildings much more effectively to stabilize indoor temperatures; driving more fuel-efficient cars or expanding well-functioning public transportation systems; and reducing the amount of energy that is wasted through operating industrial machinery and transmitting electricity over the grid.

Expanding energy efficiency investments supports rising living standards because raising energy efficiency standards, by definition, saves money for energy consumers. A major 2010 study by the National Academy of Sciences (NAS) found, for the U.S. economy, that "energy efficient technologies…exist today, or are expected to be developed in the normal course of business, that could potentially save 30 percent of the energy used in the U.S. economy while also saving money." Similarly, a 2010 McKinsey and Company study focused on developing countries found that, using existing technologies only, energy efficiency investments could generate savings in energy costs in the range of 10 percent of total GDP, for all low- and middle-income countries.

In her 2015 book, *Energy Revolution*: *The Physics and Promise of Efficient Technology*, the Harvard University physicist Mara Prentiss argues, further, that such estimates understate the realistic savings potential of energy efficiency investments. This is because, in generating energy by burning fossil fuels, about two-thirds of the total energy available is wasted while only one-third is available for powering machines. By switching to renewable energy sources, the share of wasted energy falls by 50 percent. This is what Prentiss terms the "burning bonus."

After taking account of the burning bonus as well as the efficiency gains available in the operations of buildings, transportation systems and industrial equipment, Prentiss concludes, with respect to the U.S. economy specifically, that economic growth could proceed at a normal rate while total energy consumption could remain constant or even decline in absolute terms. Prentiss's conclusions regarding the U.S. economy are consistent with the most recent projections for U.S. energy demand—as well as global energy demand—by the International Energy Agency (IEA 2019). The IEA assumes that the U.S. economy will grow at a 2.0 percent average annual rate between 2018 – 2040. Nevertheless, under their "Current Policies Scenario," which reflects existing policy commitments within the U.S. but nothing beyond these, the IEA assumes that U.S. energy consumption will decline by an average of -0.2 percent per year. But under its more ambitious Sustainable Development Scenario, the IEA estimates that U.S. energy demand will fall by -1.3 percent per year, even while economic growth still proceeds at a 2.0 percent average rate.[65]

Estimating Costs of Efficiency Gains

How much will it cost to achieve major gains in energy efficiency, in general and with respect to California specifically? In fact, estimates as to the investment costs for achieving energy efficiency gains vary widely. For example, the 2010 study by the National Academy of Sciences estimated average costs for building, transportation and industrial efficiency improvements in the United States at $29 billion per Q-BTU of energy savings. More recent studies, focused on the U.S. building sector alone, report similar cost estimates.[66] However, a 2008 World Bank study by Taylor et al. puts average costs at $1.9 billion per Q-BTU of energy savings, based on a study of 455 projects in both industrial and developing economies, a figure that is only 7 percent of the National Academy of Sciences estimate. A 2010 study by the McKinsey consulting firm estimates costs for a wide range of non-OECD economies at $11 billion per Q-BTU of energy savings.

It is not surprising that average costs to raise energy efficiency standards should be significantly higher in industrialized economies. A high proportion of overall energy efficiency investments are labor costs, especially projects to retrofit buildings and industrial equipment. However, these wide differences in cost estimates between the various studies do not simply result from variations in labor and other input costs by regions and levels of development.

Thus, the World Bank estimate of $1.9 billion per Q-BTU includes efficiency investment projects in both industrialized and developing countries.

These alternative studies do not provide sufficiently detailed methodological discussions that would enable us to identify the main factors generating these major differences in cost estimates. But it is at least reasonable to conclude from these figures that, with on the ground real-world projects, there are likely to be large variations in costs down to the project-by-project level. Thus, the costs for energy efficiency investments that will apply in any given situation will necessarily be specific to that situation, and must always be analyzed on a case-by-case basis. At the same time, for our present purposes, we need to proceed with some general rules-of-thumb for estimating the level of savings that are attainable through a typical set of efficiency investments in California.

A conservative approach is to use the National Academy of Sciences estimate as a baseline figure, at $29 billion per Q-BTU of energy savings through efficiency investments. In addition, it would be prudent to assume that the average costs per Q-BTU of savings will have increased. This is because California has been making significant investments in energy efficiency for decades, through establishing and maintaining high efficiency standards for appliances and other equipment—including refrigerators, TVs, computers, dishwashers, air conditioners, and lightbulbs, along with buildings and vehicles. Further efficiency gains in California are still also achievable, as we discuss below.[67] For now, the fact that the state is already operating at a high efficiency level suggests that lower-cost energy savings investments have already largely been implemented. As such, we will assume here that the average costs will be $35 billion to achieve one Q-BTU of energy savings in California, or $35 million per T-BTU.

Rebound Effects

Raising energy efficiency levels will generate "rebound effects"—i.e. energy consumption increases resulting from lower energy costs. But such rebound effects are likely to be modest in California, within the current context of a statewide project focused on reducing CO_2 emissions and stabilizing the climate. Among other factors, energy consumption levels in California are close to saturation points in the use of home appliances and lighting—e.g. we are not likely to clean dishes much more frequently because we have a more efficient dishwasher. The evidence shows that, in general, consumers in advanced economies are likely to heat and cool their homes as well as drive their cars more when they have access to more efficient equipment. But these increased consumption levels are usually modest.[68] Even more to the point for our present discussion, the California economy is already operating at a high efficiency level. The evidence that we will review below shows that this high efficiency level has not generated significant rebound effects.

Prospects for Clean Renewable Energy

A critical factor for building a net zero economy in California, and throughout the world, by 2045 is the fact that, on average, the costs of generating electricity with clean renewable energy sources are now at parity or lower than those for fossil fuel-based electricity. Table 2.4 shows the most recent figures reported by the International Renewable Energy Agency (IRENA), for 2010 and 2019, on the "levelized costs" of supplying electricity through alternative energy sources. Levelized costs take account of *all costs* of producing and delivering a kilowatt of electricity to a final consumer. The cost calculations begin with the upfront capital expenditures needed to build the generating capacity, include both fixed and variable operations and maintenance costs, continue through to the transmission and delivery of electricity, and include the costs of energy that is lost during the electricity-generation process.

As we see in Table 2.4, the levelized costs for fossil-fuel generated electricity range between 5.0 and 17.7 cents per kilowatt hour as of 2019. The average figures for the four clean renewable sources are all within this range for fossil fuels as of 2019, with solar at 6.8 cents, onshore wind at 5.3 cents, hydro at 4.7 cents and geothermal at 7.3 cents. The costs of geothermal and hydro did not fall, and actually rose somewhat, between 2010 and 2019. However, the costs of onshore wind fell by 38 percent, from 8.6 to 5.3 cents.[69] The most impressive result though is with solar PV, in which levelized costs fell by 82 percent from 2010 to 2019, from 37.8 cents to 6.8 cents per kilowatt hour. These average cost figures for solar and wind should continue to decline still further as advances in technology and economies of scale proceed along with the rapid global expansion of these sectors.[70]

We emphasize that these cost figures from the IRENA are simple averages. They do not show differences in costs due to regional or seasonally-specific factors.[71] In particular, solar and wind energy costs will vary significantly by region and season. Moreover, both solar and wind energy are intermittent sources—i.e. they only generate energy, respectively, when the sun is shining or the wind is blowing. These issues of energy storage will become significant as California, the U.S., and global economies approach the net zero emissions goal by 2045. Over the decade 2021 – 2030, these issues will not be pressing. This is because petroleum,

TABLE 2.4
Average Global Levelized Costs of Electricity from Utility-Scale Renewable Energy Sources vs. Fossil Fuel Sources, 2010 – 2019

Average levelized costs for fossil-fuel generated electricity:
5.0 – 17.7 cents per kilowatt hour

	2010	2019
Solar PV	37.8 cents	6.8 cents
Onshore wind	8.6 cents	5.3 cents
Hydro	3.7 cents	4.7 cents
Geothermal	4.9 cents	7.3 cents

Source: https://www.irena.org/publications/2020/Jun/Renewable-Power-Costs-in-2019.

natural gas, high-emissions bioenergy and nuclear power will be supplying over 75 percent of California's total energy supply as of 2021, with that figure still maintained at roughly 40 percent as of 2030, even as California achieves major improvements in energy efficiency. Thus, the economy's baseload energy sources will continue to be fossil fuels through 2030 and several years beyond.

Keeping all such considerations in mind, we can still roughly conclude from these figures that, for the most part, clean renewable energy sources are rapidly emerging into a position at which they can produce electricity at comparable or lower costs than non-renewable sources and high-emissions bioenergy. As such, assuming that solar, wind, low-emissions bioenergy, geothermal, and small-scale hydro can be scaled up to meet virtually all the state's energy demand by 2045, then the costs to consumers of purchasing this energy should not be significantly different from what these consumers would have paid for non-renewable energy. Indeed, overall, the costs to consumers of purchasing electricity from clean renewable sources are likely to be *lower* than what they would be from fossil fuel sources. It is critical to also emphasize that this is *without* factoring in the environmental costs of burning oil, coal, natural gas and high-emissions bioenergy, including the range of costs of climate change in California that we have described earlier.

Costs of Expanding Renewable Capacity

With most clean renewable technologies, the largest share of overall costs in generating electricity is capital costs—i.e. the costs of producing new productive equipment, as opposed to the costs of operating and maintaining that productive equipment once it has been built and is generating energy. These capital costs are between 71 – 75 percent for solar, wind, and hydro power. They are somewhat lower, at 54 percent for geothermal power, and lower still, at 42 percent for low-emissions bioenergy. But even with bioenergy, capital costs are still the largest cost component.[72] From these figures on levelized costs, we can also estimate the capital costs of installing renewable energy capacity as a lump sum—i.e. how much investors need to spend *upfront* to put this capital equipment into place and in running order.

We produce estimates of these lump sum capital costs in Table 2.5. Specifically, these figures represent the present values of total lump-sum capital expenditures needed to produce one Q-BTU of electricity from these various clean renewable sources.[73] As we see,

TABLE 2.5

Capital Expenditure Costs for Building Renewable Electricity Productive Equipment

Present values of total lump-sum capital costs per Q-BTU of electricity

Solar PV	$97 billion
Onshore wind	$110 billion
Low-emissions bioenergy	$148 billion
Geothermal	$76 billion
Small-scale hydro	$138 billion
Weighted average costs *Assuming investments are 50% solar, 20% wind, 15% bioenergy, 7.5% geothermal, 7.5% small-scale hydro*	**$109 billion**

Sources: U.S. EIA, https://www.eia.gov/outlooks/aeo/pdf/electricity_generation.pdf. See Pollin et al. (2014) pp. 136 – 37 for methodology in converting levelized costs per Q-BTU into lump-sum capital costs.

these cost figures are $97 billion for solar PV, $110 billion for onshore wind, $148 billion for low-emissions bioenergy, $76 billion for geothermal, and $138 billion for small-scale hydro.

As we will discuss further later, we will assume that with California's clean energy investment project, the expansion of clean renewable energy capacity will consist of 50 percent solar PV, 20 percent onshore wind, 15 percent low-emissions bioenergy, and 7.5 percent respectively for geothermal and small-scale hydro. With these relative proportions, a weighted average of the capital costs for expanding the clean renewable energy supply by 1 Q-BTU would be $109 billion, as we show in Table 2.5.

This $109 billion figure can serve as a benchmark for estimating the average costs of expanding the supply of clean renewable energy within California. At the same time, as with our cost estimate for investments in energy efficiency, we will want to err, if anything, on the side of overestimating, rather than underestimating, the costs of expanding clean renewable energy. One consideration is that, with the build-out of the clean energy supply proceeding rapidly throughout the U.S, and globally, over the next decade and beyond, the average costs are likely to rise as production bottlenecks emerge. In addition, these figures do not include the costs of storing energy from the intermittent energy sources, i.e. solar and wind power. In turn, solar and wind will be the two most significant renewable energy sources for California. The additional storage costs of delivering solar and wind power therefore need to be incorporated into the overall cost estimates.

For these reasons, we assume that the average costs of expanding the supply of clean renewable energy in California will be $200 billion per Q-BTU, i.e. about 80 percent higher than the $109 billion average figure we have derived from the current levelized costs data.

We can now work with our two rough high-end estimates of the overall costs of both raising energy efficiency standards and building new clean renewable energy capacity—$35 billion per Q-BTU ($35 million per T-BTU) for efficiency gains and $200 billion per Q-BTU ($200 million per T-BTU) for expanding renewable capacity—to generate an estimate of the total costs of achieving a 50 percent CO_2 emissions reduction in California by 2030 and to reach net zero emissions by 2045.

Determinants of California's CO_2 Emission Levels

Table 2.6 shows how, as of 2018, California generated approximately 389 million tons of CO_2 from burning fossil fuels—primarily oil and natural gas, with small amounts of bioenergy and a now negligible coal sector. Oil consumption is at 3.5 Q-BTUs, natural gas is at 2.2 Q-BTUs, while coal is at only 33 T-BTUs and bioenergy is at 297 T-BTUs. We also see the totals for CO_2 emissions generated by the respective sources, with petroleum at 242 million tons (63 percent), natural gas at 117 million tons (30 percent), coal at 3 million tons (0.8 percent), and bioenergy at 27 million tons (7 percent).

It is clear from these figures that driving down overall emissions in California from 389 to 193 million tons by 2030 will require major reductions first and foremost with oil and gas, which are responsible for 93 percent of total emissions as of 2018. Operating within a framework in which energy efficiency rises significantly between 2021 – 2030, we assume that the consumption of oil, natural gas and high-emissions bioenergy will all fall by 50 percent as of 2030 and that coal consumption will be phased out entirely. Thus, as we see in Table 2.6, oil falls from 3.51 to 1.76 Q-BTUs as of 2030, natural gas falls from 2.2 to 1.1 Q-BTUs, and high-emissions bioenergy falls rom 297 – 149 T-BTUs. Coal consumption, again, is brought to zero by 2030. Through following this scenario, total CO_2 emissions in California will fall by half, from 389 to 193 million tons between 2018 and 2030. Columns 4 and 5 of Table 2.6 present the calculations through which we derive this result.

TABLE 2.6
Sources of CO_2 Emissions for California: *2018 Actuals and 2030 Projections*

	2018 Actuals			2030 Projections	
	1) 2018 Energy consumption *(in T-BTUs)*	**2) 2018 CO_2 emissions** *(in million metric tons)*	**3) CO_2 emissions per Q-BTU** *(in millions of tons; = column 2/ (column 1/1000))*	**4) 2030 Energy consumption** *(in T-BTUs)*	**5) 2030 CO_2 emissions** *(in millions of tons; = column 3 x column 4/1000)*
Fossil Fuels					
Petroleum	3,512	242	68.9	1,756	121
Natural gas	2,207	117	53.0	1,104	59
Coal	33	3	90.9	0	0
Fossil fuel totals	5,752	362	---	2,860	180
Bioenergy	297	27	*90— rough approximation*	149	13
Totals, including bioenergy estimate	**6,049**	**389**	---	**3,009**	**193**

Notes: 2018 emissions figures are projected from the most recent 2017 figures, assuming constant CO_2 emissions per Q-BTU for 2017 and 2018. Assumption made for the 2030 projected scenario is that oil, natural gas and bioenergy are reduced by 50 percent and coal is phased out completely.

Source: US EIA, https://www.eia.gov/environment/emissions/state/analysis/.

GDP, Energy Intensity, and Emissions Intensity as Emissions Drivers

In order to develop an effective strategy for achieving California's emissions reduction goals, it will be useful to present a more detailed breakdown of the factors generating the state's current levels of emissions. More specifically, it will be valuable to decompose the emissions per capita ratio for California, as well as other states and the U.S. overall, into three component parts. This yields three ratios, each of which provides a simple measure of one major aspect of the climate change challenge, for California, the rest of the U.S. states and elsewhere. That is, CO_2 emissions per capita can be expressed as follows:

Emissions/population = (GDP/population) x (Q-BTUs/GDP) x (emissions/Q-BTU).

These three ratios provide measures of the following in each state, regional, or country setting:

1. *Level of development:* Measured by GDP per capita (i.e. GDP/population);
2. *Energy intensity:* Measured by Q-BTUs/GDP;
3. *Emissions intensity:* Measured by emissions/Q-BTU.

In Table 2.7, we show these ratios for California, as well as, for comparison purposes, the United States overall and India, as well as five other states: Ohio, Kentucky, New York, Pennsylvania, Texas, and Colorado. We work with 2017 data in this table, since this is the most recent year for emissions data that includes all U.S. states.

TABLE 2.7

Determinants of Per Capita CO_2 Emissions Levels in Various States, 2017

Level of development, energy intensity and emissions intensity

CO_2 emissions/population = (GDP/population) x (Q-BTUs/GDP trillion dollars) x (Emissions/Q-BTU)

	Per capita CO_2 emissions *(in metric tons)*	Per capita GDP *(in 2017 dollars)*	Energy intensity ratio: *Q-BTUs/trillion dollars GDP*	Emissions intensity ratio: *CO_2 emissions in millions of tons/Q-BTU*
California	**9.8**	**$71,626**	**2.8**	**48.8**
United States	17.2	$60,062	5.0	57.2
India	1.8	$2,104	13.4	66.8
Ohio	18.6	$55,347	5.6	59.3
Kentucky	26.7	$45,082	8.3	71.6
New York	8.7	$81,887	2.3	46.5
Pennsylvania	18.0	$58,204	5.1	60.6
Texas	25.8	$58,866	8.1	54.4
Colorado	16.2	$62,368	4.2	62.1

Sources: EIA for emissions figures, U.S. Census for population figures, and Bureau of Economic Analysis for state-level GDP figures. Figures are inclusive of bioenergy emissions. India data are from https://www.iea.org/countries/india.

Some significant observations emerge through considering these ratios for 2017. The first, most generally, is that there are three distinct ways in which any country, state or region can achieve a low figure for per capita emissions. The first is for the relevant economic area—the state, country or region—to operate at a low level of economic activity—i.e. at a low GDP level. For example, the Indian economy operates with a very low figure for emissions per capita of 1.8. But this is entirely because per capita income in India is also still extremely low, at about $2,100.

By contrast, per capita income in California as of 2017 was nearly $72,000. This is about 20 percent above the average figure for the U.S. overall, at $60,062. California's ranking in 2017 was 8th in per capita income among the 50 U.S. states.

With respect to this average income level, California could, hypothetically, reduce its per capita emissions figure by half as of 2030 by also cutting per capita GDP in half, to around $36,000, while maintaining its existing energy infrastructure fully intact. But this is obviously not a program for expanding well-being while also reducing emissions. To the contrary, the aim of a statewide clean energy project, again, is to achieve the 2030 emissions reduction level to less than 200 million tons of CO_2 while the state's economy grows at a reasonable rate and job opportunities expand.

We therefore need to focus on the two other factors that, as a matter of straightforward accounting, are responsible for California's current level of per capita emissions at present. These are:

1. ***Energy efficiency:*** The state operates at an energy efficiency level that is fully 44 percent below the national average, with an energy intensity ratio of 2.8 Q-BTUs per $1 trillion in GDP versus the U.S. national average of 5.0. Moreover, even this figure is a high-end estimate of California's energy intensity ratio. As we discuss further below, this is because it includes the energy generated in California that the state exports as electricity to other states.

   Even working for now with this high-end energy intensity ratio for California, the figure is still well below those of all but one other of the large U.S. states in our sample that includes Ohio, Pennsylvania, Texas and Colorado. Only New York is operating at a similarly high level of energy efficiency, with its energy intensity rate, at 2.3 Q-BTUs per $1 trillion of GDP, somewhat lower than that for California. New York's high efficiency level is due primarily to the intensive use in the state of both rail transit and apartment-based residential dwellings. By contrast, California has achieved its high efficiency level mostly through establishing and maintaining high efficiency standards for appliances and other equipment—including refrigerators, TVs, computers, dishwashers, air conditioners, and lightbulbs, along with buildings and vehicles. Further efficiency gains in California are still also achievable, as we discuss below.[74]

2. ***Clean-burning energy:*** California's emissions intensity ratio of 48.8 CO_2 emissions per Q-BTU of energy is about 15 percent below the U.S. average of 57.2. This figure, again, is comparable to that for New York state, but lower than those for the other large states in Table 2.7, Ohio, New York, Pennsylvania, Texas and Colorado. California's relatively low emissions intensity ratio results mainly from its relatively high level of solar and hydro production, along with, to a lesser extent, wind and geothermal power.

   In addition to these factors explaining California's level of per capita emissions at present, it is also important to recognize that the state has achieved some gains over time in what is termed "absolute decoupling"—i.e. achieving absolute reductions in emissions per capita levels over the recent past even while both average incomes per person and population in the state have grown. We can see the factors driving the absolute decoupling trend in Table 2.8. As the table shows, per capita emissions fell between 1999 and 2018 from 11.5 to 9.9 tons, while per capita GDP rose from $53,500 to $76,100. This amounts to an average reduction in emissions per capita of about 0.8 percent per year while average per capita incomes rose by 1.9 percent per year. This absolute decoupling resulted entirely through gains in energy efficiency in California over this 20-year period. The share of total energy consumption in the state supplied by renewable energy has remained basically unchanged over this 20-year period.

California's absolute decoupling trajectory is certainly a favorable development. At the same time, for the state to reduce emissions by 50 percent by 2030 will require a much more aggressive, absolute, decoupling trajectory. Specifically, emissions will need to fall by an average of 6.7 percent per year. We assume that this nearly 7 percent per year decline in emissions will occur while average per capita incomes in the state will continue rising, at a rate at least equal to the 1.9 percent rate that prevailed from 1999 – 2018.

To accomplish these two ends will therefore require a major mobilization to achieve both further gains in energy efficiency as well as a dramatic expansion in the state's clean renewable energy generating capacity. These are the issues to which we now turn.

TABLE 2.8
Determinants of California State Per Capita CO_2 Emissions, 1999 and 2018
Level of growth, energy intensity and energy mix

	Total CO_2 emissions from fossil fuel and bioenergy consumption *(in million metric tons)*	Population	Per capita emissions *(in metric tons)*	GDP *(in 2018 dollars)*	Per capita GDP *(in 2018 dollars)*	Energy consumption *(in T-BTUs)*	Energy intensity ratio *(Q-BTUs per trillion of 2018 dollars GDP)*	Emissions intensity ratio *(CO_2 emissions in millions of tons/Q-BTU)*
1999	382	33.1 million	11.5	$1.77 trillion	$53,500	7,802	4.4	49.0
2018	389	39.4 million	9.9	$3.00 trillion	$76,100	7,967	2.7	49.0

Source: See Table 2.7.

Achieving a 50 Percent Emissions Reduction by 2030

The 10-year clean energy investment initiative being proposed in this study is designed to achieve, again, two interrelated fundamental goals. The first is to bring total CO_2 emissions in California down by 50 percent, to approximately 193 million tons by 2030, from its 2018 level of 389 million tons. The second is to advance this climate stabilization program while the California economy grows at a healthy rate between now and 2030, so that existing jobs are protected, job opportunities expand, and average well-being rises throughout the state. In this section of the study, we describe the clean energy investment levels that will be needed to bring together these two goals.

To explore the prospects for achieving the 2030 emissions reduction goal within the context of a growing California economy, we must, unavoidably, work with some assumptions as to the state's real economic growth trajectory between 2021 - 2030. Thus, we assume that the California economy will grow in real (i.e. inflation-adjusted) terms between now and 2030 at an average rate of 2.5 percent per year. This figure is modestly below the 2.8 percent growth rate that California experienced over the recent 20-year period, i.e. 1999 – 2018.[75] If we assume that the California economy, and the U.S. economy more generally, do successfully recover from the recession tied to the COVID pandemic, it is reasonable to assume that that economy's growth trajectory will be able to roughly match that of 1999 – 2018.

In Table 2.9, we first report on California's real GDP as of 2018 (expressed in 2018 dollars) and the projected level in 2030, assuming the economy's average real growth rate is maintained at 2.5 percent through 2030. We see that, under this growth assumption, California's real GDP will be approximately $4.03 trillion in 2030, growing from the 2018 figure of $3.0 trillion. Assuming again a 2.5 percent average annual growth rate, the 2021 GDP will be $3.23 trillion. The midpoint over the 2021 – 2030 decade will be effectively January 1, 2026. California's real GDP will be at $3.61 trillion at that midpoint.

Within this framework, we can then project an energy and CO_2 emissions profile for California for 2030. We consider two distinct scenarios. For the first 2030 scenario, we assume that the state's energy infrastructure as of 2018 remains basically intact through 2030. We see the results of this scenario in Table 2.10. Specifically, in column 1 of Table 2.10, we show the actual breakdown of energy consumption and emissions as of 2018. In column 2,

TABLE 2.9
California State GDP Levels: *2018 Actual and Projections for 2021 – 2030*
Figures are in 2018 dollars

2018 GDP	$3.00 trillion
Projected average growth rate through 2030	2.5%
Projected 2021 GDP	$3.23 trillion
Projected 2030 GDP	$4.03 trillion
Projected midpoint GDP between 2021 – 2030 *(average of 2025 and 2026)*	$3.61 trillion

Source: BEA and authors' calculations.

TABLE 2.10
California State Energy Consumption and Emissions:
2018 Actuals and 2030 Alternative Projections

	1) 2018 actuals	2) 2030 with approximate Steady State Energy Infrastructure *(= categories grow at 2.5% average annual rate)*	3) 2030 through Clean Energy Investment Program
1) Real GDP *(in 2018 dollars)*	$3.00 trillion	$4.03 trillion	$4.03 trillion
2) Energy consumption *(T-BTU)*	7,967	10,715	8,060
3) Energy intensity ratio *(Q-BTUs / $1 trillion of GDP)*	2.7	2.7	2.0
4) Electricity imports from other U.S. states	866	1,165	866
Energy mix for in-state supply			
5) Non-renewables and bioenergy (T-BTUs—rows 6-10)	*6,239*	*8,390*	*3,009*
6) Petroleum	3,512	4,723	1,756
7) Natural gas	2,207	2,968	1,104
8) Coal	33	44	0
9) High-emissions bioenergy	297	399	149
10) Nuclear	190	256	0
11) Clean renewables (T-BTUs = row 2 – (row 4 + row 5))	*862*	*1,160*	*4,185*
12) Solar	382	514	2,094
13) Wind	128	172	837
14) Low-emissions bioenergy	0	0	628
15) Geothermal	108	145	313
16) Hydro	240	323	313
Emissions			
17) Total CO_2 emissions *(million metric tons)*	389	523	193
18) Emissions Intensity Ratio *(CO_2 emissions per in-state-consumed Q-BTUs = row 17 / (row 2/1000)*	48.8	48.8	23.9

Source: EIA, State Energy Data System (SEDS): https://www.eia.gov/state/seds/seds-data-complete.php?sid=US#Consumption.

we then present projected figures, assuming California's economy grows at an average annual rate of 2.5 percent through 2030 and the state's energy infrastructure remains basically intact. We term this the "steady state" energy infrastructure trajectory for California. In this scenario, the state's existing energy sources grow at exactly the state's overall 2.5 percent annual GDP growth rate.[76] In column 3, we then present figures through which California reduces emissions by 50 percent as of 2030 while maintaining an average annual GDP growth rate of 2.5 percent.

In the steady-state scenario, we assume that California's electricity imports increase at the same 2.5 percent average annual growth rate as the overall state economy. In the clean energy investment program, we assume that electricity imports remain at the same level as the actual 2018 figure of 866 T-BTUs. For simplicity, we also assume that the same proportions of energy supply that generates the state's imported electricity will reflect the proportions of energy supplied through in-state production. This is how, for example, we are able to show in column 3 that, under the clean energy investment scenario, the consumption of solar energy in California rises across-the-board from 382 T-BTUs in 2018 to 2,094 T-BTUs in 2030. The 2,094 figure includes electricity consumed within California that has been generated both within the state as well as imported from other states.

Within this overall set of assumptions, we then see in row 3, columns 1 and 2, that California's energy intensity ratio remains constant between 2018 and 2030, at 2.7 Q-BTUs per $1 trillion in GDP. The state's emissions intensity ratio also remains unchanged, at 48.8, as shown in row 18, columns 1 and 2. Given the steady-state assumption of a stable energy infrastructure between 2018 and 2030 while the economy grows at 2.5 percent per year, we then see the impact on statewide CO_2 emissions in row 17 of Table 2.10. That is, total CO_2 emissions increase from 389 to 523 million tons, an increase of 34 percent.

In column 3 of Table 2.10, we then show the impact on the energy mix and emissions levels of a clean energy program focused on bringing down CO_2 emissions to 193 million tons by 2030. The first component of this program is energy efficiency investments. As noted above, we assume energy efficiency investments will span across the building, transportation and industrial sectors of the California economy. At the same time, because, overall, California has already achieved a high efficiency level (i.e. a low energy intensity ratio) through investments undertake over the previous 2-3 decades, we assume that the opportunities for further efficiency gains as of 2030 will be relatively modest in comparison with other U.S. states—i.e. those states which presently operate at much lower efficiency levels. Specifically, therefore, we assume that, by 2030, California is capable of reducing its energy intensity ratio from the 2018 level of 2.7 to 2.0 Q-BTUs per $1 trillion of GDP for its in-state energy consumption level. This would be a 26 percent gain in overall energy efficiency in the state, achieved over the 2021 – 2030 decade. At this energy intensity level, California's energy infrastructure as of 2030 would remain among the most efficient, if not the most efficient, among U.S. states.

Working from this energy intensity level, we then consider the energy mix that will be necessary to allow for 8,060 T-BTUs of in-state energy consumption (including 866 T-BTUs of electricity imports from other states) while still maintaining emissions at no more than 193 million tons. As we have seen in Table 2.6, in order to bring overall CO_2 emissions in California down to 193 million tons by 2030, one viable path would be for the consumption of natural gas, oil, and high-emissions bioenergy to all fall by 50 percent, while coal is phased out altogether. As we see in column 3 of Table 2.10, this implies that oil is at 1,756 T-BTUs as of 2030, natural gas is at 1,104, and high-emissions bioenergy is at 149. We also assume in this scenario that nuclear energy in California is phased out by 2030. This is consistent with the current plans to shut down both reactors at Diablo Canyon by 2025, and with no plans in place to build new nuclear facilities in the state. In combination then, the non-renewable energy sources along with high-emissions bioenergy would provide California with a total of about 3,000 T-BTUs of energy in 2030 (rounded from 3,009 T-BTUs). We finally also assume that California will maintain its electricity imports at 866 T-BTUs.

This then entails that about 4,200 (rounded from 4,185) T-BTUs of energy will need to be provided by clean renewable sources, combined with 866 in imported electricity, in order for California's overall energy consumption plus its electricity imports to reach about 8,000 T-BTUs (rounded from 8,060) in 2030.

As of 2018, all clean renewable sources—solar, wind, low-emissions bioenergy, geothermal, and hydro—combined to supply 862 T-BTUs of energy to California. Effectively then, about 3,300 T-BTUs (rounded from 3,323) of *new supply* needs to be provided by wind, solar, hydro, and geothermal in order to bring California's total energy supply—to reach 8,000 T-BTUs in 2030, with emissions falling by 50 percent, from 389 to 193 million tons as of 2030.

As discussed above, we assume, as a high-end estimate, that the average lump-sum capital expenditures needed to expand clean renewable energy supply by 1 Q-BTU will be $200 billion. This then means that, to expand the clean renewable supply in California by 3,323 T-BTUs, will require $665 billion in new capital expenditures. Working, again, with the assumption that this is a 10-year investment program, this implies that the average level of expenditures per year to increase the supply of clean renewable energy by about 3,300 T-BTUs in 2030 will be $66.4 billion per year.

In Table 2.11, panels A-C, we summarize the main features of the 2030 clean energy investment program. These include the following:

- ***Efficiency.*** $ 9.3 billion per year in energy efficiency investments between 2021 – 2030, amounting to about 0.26 percent of California's projected midpoint GDP between 2021 – 2030. These efficiency investments will generate 2,655 T-BTUs of energy savings relative to the steady state growth path for California through 2030. This, again, is a 26 percent improvement in energy efficiency throughout California's economy relative to 2018 energy use levels.
- ***Clean renewables.*** $66.4 billion per year for investments in solar, wind, low-emissions bioenergy, geothermal, and small-scale hydro power. This will amount to about 1.8 percent of California's projected midpoint GDP between 2021 – 2030. It will generate an increase of 3,323 T-BTUs of clean renewable supply by 2030.
- ***Overall program and emissions reduction.*** Combining the efficiency and clean renewable investments, the program will therefore cost about $76 billion per year, or 2.1 percent of California's projected midpoint GDP between 2021 – 2030. Overall, this program will generate 5,978 T-BTUs in either energy savings relative to the steady state scenario or expanding the clean renewable energy supply. The end result of this program will be that overall CO_2 emissions in California in 2030 will be 193 million tons, 50 percent less than its level for 2018. California will have achieved this 50 percent emissions reduction while the state's economy also will have grown at an average rate of 2.5 percent per year through 2030.

TABLE 2.11
California Clean Energy Investment Program for 2021 – 2030

A) Energy Efficiency Investments

1. 2030 Energy intensity ratio	2.0 Q-BTUs per $1 trillion GDP *(26% improvement over 2.7 Q-BTU per $1 trillion GDP steady state figure)*
2. Total energy consumption	8,060 T-BTUs *(= 26% reduction relative to 10,715 T-BTU steady state figure)*
3. Energy saving relative to steady state	2,655 T-BTUs *(= 10,715 – 8,060 T-BTUs)*
4. Average investment costs per Q-BTU in efficiency gains	$35 billion per Q-BTU
5. Costs of energy savings	$92.9 billion *(= $35 billion x 2.655 Q-BTUs in savings)*
6. Average annual costs over 2021 – 2030	$9.3 billion *(= $92.9 billion/10)*
7. Average annual costs of efficiency gains as % of midpoint GDP	0.26% *(= $9.3 billion/$3.61 trillion)*

B) Clean Renewable Energy Investments

1. Total renewable supply necessary	4,185 T-BTUs *(= 8,060 T-BTUs – (3,009 T-BTUs supplied by non-renewables/biomass + 866 T-BTUs by imports))*
2. Expansion of renewable supply relative to 2018 level	3,323 T-BTUs *(= 4,185 – 862 T-BTUs)*
3. Average investment costs per Q-BTU for expanding renewable supply	$200 billion per Q-BTU
4. Costs of expanding renewable supply	$664.6 billion *(= 3.323 Q-BTUs x $200 billion)*
5. Average annual costs over 2021 – 2030	$66.4 billion *(= $664.6 billion/10)*
6. Average annual costs of renewable supply expansion as % of midpoint GDP	1.8% *(= $66.4 billion/$3.61 trillion)*

C) Overall Clean Energy Investments: Efficiency + Clean Renewables

1. Total clean energy investments	$757.7 billion *(= $92.9 billion for energy efficiency + $664.6 billion for renewables)*
2. Average annual investments	$75.8 billion *(= $757.7 billion/10)*
3. Average annual investments as share of midpoint GDP	2.1% *(= $75.8 billion/$3.61 trillion*
4. Total energy savings or clean renewable capacity expansion	5,978 T-BTUs *(= 2,655 T-BTUs in energy saving + 3,323 T-BTUs in clean renewable supply expansion)*

Sources: Tables 2.9 – 2.10.

Is $76 Billion per Year in Clean Energy Investments Realistic for California?

The short answer is "yes." To understand why, it is important to consider our estimate of California's annual clean energy investment needs within the broader context of the state's overall economic trajectory. As we have already noted above, this $76 billion annual investment figure represents about 2.1 percent of California's average GDP over 2021 – 2030, assuming that the state grows, on average, at about 2.5 percent per year over that 10-year period. In other words, our estimate of California's annual clean energy investment needs for bringing CO_2 emissions down in the state by 50 percent as of 2030 implies that nearly 98 percent of all economic activity in California can continue to be directly engaged in activities *other than* clean energy investments.

It is also critical to recognize that California's clean energy transition will deliver lower energy costs for all state consumers. This results because raising energy efficiency standards means that, by definition, consumers will spend less for a given amount of energy services, such as being able to travel 100 miles on a gallon of gasoline with a high-efficiency plug-in hybrid vehicle as opposed to 30 miles a gallon with a standard gasoline-powered car. Moreover, as we have seen, the costs of supplying energy through solar, wind, low-emissions bioenergy, geothermal and hydro power are now, on average, roughly equal to or lower than those for fossil fuels and nuclear energy.

At the same time, the magnitude of the challenge to scale up clean energy investments in California will be formidable. We can see this by considering recent clean energy investment levels in the state. According to the most recent available data, for 2019, clean energy investments in California included $5.2 billion in solar power, $1.5 billion in wind power, and $1.5 billion in energy efficiency, for a total of $7.1 billion.[77] Thus, even while California is currently highly advanced in both its level of energy efficiency and its supply of clean renewable sources relative to the rest of the United States, its investment levels still remain modest relative to the target of reaching an average of $76 billion per year in new investments. Annual clean energy investments in the state will need to increase roughly 10-fold in order to expand total clean renewable supply in the state to the point at which a zero emissions economy becomes achievable.

Leveraging Public Funds for Expanding Total Clean Energy Investments

What level of public funding will be needed to generate an average of roughly $76 billion per year in total new clean energy investments in California? To help answer that question, it will be useful to briefly review the experience with the federal Department of Energy Loan Guarantee Program, which was one part of the 2009 American Recovery and Reinvestment Act—i.e. the Obama stimulus program. This program helped underwrite about $14 billion in new clean energy investments between 2009 - 2013. Even after taking full account of the large-scale and widely publicized failure of the Northern California solar company Solyndra, the default rate and corresponding financial obligations stemming from this program were modest. According to our estimates discussed in Pollin et al. (2014), total losses covered by the government's loan guarantees amounted to about $300 million, i.e. equal to about 2.1 percent of the $14 billion in new loans for clean energy investments that the government guaranteed. This means that the leverage rate for the loan guarantee program was about $47 in additional clean energy investments underwritten by $1 of federal support.

If California were able utilize its full set of existing policy tools, including the set of financial subsidies, tax incentives, and regulations described above to leverage at the same 47/1 rate as the 2009 federal Energy Loan Guarantee program, that would imply that the state would need to spend about only about $1.6 billion per year to deliver $76 billion in total clean energy investments in California. Such public spending could take the form of direct public investments, loan guarantees and other forms of credit subsidies, or tax benefits. The remaining roughly $74 billion would be coming from private investors. The $1.6 billion in public funding would amount to about 0.8 percent of the state's total budget of roughly $202 billion for fiscal year 2020 – 2021.[78]

However, for various reasons, this leverage ratio is almost certainly too high. One factor is that, to date, California's existing clean energy programs that we discussed above have been operating at a relatively small scale, including the renewable energy and energy efficiency grant, loan, loan guarantee and rebate programs. The existing administrative capacity operating these programs at present is therefore not likely to be sufficient to operate them at a scale equivalent to the 2009 federal program. On the other hand, the framework does exist to bring these programs to scale, to match the challenge of building a clean energy infrastructure and achieve net zero emissions by 2045.

Considering these and related factors, it is certainly difficult to establish firmly what we would expect the average leveraging ratio to be for public funds to finance the state's overall public plus private clean energy investment project. This would include funding from the federal government as well as California's state and municipal budgets. A reasonable low-end assumption would be that California is capable of leveraging $9 in private clean energy investments for every $1 provided in public funds, assuming the state's clean energy incentive and regulatory policies are operating effectively.

For 2021 – 2022, the first years of the investment program, overall investment spending would be around $68 billion (with $76 billion/year being the midpoint amount over 2021 – 2030). For 2021, this would imply that the state would need to contribute about $6.8 billion on clean energy projects, an amount that would then be matched by $61 billion in private sector investments. The $6.8 billion in public investments would amount to about 3.4 percent of California's 2020-2021 state budget.

3. CLEAN ENERGY INVESTMENTS AND JOB CREATION

In Tables 3.1 and 3.2, we present our estimates as to the job creation effects of investing in energy efficiency in California. Tables 3.3 and 3.4 then present comparable estimates for investments in clean renewable energy in the state. In both cases, we report two sets of figures—first, job creation per $1 million in expenditure, then, job creation given the average annual level of investment spending we have proposed for between 2021 – 2030, i.e. $9.3 billion in energy efficiency and $66.4 billion in clean renewable energy.

Before reviewing the actual data on job creation, we need to briefly consider some methodological points. The first is describe the three channels through which jobs will be created as a result of any expansion of spending in any area of spending in the economy, including clean energy investments. These are direct, indirect and induced jobs. We then need to consider how to measure job creation over time—that is, how best to understand the extent of job creation relative to the size of California's overall labor market at any given point in time.

Direct, Indirect and Induced Job Creation

To illustrate the three channels through which jobs are created, through clean energy investments or any other category of spending in the economy, consider the impacts of investments in the respective areas of home retrofitting or installing solar panels:

1. *Direct effects*—the jobs created, for example, by retrofitting buildings to make them more energy efficient or installing solar panels;
2. *Indirect effects*—the jobs associated with industries that supply intermediate goods for the building retrofits or solar panels, such as glass, steel, and transportation. In other words, indirect effects measure job creation along the clean energy investment supply chain;
3. *Induced effects*—the expansion of employment that results when people who are paid in the construction or steel industries spend the money they have earned on other products in the economy. These are the multiplier effects within a standard macroeconomic model.

In Tables 3.1 – 3.4, we first report figures for direct and indirect jobs, along with the totals for these main job categories. We then include the figures on induced jobs and show total job creation when induced jobs are added to that total.

After presenting these results on overall job creation through clean energy investments, we then review later in this section data on quality indicators for the newly created jobs, including figures on compensation levels, health insurance and pension coverage, and unionization rates in the various clean energy sectors. We next provide figures on the demographic profile of the existing workforce in the clean energy sectors, including the levels of educational attainment as well as the proportion of jobs in each sector held by people of color and woman. We also show the breakdown of overall employment creation between private- and public-sector jobs.

Time Dimension in Measuring Job Creation: Jobs-per-Year vs. Job Years

Any type of spending activity creates employment over a given amount of time. To understand the impact on jobs of a given spending activity, one must therefore incorporate a time dimension into the measurement of employment creation. For example, a program that creates 100 jobs that last for only one year needs to be distinguished from another program that creates 100 jobs that continue for 10 years each. It is important to keep this time dimension in mind in assessing the impact on job creation of any clean energy investment activity. The same will be true when, in Section 4, we assess the employment impacts in California of investments in infrastructure, manufacturing, land restoration and agriculture.

There are two straightforward ways in which one can express the time dimensions in these job creation estimates. One is through measuring job years. This measures cumulative job creation over the total number of years that jobs have been created. Thus, an activity that generates 100 jobs for 1 year would create 100 job years. By contrast, the activity that produces 100 jobs for 10 years would generate 1,000 job years.

The other way to report the same figures would be in terms of jobs-per-year. Through this measure, we are able to provide detail on the year-to-year breakdown of the overall level of job creation. Thus, with the 10-year investment programs in our example, we could express the effects of these investment programs as creating 100 jobs per year over 10 years.

This jobs-per-year measure is most appropriate for the purposes of this study. The reason that jobs-per-year is a better metric than job years is because the impact of any new investment, whether on clean energy or anything else, will be felt within a given set of labor market conditions at a point in time. Reporting cumulative job creation figures over multiple years prevents us from scaling the impact of investments on job markets at a given point in time, e.g. within a given year. As we will see, we estimate that the combined investment programs that we develop in this section and Section 4 will create about 1 million jobs within California per year between 2021 – 2030. We are able to scale this job creation estimate to the size of the California labor market. Thus, as of 2019, California's overall labor force included 19.4 million people. Adding 1 million jobs to this labor force would therefore increase 5.4 percent more jobs into the overall California labor force.

If we then assume that the clean energy investments continue for 10 years at the same scale, that would mean 1 million jobs per year would be created through these investments. This would continue to maintain overall job opportunities in the California economy at a level that is 5.4 percent greater than it would have been without the injection of the combined investment programs (after allowing also for the natural growth of the California labor market). However, if we measure this employment impact in terms of cumulative job creation, the 10 years' worth of investment would, by this measure, amount to over 10 million jobs. It is misleading to compare that 10 million cumulative job creation figure to the total size of the California labor market, amounting to 20 million people as of 2019. If we did want to scale the cumulative job creation figure of 10 million over 2021 – 2030, the appropriate comparison would be with the cumulative job figures for the whole California economy over 10 years. But this cumulative jobs figure is not a clear or useful way to understand labor market conditions at any given point in time.

Job Creation through Energy Efficiency Investments

In Table 3.1, we show the job creation figures per $1 million in spending for our five categories of efficiency investments: building retrofits; industrial efficiency, including combined heat and power (CHP) technology; electrical grid upgrades; public transportation expansion and upgrades; and expanding the high efficiency auto fleet, including electric vehicles. As Table 3.1 shows, direct plus indirect job creation per $1 million in spending ranges between 0.7 jobs for expanding the high efficiency automobile fleet to 13.6 jobs for public transportation expansion and upgrades.

In Table 3.2, we show the level of job creation through spending an average of $9.3 billion per year on these efficiency projects in California between 2021 – 2030. We have assumed that the overall level of funding is channeled into the various energy efficiency areas as follows: 40 percent for building retrofits; 20 percent for industrial efficiency and CHP; 15 percent respectively for electrical upgrades and public transportation expansion/upgrades; and 10 percent for expanding the fleet of high-efficiency automobiles. Working with this assumption, the overall result of $9.3 billion per year in efficiency investments in California will be the creation of 40,199 direct jobs and 13,222 indirect jobs, for a total of 53,421 direct plus indirect jobs created through this energy efficiency investment program. Including induced jobs adds another 16,929 jobs to the total figure. This brings the total job creation figure for efficiency investments, including induced jobs to 70,350 jobs.

TABLE 3.1
Job Creation in California through Energy Efficiency Investments
Job creation per $1 million in efficiency investments

	Direct jobs	Indirect jobs	Direct + indirect jobs	Induced jobs	Direct, indirect + induced jobs
Building retrofits	3.7	2.0	5.7	2.0	7.7
Industrial efficiency, including combined heat and power	2.9	1.1	4.0	1.7	5.7
Electrical grid upgrades	2.8	0.8	3.6	1.5	5.1
Public transportation expansion/upgrades, including rail	12.0	1.6	13.6	2.8	16.4
Expanding high efficiency automobile fleet	0.3	0.4	0.7	0.3	1.0

Sources: Authors' calculations using IMPLAN 3.1. See Appendix 1.

TABLE 3.2
Annual Job Creation in California through Energy Efficiency Investments, 2021 – 2030
Job creation through average annual spending of $9.3 billion in efficiency investments

ASSUMPTIONS FOR ENERGY EFFICIENCY INVESTMENTS
- 40% on building retrofits
- 20% on combined heat and power (CHP) and other industrial efficiency measures
- 15% on electrical grid upgrades
- 15% on public transportation expansion/upgrades
- 10% on expanding high-efficiency auto fleet

	Spending amounts	Direct jobs	Indirect jobs	Direct + indirect jobs	Induced jobs	Direct, indirect + induced jobs
Building retrofits	$3.7 billion	13,690	7,400	21,090	7,400	28,490
Industrial efficiency, including combined heat and power	$1.9 billion	5,510	2,090	7,600	3,230	10,830
Electrical grid upgrades	$1.4 billion	3,920	1,120	5,040	2,100	7,140
Public transportation expansion/upgrades, including rail	$1.4 billion	16,800	2,240	19,040	3,920	22,960
Expanding high efficiency automobile fleet	$930 million	279	372	651	279	930
TOTALS	**$9.3 billion**	**40,199**	**13,222**	**53,421**	**16,929**	**70,350**

Sources: See Tables 2.11 and 3.1.

Job Creation through Clean Renewable Energy Investments

In Table 3.3, we show the job creation figures for our five clean renewable energy categories—solar, onshore wind, low-emissions bioenergy, geothermal, and small-scale hydro. As we see, the extent of direct plus indirect jobs ranges from 2.7 direct plus indirect jobs per $1 million in expenditure for onshore wind projects to 7.4 direct and indirect jobs for investing $1 million in small-scale hydro. Adding induced jobs brings the range to 3.9 jobs for wind, 4.4 for solar and low-emissions bioenergy, 8.9 for geothermal and 10.3 for small-scale hydro.

Based on these proportions, we see in Table 3.4 the levels of job creation in California generated by spending an average of $66.4 billion per year between 2021 – 2030 in these areas of clean renewable energy. As we see in Table 3.4, we have divided total spending levels as follows: 50 percent for solar, 20 percent for wind, 15 percent for low-emissions bioenergy, and 7.5 percent respectively for geothermal and small-scale hydro.

Following from these budgetary assumptions, we see in Table 3.4 that total direct plus indirect job creation generated in California by this large-scale expansion in the state's clean renewable energy supply will be 241,240 jobs. If we include induced jobs, then the total rises to 347,560 jobs.

Table 3.5 brings together our job estimates for both energy efficiency and clean renewable energy through spending about $75.8 billion per year on this project in California

TABLE 3.3
Job Creation in California through Clean Renewable Energy Investments:
Job creation per $1 million in clean renewable investments

	Direct jobs	Indirect jobs	Direct + indirect jobs	Induced jobs	Direct, indirect + induced jobs
Solar	2.1	0.9	3.0	1.4	4.4
Onshore wind	1.8	0.9	2.7	1.2	3.9
Low-emissions bioenergy	3.0	0.8	3.8	1.6	4.4
Geothermal	4.6	1.6	6.2	2.7	8.9
Small-scale hydro	5.9	1.5	7.4	2.9	10.3

Sources: Authors' calculations using IMPLAN 3.1. See Appendix 1.

TABLE 3.4
Annual Job Creation in California through Clean Renewable Energy Investments, 2021 – 2030
Job creation through average annual spending of $66.4 billion in clean renewable investments

ASSUMPTIONS FOR CLEAN RENEWABLE INVESTMENTS *(percentages are rounded)*
- 50% on solar PV energy
- 20% on onshore wind energy
- 15% on low-emissions bioenergy
- 7.5% on geothermal energy
- 7.5% on small-scale hydro

	Spending amounts	Direct jobs	Indirect jobs	Direct + indirect jobs	Induced jobs	Direct, indirect + induced jobs
Solar	$33.2 billion	69,720	29,880	99,600	46,480	146,080
Onshore wind	$13.2 billion	23,760	11,880	35,640	15,840	51,480
Low-emissions bioenergy	$10.0 billion	30,000	8,000	38,000	16,000	54,000
Geothermal	$5.0 billion	23,000	8,000	31,000	13,500	44,500
Small-scale hydro	$5.0 billion	29,500	7,500	37,000	14,500	51,500
TOTALS	**$66.4 billion**	**175,980**	**65,260**	**241,240**	**106,320**	**347,560**

Sources: See Tables 2.11 and 3.3.

between 2021 – 2030. We show total figures for direct plus indirect jobs only, then we also show the total when induced jobs are included.

We see in row 13 of Table 3.5 that total average direct and indirect job creation for 2021 – 2030 is 294,661 jobs and 417,910 jobs when we add induced jobs to the total. As we see in row 14, this level of job creation amounts to between 1.5 and 2.2 percent of the total workforce in California as of 2019, the range depending on whether we include induced jobs in the total.

TABLE 3.5
Annual Job Creation in California through Combined Clean Energy Investment Program
Average annual figures for 2021 – 2030

Industry	Number of direct and indirect jobs created	Number of direct, indirect and induced jobs created
$9.3 billion in energy efficiency		
1) Building retrofits	21,090	28,490
2) Industrial efficiency, including combined heat and power	7,600	10,830
3) Electrical grid upgrades	5,040	7,140
4) Public transportation expansion/upgrades, including rail	19,040	22,960
5) Expanding high efficiency automobile fleet	651	930
6) Total energy efficiency job creation	*53,421*	*70,350*
$66.4 billion in clean renewables		
7) Solar	99,600	146,080
8) Onshore wind	35,640	51,480
9) Low emissions bioenergy	38,000	54,000
10) Geothermal	31,000	44,500
11) Small-scale hydro	37,000	51,500
12) Total job creation from clean renewables	*241,240*	*347,560*
13) TOTALS *(= rows 6+12)*	**294,661**	**417,910**
14) TOTAL AS SHARE OF 2019 CALIFORNIA LABOR FORCE *(Labor force at 19.4 million)*	**1.5%**	**2.2%**

Sources: Tables 3.2 and 3.4, U.S. Department of Labor.

Indicators of Job Quality

In Table 3.6, we provide some basic measures of job quality for the jobs that will be generated through clean energy investments in California. These basic indicators include: 1) average total compensation (including wages plus benefits); 2) the percentage of workers receiving health insurance coverage; 3) the percentage having retirement plans through their employers; and 4) the percentage that are union members. All of the figures we report here describe *existing conditions* for workers currently employed in the various energy efficiency and clean renewable sectors. Of course, as we consider below, these currently existing conditions are subject to change, especially with investments in these activities significantly expanding job opportunities.

We focus here on the *direct* jobs that will be created through clean energy investments in California. By definition, the direct jobs are the ones that are fully integrated within the

TABLE 3.6
Indicators of Job Quality in California Clean Energy Industries: Direct Jobs Only

	Energy Efficiency Investments				
	1. Building retrofits *(13,690 workers)*	**2. Industrial efficiency** *(5,510 workers)*	**3. Grid upgrades** *(3,920 workers)*	**4. Mass transit** *(16,800 workers)*	**5. High-efficiency autos** *(279 workers)*
Average total compensation	$73,700	$91,900	$83,300	$37,600	$88,700
Health insurance coverage, percentage	37.2%	49.5%	47.8%	34.4%	67.9%
Retirement plans, percentage	24.4%	32.7%	28.1%	20.1%	51.1%
Union membership, percentage	18.7%	7.5%	15.7%	17.2%	7.2%

	Clean Renewable Energy Investments				
	6. Solar *(69,720 workers)*	**7. Onshore wind** *(23,760 workers)*	**8. Low-emissions bioenergy** *(30,000 workers)*	**9. Geothermal** *(23,000 workers)*	**10. Small-scale hydro** *(29,500 workers)*
Average total compensation	$96,500	$94,000	$83,500	$92,600	$79,700
Health insurance coverage, percentage	46.2%	46.8%	37.4%	43.4%	40.0%
Retirement plans, percentage	31.6%	32.0%	24.4%	29.4%	26.5%
Union membership, percentage	13.1%	17.7%	17.2%	14.9%	18.5%

Sources: See Appendix 2.

state's clean energy investment activities. As such, the characteristics associated with these directly created jobs will most fully reflect the specific range of opportunities that will result through building a clean energy economy in California. The jobs created through the indirect and induced channels will be more diffuse in their characteristics. Indeed, the characteristics of the induced jobs created will simply reflect the overall characteristics of California's present-day workforce.

Starting with compensation figures, we see that the averages range widely, between about $38,000 for workers in the mass transit sector to about $97,000 in the solar sector.

The range for workers carrying employer-based health insurance coverage is also wide, from 34 percent of workers in the mass transit sector to 68 percent in high-efficiency autos. Including all of the areas of employment, less than half of all workers are provided with employer-sponsored health insurance.

The level of coverage with respect to private retirement plans is lower than that for health insurance. The low-end figure is with mass transit, in which about 20 percent of workers have retirement plans. The highest figure is with the high efficiency autos, at about

51 percent. Across-the-board, however, no more than about one-third of the workers in all the clean energy sectors have employer-sponsored retirement plans. Only a minority of workers in the various clean energy sectors are represented by unions. The low figures are in industrial efficiency and high-efficiency autos, in which less than 10 percent of workers are union members. With the other 8 clean energy sectors, union membership ranges from 13 – 19 percent of the respective workforces. Across-the-board, the level of union membership is above the U.S. private sector average, which was 6.2 percent as of 2019. With 8 of the 10 sectors included, the union membership rate is substantially above the private sector average.

This relatively high unionization rate for clean energy sector workers in California can therefore serve as a foundation for raising job quality standards broadly, as the state's clean energy transformation proceeds. As one feature of the overall clean energy transition project for California, the state should therefore require neutrality with respect to union organizing campaigns in any clean energy investment projects that are either state-owned or partially financed by the state.

More generally, these indicators of job quality will be valuable for purposes of comparison when we consider the jobs that will be lost in California because of the contraction of fossil fuel production and consumption in the state through 2030. What is especially important to highlight now—in anticipating our discussion in Section 6 on workers in California's fossil fuel related industries—is that, for the most part, the compensation figures in clean energy industries are lower than those for fossil fuel industry-based workers. As such, one of the aims of a clean energy investment agenda for California should be to raise wages, benefits and working conditions in the newly-created clean energy investment industries.

Educational Credentials and Race/Gender Composition for Clean Energy Jobs

In Table 3.7, we present data on the educational credentials for workers in jobs that are directly tied to clean energy investment activities in California as well as the race and gender composition of these workers.

Educational Credentials

With respect to educational credentials, we categorize all workers who would be employed directly by clean energy investments in California according to three educational credential groupings: 1) shares with high school degrees or less; 2) shares with some college or Associate degrees; and 3) shares with Bachelor's degree or higher.

As Table 3.7 shows, the level of educational credentials are generally similar across industries. Thus, in 9 of the 10 industries listed, more than one-third of the workers have high school degrees or less. The one exception is industrial efficiency, in which only 19 percent of the workers have high school degrees or less, while 62 percent have Bachelor's degrees or higher. Otherwise, with the other 9 industries, the share of workers with Bachelor's degrees or higher ranges between 14 – 34 percent.

If we consider this range of clean energy investment areas as a whole, a significant share of the newly generated jobs in the various clean energy sectors will be open to workers with a high school degree or less, as well as those with mid-level credentials, such as Associate

TABLE 3.7
Educational Credentials and Race/Gender Composition of Workers in California Clean Energy Industries: Direct Jobs Only

	Energy Efficiency Investments				
	1. Building retrofits *(13,690 workers)*	2. Industrial efficiency *(5,510 workers)*	3. Grid upgrades *(3,920 workers)*	4. Mass transit *(16,800 workers)*	5. High-efficiency autos *(279 workers)*
Share with high school degree or less	60.8%	18.7%	60.9%	42.6%	35.7%
Share with some college or Associate degree	25.0%	19.7%	24.4%	34.2%	30.5%
Share with Bachelor's degree or higher	14.3%	61.6%	14.7%	23.3%	33.8%
Racial and gender composition of workforce					
Pct. Black, Indigenous and People of Color	62.0%	44.6%	63.9%	64.5%	69.7%
Pct. female	8.7%	34.6%	9.0%	19.8%	22.4%

	Clean Renewable Energy Investments				
	6. Solar *(69,720 workers)*	7. Onshore wind *(23,760 workers)*	8. Low-emissions bioenergy *(30,000 workers)*	9. Geothermal *(23,000 workers)*	10. Small-scale hydro *(29,500 workers)*
Share with high school degree or less	46.7%	51.4%	61.2%	51.0%	57.1%
Share with some college or Associate degree	21.6%	25.2%	24.0%	22.9%	24.5%
Share with Bachelor's degree or higher	31.7%	23.4%	14.8%	26.1%	18.4%
Racial and gender composition of workforce					
Pct. Black, Indigenous and People of Color	61.0%	60.1%	63.2%	60.5%	60.5%
Pct. female	19.0%	13.6%	10.6%	15.6%	10.0%

Sources: See Appendix 2.

degrees. This means that there will be a substantial expansion of employment opportunities for workers that more generally face difficulties finding good-quality jobs.

Race and Gender Composition

In 9 of the 10 industries, the jobs created by clean energy investments are held predominantly by men who are Black, Indigenous and People of Color (BIPOC). For these 9 industries, the share of jobs held by BIPOC ranges narrowly between 60 – 70 percent, compared to 63 percent in the workforce statewide. The one exception in which the share of BIPOC is below half is industrial efficiency, in which the share is 45 percent. Overall, the growth of California's clean energy economy will continue to create increasing opportunities on a large scale for the state's BIPOC population.

By contrast, the representation of women in the clean energy sectors of California's economy is low. The high figure is in industrial efficiency, in which 35 percent of workers—still only a bit more than one-third of the total—are female. The female share of the workforce in the eight other clean energy industries ranges between only 9 – 22 percent, even while women make up 45 percent of California's workforce.

Despite this disparity in the current gender composition of the workforce in California, the large-scale expansion of the state's clean energy economy will provide a major opportunity to expand job opportunities for women. An initiative focused on equal opportunity in the growing clean energy investment areas could be readily integrated into the broader investment project.

Prevalent Job Types with Clean Energy Investments

To provide a more concrete picture of the jobs that will be created in California through investments in energy efficiency and clean renewable energy, in Tables 3.8-3.13, we report on the prevalent job types associated with four of the major efficiency and renewable energy activities. Table 3.8 provides data for investments in building retrofits, our largest category of energy efficiency investments. Table 3.9 focuses on industrial efficiency, including combined heat and power (CHP). Table 3.10 shows results for electrical grid upgrades and Table 3.11 for public transportation. Table 3.12 then reports these same figures for the largest category of clean renewable energy investments, solar energy. Table 3.13 shows the employment profile for four other areas of clean renewable energy investments, i.e. wind, low-emissions bioenergy, geothermal and hydro power. In all cases, we report on the job categories in which we estimate that 5 percent or more of the new jobs will be created through clean energy investments.

It is difficult to summarize the detailed data on job categories presented in these tables. But it will be useful to underscore a few key patterns. First, a high proportion of jobs will be created in the construction industry through all of the clean energy investment activities. Of course, this is true with the 66 percent of jobs created through building retrofit investments. But we also find that 47 percent of jobs in the solar sector will be in construction, along with 55 percent of jobs in other areas of renewable energy investments, along with 17

TABLE 3.8
Building Retrofits: Prevalent Job Types in California Industry
(Job categories with 5 percent or more employment)

Job category	Percentage of direct jobs	Representative occupations
Construction	66.0%	Pipefitters; painters; laborers
Management	16.2%	General managers; chief executives; construction managers

Source: See Appendix 2.

TABLE 3.9
Industrial Efficiency, including Combined Heat and Power: Prevalent Job Types in California Industry
(Job categories with 5 percent or more employment)

Job category	Percentage of direct jobs	Representative occupations
Business operation specialists	25.2%	Logisticians; purchasing agents; human resource workers
Management	21.9%	Operations managers; marketing managers; chief executives
Architecture and engineering	9.7%	Engineering technicians; mechanical engineers; civil engineers
Construction	9.6%	Electricians; carpenters; laborers
Office and administrative support	7.0%	Auditing clerks; general office clerks; administrative assistants
Computer and mathematical science	5.3%	Computer support specialists; computer programmers; computer system analysts

Source: See Appendix 2.

TABLE 3.10
Electrical Grid Upgrades: Prevalent Job Types in California Industry
(Job categories with 5 percent or more employment)

Job category	Percentage of direct jobs	Representative occupations
Construction	28.8%	Pipelayers; first-line supervisors; laborers
Production	27.3%	Electrical assemblers; inspectors; welding workers
Installation and maintenance	15.2%	Truck mechanics; general maintenance workers; industrial machinery mechanics
Management	10.1%	General managers; sales managers; chief executives
Sales	5.2%	Real estate brokers; manufacturing sales representatives; wholesale sales representatives

Source: See Appendix 2.

percent in public transportation and 10 percent in industrial efficiency. The specific types of construction industry jobs will vary widely, given the different types of construction projects that will be pursued. Overall, clean energy investments will create large numbers of jobs for electricians, pipefitters, carpenters, painters, and laborers.

Jobs in management also constitute a large share of overall job creation across all categories, accounting for between 10 – 22 percent in all industries other than public transportation, and with 8 percent in public transportation. Beyond this, what emerges generally from Tables 3.8-3.13 is that clean energy investments will generate a wide range of new employment opportunities, including in manufacturing. This broad range of new opportunities will be available for workers in California that will have been displaced by the contraction of the state's fossil fuel industry activities, as well as more broadly throughout the state's labor force.

TABLE 3.11
Public Transportation: Prevalent Job Types in California Industry
(Job categories with 5 percent or more employment)

Job category	Percentage of direct jobs	Representative occupations
Transportation	60.3%	Railroad conductors; first-line supervisors; bus drivers
Construction	17.4%	Electricians; painters; carpenters
Management	7.9%	Transportation managers; general managers; construction managers

Source: See Appendix 2.

TABLE 3.12
Solar: Prevalent Job Types in California Industry
(Job categories with 5 percent or more employment)

Job category	Percentage of direct jobs	Representative occupations
Construction	46.6%	Pipelayers; first-line supervisors; laborers
Management	16.9%	Financial managers; marketing managers; chief executives
Life, physical and social science	9.0%	Biological technicians; biological scientists; physical science technicians
Office and administrative support	6.0%	Customer service representatives; bookkeeping clerks; secretaries

Source: See Appendix 2.

TABLE 3.13
Wind/Low-Emissions Bioenergy/Geothermal/ Small-Scale Hydro: Prevalent Job Types in California Industry
(Job categories with 5 percent or more employment)

Job category	Percentage of direct jobs	Representative occupations
Construction	55.3%	Plumbers; painters; carpenters
Management	16.4%	Sales managers; operations managers; construction managers
Office and administrative support	5.4%	First-line supervisors; accounting clerks; administrative assistants

Source: See Appendix 2.

Public Sector Job Creation

As noted above, the data we have provided thus far on job creation through clean energy investments includes figures on both private and public sector employment. We now present more focused figures on the public sector jobs that will be generated through the clean energy program we have developed here. In the next section of the study, we will also break out the public sector's share of job created generated by investments in infrastructure, manufacturing development, land restoration and agriculture. We focus on *direct job* creation, as we have with our results on job quality, educational credentials and the racial and gender composition of the clean energy workforce.

As we see in Table 3.14, of the approximately 216,000 total direct jobs that will be created on average in California through the energy efficiency and clean renewable energy investment program, about 8,500 of the jobs will be in the public sector. These public sector jobs will therefore account for a bit less than 4 percent of all the jobs created through California's clean energy investment program.

With energy efficiency investments specifically, the share of public sector job creation is higher, at 6.2 percent of the total level of about 40,200 jobs created. The main reason that public sector job creation is higher in energy efficiency is that the efficiency investments include spending on expanding California's public transportation system, including both bus and rail transit systems in the state. Thus, nearly 40 percent of the direct public sector jobs generated through energy efficiency investments will be in the area of mass transportation. This will include jobs for bus drivers, transportation attendants and transportation inspectors.

TABLE 3.14
Public Sector Jobs Created through Clean Energy Investments: Direct Jobs Only
Average annual figures for 2021 – 2030

	Public sector direct jobs created	Total direct jobs created	Public sector share of total direct jobs created
Energy efficiency	2,492	40,199	6.2%
Clean renewables	5,982	175,980	3.4%
TOTAL	8,475	216,179	3.9%

Source: See Appendix 2.

Requirements for Generating Good-Quality Jobs

What is clear from the evidence we have reviewed is that: 1) large-scale job creation will certainly result in California through clean energy investments in the range of $76 billion per year, or 2.1 percent of average state GDP over 2021 – 2030; but that 2) these jobs will not necessarily be good jobs. As we have seen, average compensation varies fairly widely in the various clean energy sectors, from roughly $38,000 for workers in the mass transit sector to about $97,000 in the solar energy sector. The overall average for all clean energy sectors, at $86,000 is well above the average compensation level for U.S. workers overall, which is about $65,000. But they are in line with clean energy sectors nationally, in which average compensation is at about $83,000.[79] At the same time, as we will review below, the compensation figures in the current clean energy sectors remain well below those for workers in California's fossil fuel-based industries, in which average compensation is about $130,000. The clean energy economy should be able to provide job quality standards that are comparable to those in the state's current fossil fuel-based industries.

As we have seen, the level of union membership in California's clean energy sectors is well above the economy-wide national average for private sector workers. The expansion of California's clean energy economy creates a major opportunity to build on these existing above-average conditions. This is especially the case, since an effective union presence and strong labor standards will be critical in determining whether the jobs created through clean energy investments in California will be good jobs.

This becomes clear in comparing the respective experiences in the utility-scale solar installation sectors in California with that of Arizona. We have seen that the California utility-scale solar sector operates within a framework of relatively strong unions and, as a result, relatively effective labor laws. Both the union presence and labor laws are relatively weak in Arizona. A 2014 study by University of Utah economist Peter Phillips describes how these distinct institutional settings play out within the respective state-level utility-scale solar installation labor markets.[80] Phillips writes:

> Jobs building utility-scale solar electricity generating facilities are not inevitably good jobs paying decent wages and benefits and providing career training within construction. Under some labor market conditions, many solar farm jobs can be bad jobs paying low wages, with limited benefits or none at all, working for temporary labor agencies with no prospect for training, job rotation, or career development.
>
> In California, this low-road approach to utility-scale solar construction is uncommon for several reasons. First, when any federal funds are involved, the project is governed by federal prevailing wage regulations mandating that, for each occupation on the project, the wage in the local area that prevails for that occupation, based on Davis-Bacon surveys, must be paid.
>
> All states are covered by the federal Davis-Bacon Act, but in some states, such as Arizona, for some construction crafts, nonunion rates prevail in many counties, meaning that prevailing wage jobs can be paid low wages with limited benefits. In California, union strength has meant that in most cases on prevailing wage solar projects, workers will get paid good wages with good benefits. State right-to-work laws play a role in determining union strength. By undercutting union strength, Arizona's right-to-work law plays a role in determining the low-road practices found on some solar farm construction in that state. In contrast, California's resistance to right-to-work regulations reinforces federal Davis-Bacon wage mandates, thereby helping lead California's solar farm work along a high-road approach to construction (2014, p. 45).

In addition to the support for good clean energy industry jobs provided by unions and labor standards, it will also be critical that workers have access to high-quality training programs that will enable them to enter their new jobs with the skills they need to succeed. Without high-quality and accessible training opportunities, the likelihood increases that labor force quality standards will become compromised. Sam Appel of the Blue/Green Alliance of California has documented this problem in California's energy efficiency sector, writing as follows:

> Poor installation of energy efficiency (EE) measures is a pervasive problem in California, and nationally. Industry, government, and academic studies show that poor installation of EE measures often results in energy savings losses of up to 50 percent compared to projected savings goals. The California Energy Commission, for instance, reports that up to 85 percent of replacement HVAC systems are installed or designed incorrectly, resulting in substantial unrealized energy savings. Ratepayer-funded studies also find that lighting control systems installed by workers without lighting-control specific certification result in high rates of installations errors leading to lost savings.
>
> Poor workforce standards and insufficient training pipelines are the root cause of pervasive installation errors. California's Investor Owned Utilities (IOUs) confirm that workers installing ratepayer-subsidized HVAC systems rarely have the technical knowledge, skills, or abilities necessary to implement industry standards for HVAC quality installation and, as a result, there are "high failure rates for job performance on routine tasks." To paint a picture, less than half of HVAC technicians in California are even aware of basic national standards for work quality, according to studies conducted by California agencies.
>
> Without explicit workforce standard policies on the books … California EE program administrators have relied on code compliance, contractor licensing requirements, and safety and building permit requirements to ensure proper installation. These minimal, insufficient requirements lead to the proliferation of a low skill, low pay workforce.

The problems described by Appel with poor workforce standards and insufficient training pipelines in the California energy efficiency sector are also being reported by employers in the sector from their distinct perspectives. In Tables 3.15 and 3.16 below, we report on the results of a 2018 survey conducted by the U.S. Labor Department, in which, among other questions, employers in clean energy sectors were asked whether they faced difficulties in hiring new workers. We show the survey results in the three largest areas of clean energy employment to date in the U.S.—i.e. energy efficiency, in which 2018 employment was at 2.3 million; solar electricity, with 242,343 people employed; and wind electricity, with 111,166 people employed. We show the results for each clean energy sector broken out according to sub-sectors, including construction; professional/business services; manufacturing; wholesale trade, distribution and transport; utilities; and other services.

In the energy efficiency sector, the largest source of employment by far is in construction, with 1.3 million out of the total employment of 2.3 million—i.e. 56 percent of total energy efficiency employment. We see in Table 3.15 that fully 84 percent of employers reported difficulties in hiring workers, with 52 percent finding it "very difficult" to hire qualified workers.

The results are only moderately lower in the other sub-sectors within energy efficiency. Thus, manufacturing firms reported the lowest level of hiring difficulties, at 72 percent. As

TABLE 3.15

Firms that Reported Hiring Difficulties in Solar, Wind and Energy Efficiency Sectors

A) Energy Efficiency; 2018 Employment = 2.3 million

	2018 Employment level	Firms Reporting Hiring Difficulties		
		Somewhat difficult	Very difficult	All firms reporting difficulties
Construction	1.30 million	32%	52%	84%
Professional/business services	484,481	21%	61%	82%
Manufacturing	321,581	14%	58%	72%
Wholesale trade, distribution, transport	180,339	24%	48%	72%
Other services	42,881	40%	36%	76%

B) Solar Electric Power; 2018 Employment = 242,343

	2018 Employment level	Firms Reporting Hiring Difficulties		
		Somewhat difficult	Very difficult	All firms reporting difficulties
Construction	177,320	54%	31%	85%
Professional/business services	48,142	57%	16%	73%
Manufacturing	46,539	60%	18%	78%
Other services	32,937	54%	23%	77%
Wholesale trade, distribution, transport	26,759	73%	6%	79%
Utilities	3,295	31%	31%	62%

C) Wind Electric Power; 2018 Employment = 111,166

	2018 Employment level	Firms reporting hiring difficulties		
		Somewhat difficult	Very difficult	All firms reporting difficulties
Construction	36,706	58%	28%	86%
Professional/business Services	27,058	66%	15%	81%
Manufacturing	26,490	53%	26%	79%
Wholesale trade, distribution, transport	11,783	77%	8%	85%
Utilities	6,231	50%	33%	83%
Other services	2,898	40%	33%	73%

Source: *The 2019 U.S. Energy & Employment Report* (https://www.usenergyjobs.org/).

TABLE 3.16
Summary Figures: All Firms Reporting Hiring Difficulties in Energy Efficiency, Solar Electricity and Wind Electricity Sectors

	Energy efficiency	Solar electricity	Wind electricity
Construction	84%	85%	86%
Professional/business services	82%	73%	81%
Manufacturing	72%	78%	79%
Wholesale trade, distribution, transport	72%	77%	85%
Utilities	---	79%	83%
Other services	76%	62%	73%

Source: *The 2019 U.S. Energy & Employment Report* (https://www.usenergyjobs.org/).

we see in Tables 3.15 B and C, as well as in the summary Table 3.16, these patterns are similar in the solar and wind electricity sectors and sub-sectors as well.

The survey further found that "lack of experience, training or technical skills" was the most important reason that employers were facing difficulties in hiring workers. The other, less significant factors were location and a relatively small applicant pool.

The study's conclusion from these survey results is that "The need for technical training and certifications was also frequently cited, implying the need for expanded investments in workforce training and closer coordination between employers and the workforce training system," (NASEO 2019, p. 6).

Putting California on the High Road

The June 2020 study *Putting California on the High Road: A Jobs and Climate Action Plan for 2030* provides an extensive and careful analysis of measures that need to be implemented to ensure that the jobs created in building a zero-emissions California economy are high-quality jobs. This study examines a range of issues for both the supply- and demand-sides of California's labor market, and also on a sector-by-sector basis. It will be useful here to quote directly from some of this study's main findings.[81]

> **Job Quality.** While the specifics will vary by sector and occupation, there is general agreement that a good, family-supporting job pays a living wage; offers a stable schedule; provides benefits such as health care, retirement, paid sick days, and paid family leave; offers wage increases as skills are acquired; provides safe and healthy working conditions; and complies with all workplace laws (e.g., wage and hour, employee classification, health and safety, anti-discrimination, workers' compensation, and right to organize laws).

Job Access. Historical patterns of discrimination and institutional racism have led to concentrations of people of color and women in low-wage and often unhealthy or dangerous jobs. Job access and inclusion entails ensuring that the job opportunities generated from the growth of the carbon-neutral economy are accessible to workers who reflect the diversity of the state's population. Efforts to broaden inclusion must always be coupled with attention to job quality, and vice versa, or they will simply maintain the status quo, with workers of color concentrated in the bottom of the labor market.

What is the High Road and How Do We Build It? As the term is used here, a high-road economy supports businesses that compete on the basis of the quality of their products and services by investing in their workforces; these businesses pay the wages and benefits necessary to attract and retain skilled workers, who in turn perform high-quality work. Building the high road requires interventions on both the demand side and the supply side of the labor market. Supply indicates workers and the institutions that train them; demand refers to jobs and the firms or institutions that offer them.

Demand-Side Strategies. Demand-side strategies affect the demand for labor, including the kinds of jobs that are generated, the skills that are needed, the wages and benefits employers provide, and who employers hire. Public policy can encourage improvements in job quality through industry-specific or economy-wide wage and benefit standards, such as prevailing, living, and minimum wages; skill certification requirements; enforcement of all labor and employment laws, including proper classification of employees; and collective bargaining rights. Better wages, benefits, working conditions, and career ladders support a more skilled workforce, which in turns leads to better design, installation, operation, and maintenance of technologies….Demand-side policies also include interventions to increase hiring of qualified workers from disadvantaged communities and to ensure that labor standards do not create barriers for historically excluded groups. Finally, public policy can support industry and business growth that will lead to high-road job availability, so that workers are trained for jobs that actually exist. Demand-side strategies, like wage standards, skill certification requirements, or community workforce agreements, can be incorporated into climate measures through policy, regulatory action, or program design.

Supply-Side Strategies. Supply-side strategies focus on preparing the workforce for current and future changes in the labor market that are the expected result of climate policy and the overall transition to a carbon-neutral economy. Supply-side strategies are the traditional purview of the state's workforce development community, which is made up of an interconnected set of institutions including the community college and four-year college systems, certified apprenticeship programs, nonprofit training organizations, labor-management partnerships, public workforce development agencies, and multiple state, county and municipal agency partners. This system of education and training is funded through a variety of state and federal funding sources.

For workers, training is valuable if it leads to skill development, job placement, and wage and career advancement; for employers, training is valuable if it leads to improved productivity and work quality. Public funding for training will be effective only if trained workers are hired and retained, making it critical to target public training investments toward high-road employers who see their workforce as a worthwhile investment rather than a cost to be minimized.

Workforce development is essential to building economic opportunity for those who have been marginalized, disadvantaged, and otherwise denied opportunities. Programs targeted to disadvantaged workers can secure more equality in the distribution of job opportunities, but the shortage of good jobs is an ongoing challenge for these pipeline programs. *To improve outcomes for workers in low-wage jobs, the most effective strategies are those that build skills, respond to employer needs, and improve job quality, simultaneously* (emphasis in original).

Some Specifics on Prevalent Clean Energy Economy Jobs

In closing this section on job creation through the clean energy transition in California, we present here a more detailed description of some of the prevalent jobs that will be created through the clean energy investment program in California. Specifically, we highlight the jobs of electricians, carpenters, plumbers, construction laborers, civil engineers, biological technicians, electrical and electronic engineering technicians, bus drivers, and welding professions, considering what these jobs entail within energy efficiency and renewable energy projects. We also provide some detail on current levels of compensation, union status, and training requirements for these jobs within the clean energy economy.

Electricians

Electricians perform electrical work in the building, remodeling, and maintenance of structures, and play a central role in the efficient and renewable energy economy. In raising efficiency standards, electricians employ the use of energy efficient lighting, systems and appliances; motion and occupancy sensors, dimmers, timers, and smart power strips. They install electrical consumption economizers that reduce the energy use of air-conditioning units, and programmable thermostats and daylight harvesting systems that use photosensors to detect ambient light levels. Electricians are knowledgeable about different types of renewable energy, such as solar, wind, and geothermal, and are able to integrate these sources into a comprehensive energy efficiency system. More recently, electricians need to be knowledgeable of the California Green Building Standards Code (CALGreen), which will affect most of the new construction projects, including residential and commercial (non-residential) buildings.[82]

Electricians are also integral in largescale green industrial projects. For instance, electricians work on projects such as electrifying the ports to provide shore power that reduces the need for docked ships to run their auxiliary engines during loading and unloading activities. Electricians are also key to the implementation of electric charging stations within an Electric Vehicle Network (EVN) and in homes, conducting site assessments to determine the mounting location and performing station and submeter installation and calibration. Electricians also install energy management systems on commercial and industrial facilities, maintain and repair Smart Meters, and connect appliances and troubleshoot installation problems of Residential Smart Meters. At a grid scale, electricians are heavily involved in the installation of high voltage smart grid technologies in the substations and distribution system.[83]

Job Quality. The median wage in 2020 for electricians in California was $66,548 annually ($32.00 hourly).[84] While benefit packages vary widely by company policy and union contract, electricians typically receive paid holidays, vacation, and health insurance, and work a 40-hour workweek. The work of electricians may be strenuous and require heavy lifting, standing and kneeling for long periods, and exposure to inclement weather, as well as risk of injury from electrical shock and falls from ladders, scaffolds, and roofs.

Union Status and Training. Many electricians in California are members of the International Brotherhood of Electrical Workers (IBEW). The typical entrance path to the occupation is the completion of a formal union-sponsored apprenticeship or electrical construction vocational or trade college program.[85] For the electrical apprenticeship the minimum state requirements are 8,000 hours of on-the-job training, 640 hours of classroom learning, and competency tests for each level of advancement, though all IBEW apprenticeship programs in California require between 800 and 900 hours of classroom training.[86] Certified Electricians must complete 32 hours of continuing education prior to the three year expiration date of their certification, and must keep current on updates and changes to CALGreen.[87]

Additionally, electricians working on new technologies such as smart grids may need to complete professional, short-term certificate programs to maintain current knowledge and skills regarding as rate schedules, demand response contracts, pricing strategies, and smart grid markets. The California Advanced Lighting Controls Training Program (CALCTP) is a statewide initiative aimed at upgrading the skills of currently employed electricians.[88] The program trains and certifies licensed electrical contractors and state-certified general electricians in the proper way to program, test, install, commission, and maintain advanced lighting control systems. Recently the program has expanded to include a new upgrade certification for electric vehicle charging stations, the Electrical Vehicle Infrastructure Training Program (EVITP), which is now a CPUC requirement for workers installing any utility-owned charging station.[89]

Carpenters

Carpenters work in almost every type of construction. They construct, erect, install, and repair structures made from concrete, steel, wood, and other materials. The jobs they do depend on the type of construction, but can involve installing windows, flooring, and constructing framework for homes, driving piles for docks and piers, or installing turbines in large power plants. Carpenters may also install solar, wind, hydro, and geo-recovery systems. Carpenters are central to retrofitting residential and commercial buildings, replacing doors, windows, and flashing with energy-efficient products, and caulking and sealing holes or breaks and installing or upgrading insulation to reduce heat loss as appropriate for the climate zone.[90]

Job Quality. The median wage in 2020 for Carpenters in California was $60,459 annually, or $29.07 hourly.[91] Benefits for union carpenters typically include health, dental, and vision insurance, vacation, and retirement plans, and some non-union shops may also provide benefits. Jobs vary in length, from one-day home repairs to multi-year industrial projects, and most carpenters work eight-hour days Monday through Friday with frequent opportunities for overtime.

Carpentry can be dangerous, and carpenters risk injury from falling objects, sharp tools, and power equipment, or themselves falling from high places. Carpenters often work in dusty, noisy environments, sometimes on ladders or scaffolds. Outdoor work means exposure to all types of weather conditions, and generally can be strenuous and require prolonged standing, climbing, bending, or kneeling.

Union Status and Training. In larger areas most journey-level workers and apprentices belong to unions, such as the United Brotherhood of Carpenters and Joiners of America, although smaller communities have many non-union workers. Completion of a formal apprenticeship or construction vocational or trade college program is the usual method of entry. Carpenters' apprenticeship programs usually require 48 months, 4,800 work hours, and completion of 612 hours of technical classroom instruction.

Continuing education generally isn't required for carpenters, but they do need to be knowledgeable of the CALGreen code, which will affect most new construction projects, including residential and commercial buildings.[92] Additionally, carpenters who meet the minimum education and work experience requirements can receive voluntary certification, such as Envelope Professional, Green Advantage, Leadership in Energy and Environmental Design (LEED), after passing an examination.[93]

Plumbers

Plumbers work with pipefitters and steamfitters to assemble, install, and repair pipe systems according to plans and plumbing codes. Plumbers play a central role in the clean energy and efficiency economy through the construction of new green buildings and retrofitting old ones. They install water-saving appliances and plumbing products, replace existing plumbing fixtures and fittings with energy-efficient equipment, such as faucet flow restrictors or low-flow faucets and toilets, and install plumbing for rainwater capture, gray water, or solar panel systems.

In new construction work, plumbers perform a number of critical functions and must follow the California Green Building Standards Code (CALGreen).[94] Plumbers select proper plumbing fixtures, including water saving faucets, showerheads, and toilets, and tankless hot water heaters, and install programmable irrigation controllers that are sensitive to the weather and moisture content of the soil. Plumbers may also compile information on governmental incentive programs related to the installation of energy or water saving plumbing systems or devices, install, test, or commission solar thermal or solar photovoltaic hot water heating systems, and perform domestic plumbing audits to identify ways in which customers might reduce consumption of water or energy.[95]

Job Quality. The median wage in 2020 for plumbers in California was $59,398 annually, or $28.56 hourly, and they generally work 35 to 40 hours per week.[96] Benefit packages vary across employers and unions, but plumbers typically receive benefits that include health insurance, vacation, and retirement plans. Plumbing work is generally safe, but there is risk of injury from falls off ladders, cuts from sharp tools, and burns from hot pipes or soldering equipment. Additionally, plumbing requires physical strength and stamina to frequently lift heavy pipes, stand for long periods, and work in uncomfortable or cramped positions, often outdoors in all types of weather.

Union Status and Training. Many plumbers belong to the United Association of Journeymen and Apprentices of the Plumbers and Pipefitting Industry of the United States and Canada.[97] The usual method of entry to the profession is the completion of a formal apprenticeship or vocational college program. After completing the apprenticeship program, apprentices must pass a union-administered code exam to obtain a plumbing certificate. Journey-level plumbers may become licensed as a plumbing contractor, subject to an exam and bi-annual renewal.

While continuing education is not required for plumbers, they will need to keep current on updates and changes to CALGreen. The United Association of Plumbers, Fitters, Welders, and Service Technicians has a well-developed infrastructure for creating certifications aligned with their trade as the need arises, including such diverse certifications as medical gas technician, HVACR service technician, and nuclear mechanic, most of which are certified by national or international industry and/or quality entities.[98] Plumbers can also receive voluntary credentialing, such as Leadership in Energy and Environmental Design (LEED).[99]

Construction Laborers

Construction laborers are generalists that perform many different tasks during all stages of construction. They perform a wide range of tasks on construction sites and use a variety of equipment, including jackhammers, concrete and plaster mixers, mechanical hoists, and surveying and measuring equipment. Construction laborers often work jointly on construction projects with skilled crafts workers such as carpenters, plasterers, operating engineers, and masons. For some jobs, construction laborers might use computers and other high-tech devices, for example to control robotic pipe cutters and cleaners.

Some common roles for construction laborers include preparing construction sites by removing trees, debris, asbestos, or lead-based paint from buildings; tending pumps, compressors and generators; and building forms for pouring concrete. They also build and dismantle scaffolding and other temporary structures. The duties of construction laborers on a green building site are similar to their duties on other projects, but might include specific green onsite procedures, such as material recycling plans.

Job Quality. The median wage in 2020 for construction laborers in California was $46,769 annually, or $22.49 hourly. Construction laborers working for union contractors generally receive health insurance, sick leave, vacation, and a pension plan.[100] Construction laborers generally work eight-hour shifts, although longer shifts are common and overnight work can be required. Additionally, they may work only during dry seasons, or may experience weather-related work stoppages at any time of the year.

Construction labor can be dangerous and physically demanding, with frequent lifting and carrying heavy objects and bending, kneeling, and crawling in awkward positions. They also may work high atop scaffolds or other structures. The work is frequently done outdoors in all weather conditions. Construction laborers have high rates of injury on the job, can come into contact with dangerous machinery, and may be exposed to hazardous materials such as lead-based paint, asbestos, or chemicals and fumes.[101]

Union Status and Training. Many construction laborers belong to the Laborer's International Union of North America.[102] Construction laborer jobs often have no specific education or training requirements, but workers may receive on-the-job training or formal technical training through vocational schools or union-sponsored apprenticeship programs.[103] The laborer apprenticeship program requires a minimum of 3,000 hours of on-the-job training and 200 hours of related classroom instruction.[104] Apprenticeship includes comprehensive safety training, and apprentice construction workers are less likely to experience injuries in an occupation that has very high injury rates and the highest number of fatalities of all industries in California.[105]

Another important pathway is through pre-apprenticeship programs.[106] The Flintridge Center's Apprenticeship Preparation Program (APP), serving Los Angeles County, is a pilot pre-apprenticeship program with a focus on formerly incarcerated women. The program provides a 12-week course offered three times per year that prepares participants for success in union apprenticeship programs in the building and construction trades. The APP includes the Multi-Craft Core Curriculum of North America's Building Trades Unions (NABTU), and hands-on training at Habitat for Humanity construction sites. Upon completion, Flintridge works with the Los Angeles and Orange Counties Building and Construction Trades Council to place program participants in joint apprenticeship programs working on projects governed by local hiring laws and project labor agreements.[107]

Civil Engineers

Civil engineers plan, design, and supervise the construction and maintenance of large projects including airports, bridges, buildings, dams, irrigation projects, power plants, roads, tunnels, and water supply and sewage systems. They must consider many factors during the design process, from the construction costs and expected lifetime of a project to governmental and environmental regulations and potential natural hazards, such as earthquakes and hurricanes. Engineers may also work with specialists on issues around soil, ground water contamination, or energy development and conservation.[108]

Civil engineers are deeply involved in the development of a clean and efficient energy economy across multiple important sectors. Civil engineers assist with the research and design of sustainable materials used for the construction of energy-efficient structures, and work within the renewable energy generation sector to develop and design projects that use renewable energy sources including solar, wind, geothermal, and biomass. Civil engineers also interface with the green construction sector in the design of new green structures or retrofitting existing ones. In the transportation sector, civil engineers develop and design ways to reduce the environmental impacts of various transportation projects. Civil engineers also help plan and implement environmental protection measures, such as environmental remediation, air quality, and climate change adaptation.

Job Quality. The median wage in 2020 for civil engineers in California was $109,836 annually, or $52.81 hourly.[109] Civil engineers generally receive excellent benefit packages, including health and life insurance, vacation, sick leave, and pension plans, and typically work a standard 40-hour week.

Union Status and Training. Most civil engineers are not members of unions, although those who are employed by state or local governments may belong to a union, such as Professional Engineers in California Government (PECG).[110] A bachelor's degree in civil engineering is generally the minimum educational requirement, in addition to at least four years of experience in civil engineering and a professional engineering (PE) license. Continuing education is not generally required, but civil engineers must stay current with changes to building codes and regulations, such as the California Green Building Standards Code (CALGreen), as well as state and federal environmental laws.[111]

Biological Technicians

Biological technicians work with biologists studying living organisms. They set up, operate, and maintain laboratory instruments, monitor experiments, make observations, calculate and record results, and often develop conclusions. Many biological technicians work as part of a natural resource management team, making field observations of natural resource conditions, assisting in preparation of draft reports, plans, and guidelines, and providing logistical support for contract and cooperating scientists. Biological technicians may also provide assistance to students, student conservation assistants, and volunteers involved in resource management projects and field research. Some biological technicians also aid in the production of biofuels, such as ethanol and biodiesel.[112]

Job Quality. The median wage in 2020 for biological technicians in California was $53,075 annually, or $25.52 hourly.[113] Biological technicians may expect to receive benefit packages including medical, dental, and vision insurance as well as vacation, sick leave, and a 401(k). While most biological technicians work indoors, usually in laboratories, and have regular hours, some occasionally work irregular hours to monitor experiments. Production biological technicians often work in eight-hour shifts around the clock, while others, such as those who work in state or national parks, fisheries, and other natural resource conservation areas, may perform much of their work outdoors, sometimes in remote locations.

Union Status and Training. Biological technicians are generally not unionized, except when employed by federal, state, or local government. Prospective biological technicians should have at least an associate degree or a certificate in applied science or science-related technology. Many technical and community colleges offer programs in a specific technology or more general education in science and mathematics.

Electrical and Electronic Engineering Technicians

Electrical and electronic engineering technicians perform work essential to the research and development, manufacture, and maintenance of a wide range of equipment from small appliances to power generating plants. Electrical engineering technicians deal with the design of electrical energy generating and controlling equipment, and typically install, maintain, and repair electric power distribution, generators, and motors. In a related field, electronic engineering technicians help in the development of circuits that use the electromagnetic qualities of electrical components, and may lay out, build, test, trouble shoot, repair, and modify electronic components.

Engineering technicians work with tools such as voltmeters, ohmmeters, signal generators, ammeters, and oscilloscopes. They may write computer programs to test new systems, analyze and interpret test data, or write technical reports to describe operating characteristics, failures, and limitations for engineers to consider. They set up and operate test equipment to evaluate performance of developmental parts, assemblies, or systems. This can include reading blueprints, wiring diagrams, schematic drawings, and engineering instructions for assembling electronics units, or installing and maintaining electrical control systems and solid state equipment. Additionally, engineering technicians may modify electrical prototypes, parts, assemblies, and systems to correct functional deviations and perform preventative maintenance and calibration of equipment and systems. [114]

Job Quality. The median wage in 2020 for electrical and electronic engineering technicians in California was $69,377 annually, or $33.35 hourly.[115] Generally, benefits include medical, dental, vision, retirement, and life insurance plans, as well as holidays. Some employers offer profit sharing, stock purchase plans, and bonuses.

Electrical and electronic engineering technicians work in various locations depending upon the industry. Those in electronics manufacturing plants typically work in modern buildings, though some may be exposed to hazardous materials, potential electric shock, or high noise levels. Electrical and electronic engineering technicians usually work a standard 40-hour week, although swing and night shifts may be required at plants that operate around the clock.

Union Status and Training. Unionization is not widespread among the engineering field, but electrical engineers may be represented by unions such as the International Federation of Professional and Technical Engineers[116], the International Brotherhood of Electrical Workers[117], and International Association of Machinists and Aerospace Workers[118] represent engineering technicians. Also, the Society of Professional Engineering Employees in Aerospace represents employees of Boeing in California.[119]

Most employers expect an associate degree in electrical or electronics engineering technologies or related degree typically offered by community colleges and technical institutes. Some companies accept equivalent experience instead of a degree, such as military training. Certain companies offer on-the-job training that may be combined with formal schooling. Certification is usually not required by employers.

Bus Drivers

Bus drivers provide transportation for people within or between cities. They are employed by local transit systems or intercity bus companies. They operate a range of vehicles from 15-passenger shuttles to 60-foot articulated buses carrying over 100 passengers.

Local transit bus drivers transport passengers along scheduled routes, usually within an urban area. They might collect and hand out transfers, provide change for passengers, and verify that bus passes are valid. Intercity bus drivers transport passengers between cities and states. They relate schedules, routes, fares, and other information concerning the trips, and may assist passengers with baggage. Shuttle bus drivers operate buses between set destinations, such as passengers' homes, health clinics, care centers, and public facilities. They follow and keep to time schedules and route assignments, and may perform additional accessibility services like securing wheelchairs or operate hydraulic lifts to help customers on and off the bus and into buildings. They perform routine maintenance their vehicle, such as checking the brakes, windshield wipers, and hydraulic lifts as well as adding gasoline and oil regularly.

Job Quality. The average wage in 2020 for bus drivers in California was $51,700 annually ($24.86 hourly).[120] Drivers working in the public sector will receive health and life insurance, sick leave, vacation, and pension plans, as well as free transit passes for themselves and their families. Current laws limit driving time to a maximum of ten consecutive hours, after eight consecutive hours off-duty. Drivers who work a ten-hour shift can experience fatigue, especially when driving in poor conditions. Work schedules can vary, but often include night, weekend, and holiday shifts. Drivers with the most seniority may have regular routes and regular weekly work schedules, while those with less seniority may have irregular schedules and be expected to work on short notice. Local transit bus drivers have a five-day workweek, including Saturdays and Sundays.

Union Status and Training. Many intercity and local drivers are members of the Amalgamated Transit Union, Transport Workers Union of America, United Transportation Union, or the International Brotherhood of Teamsters.[121] Many employers prefer to hire individuals with a high school diploma or equivalent and a clean driving record. A written test may also be required, as well as completion of a company-sponsored bus driver training program. Some employers may require several years of experience driving a bus or truck. Most intercity and local transit bus companies provide their driver trainees two to eight weeks of classroom and behind-the-wheel instruction.

Drivers in vehicles that carry more than ten passengers need a California Commercial Class B driver license with airbrake and passenger endorsements. This requires an approved medical form and bi-yearly medical exams going forward. Verification of Transit Training Document is required for transit bus drivers, to show that the driver has fulfilled the specified training requirements.[122]

Welders, Cutters, Solderers, and Brazers

Welders, cutters, solderers, and brazers use manual or automatic arc or gas equipment to join metal parts together by melting metal. Welding is used in the construction of ships, spacecraft parts, buildings, bridges, and refineries, among others. There are over 80 different welding processes recognized by the American Welding Society, which are used by ornamental ironworkers, sheet-metal workers, and structural and reinforcing iron and metal workers.[123]

Welding specializations include cutting, soldering, and brazing. Cutters use heat from an electric arc or stream of ionized or burning gasses to cut and trim metal objects to meet blueprint or work order specifications, or dismantle large objects such as ships, railroad cars, buildings, or aircraft. Soldering is commonly used in electronics and electrical manufacturing to connect items to or on a circuit board by melting an additional filler metal to bind the pieces. Brazing is often used in the construction industry to join metal parts using a hand torch to cover parts to delay corrosion.

A common type of welding is shielded metal arc welding, which involves using two welding electrical leads connecting a welding rod (electrode) to the metal pieces to be joined, carrying a strong electrical current. When the electrode touches the piece, a powerful electrical circuit is created which produces heat in an electrical arc. This heat melts both the base metal and the electrode together forming a solid bond (weld) when cooled. The speed in which the welder moves the heat source can ultimately affect the physical and mechanical properties of the finished weld.

Welders at all levels require practical knowledge of fabricating and assembling operations in their field. Welders typically begin as an apprentice, performing manual labor and routine, repetitive welding processes. Journey-level welders are generally able to read blueprints, perform layout work, and possess basic manipulative welding skills. A master welder is knowledgeable in welding metallurgy, understanding different metals, their characteristic reactions under intense heat, and the welding processes best suited for each metal. [124]

Job Quality. The median wage in 2020 for welders, cutters, solderers, and brazers in California was $45,564 annually, or $21.90 hourly.[125] Benefits usually include holidays, vacation, and sick leave. Many are also covered by health and life insurance and pension plans through either company or trade union agreements. Self-employed welders are responsible for providing their own benefits.

Welding working conditions can vary considerably from indoors to outdoors and light to heavy jobs, though welders often work under normal shop conditions. Welders may work on scaffolds or platforms high off the ground or in confined areas designed to contain sparks and glare. Welders are exposed to a number of hazards including ultraviolet light, dangerous fumes, and super-heated metals, and must use various safety equipment such as safety shoes, goggles, hoods with protective lenses, and other equipment designed to prevent burns and eye injuries. The normal workweek for welders is 40 hours, though shift work can be routine in factories that operate around the clock.

Union Status and Training. Welders work in many industries that are represented by trade unions. Many of today's welding occupations are covered by bargaining agreements for iron workers, pipefitters, boilermakers, ship builders, plumbers, automobile makers, and construction workers.

A high school diploma or equivalent is standard for welders. Training in welding is offered in some high schools, several adult schools, the military, vocational schools, community colleges and private welding schools. Several trade unions also offer welding apprenticeship training. Apprentice welders learn their trade while working on the job and attend evening classes for technical training.

Welders working on jobs in which failure of welds can be dangerous or life threatening must be certified. Voluntary certification is available through the American Welding Society and other trade unions in a variety of welding processes. The certification demonstrates that the holder has the knowledge, education, and experience to competently perform welding operations.[126]

4. INVESTMENT PROGRAMS FOR MANUFACTURING, INFRASTRUCTURE, LAND RESTORATION AND AGRICULTURE

California's economy would receive a major boost, both in terms of short-run stimulus and longer-term gains in employment opportunities, productivity, environmental sustainability and general well-being by investing in manufacturing, public infrastructure, agriculture and land restoration. In this section, we estimate the employment impacts of investing in 13 specific areas of manufacturing development and public infrastructure and eight specific areas in land restoration and agriculture.

The overall level of investment we propose is approximately $62 billion per year, equal to about two percent of California's 2019 GDP level of $3.1 trillion. This overall budget figure, as well as the shares we allocate to specific program areas, are derived from the so-called "THRIVE Agenda"—a bill, for the overall U.S. economy, to "Transform, Heal and Renew by Investing in a Vibrant Economy" that was introduced into Congress in February 2021 and, to date, has been endorsed by more than 100 members of Congress, including Senate Majority Leader Chuck Schumer.[127] In the area of "Creating Millions of Good, Safe Jobs with Access to Unions," the THRIVE Agenda includes the following as priorities:[128]

1. Upgrading our broken infrastructure to expand access to clean and affordable energy, transportation, high-speed broadband, and water, particularly for public systems;
2. Protecting and restoring wetlands, forests, and public lands, and cleaning up pollution in our communities;
3. Creating opportunities for family farmers and rural communities, including by untangling the hyper-consolidated food supply chain, bolstering regenerative agriculture, and investing in local and regional food systems that support farmers, agricultural workers, healthy soil, and climate resilience;[129]
4. Developing and transforming the industrial base of the United States, while creating high-skill, high-wage manufacturing jobs across the country, including by expanding manufacturing of clean technologies, reducing industrial pollution, and prioritizing clean, domestic manufacturing for the aforementioned investments; and
5. Prioritizing the mobilization of direct public investments.

The investment priorities included in the national THRIVE Agenda are broadly consistent with the most recent assessment and recommendations of the American Society of Civil Engineers (ASCE) evaluations that focus specifically on California's public infrastructure. In 2019, the ASCE provided a detailed study, *Report Card for California's Infrastructure, 2019*. Their assessment is that California's infrastructure deserves an overall grade of C-. The ASCE summarized its findings as follows:

> The 2019 California Infrastructure Report Card gave the overall infrastructure a grade of C-, which means California's infrastructure is in mediocre condition and requires attention. Infrastructure maintenance, renewal and replacement programs are critical for sustaining California's economic engine, but funding constraints continue to severely delay much-needed improvements. Our state's infrastructure renewal and replacement programs have been significantly underfunded for a long time. While the state legislature, municipalities, and California voters have made strides in recent years to raise additional revenue for our infrastructure, we have a lot of catch-up to play, and large funding gaps remain.[130]

Focusing on California, we include the full set of investment priorities in the national THRIVE Agenda. The budget amounts that we allocate for California in these national THRIVE investment areas follow directly from the national THRIVE Agenda budget, with California being allocated its share of each of THRIVE projects in proportion to its 12.1 percent share of the U.S. population. We show the full set of programs and budget amounts in Table 4.1. With these specific investment areas and budget amounts, we mean to provide a representative picture of what a large-scale public investment program for California would look like at present. At the same time, it is beyond the scope of this study to evaluate in detail the relative merits of any of the specific investment areas or the specific budgetary allocations assigned to each of them. For our purposes here, these budget allocations for each of the specific programs in the national THRIVE Agenda, scaled to California, enable us to estimate the employment impacts of the full set of investments.

Job Creation through Manufacturing and Public Infrastructure Investments

In Table 4.2, we show the job creation figures for the 13 manufacturing and public infrastructure investment areas in the THRIVE Agenda listed in Table 4.1. These include: surface transportation; water/wastewater; electricity; airports; inland waterways/marine ports; dams; hazardous and solid waste; levees; public parks and recreation; rail; schools; gas distribution pipelines—leak repairs; and broadband. As we see, the extent of direct plus indirect jobs ranges from 2.0 direct plus indirect jobs per $1 million in expenditure for repairing gas distribution pipelines to 13.3 direct and indirect jobs for financing public parks and recreation. Adding induced jobs brings the range to 3.2 jobs per $1 million for repairing gas distribution pipelines to 17.0 for public parks and recreation.

Based on these proportions, we see in Table 4.3 the levels of job creation in California generated by spending an average of $39.2 billion per year between 2021 – 2030 in these areas of manufacturing and public infrastructure investments at the levels assigned to them by the THRIVE Agenda scaled to California's population, as shown in Table 4.1

Following from these budgetary assumptions, we see in Table 4.3 that total direct plus indirect job creation generated in California by these investments will be roughly 300,000 direct plus indirect jobs per year and just under 385,000 jobs per year total if we include induced jobs.

TABLE 4.1

THRIVE Agenda Program Areas and California Budget Allocations

$61.8 billion budget allocations based on California's 12.1% of U.S. population

A) Manufacturing and Public Infrastructure Investments: $39.2 billion per year

	Spending amounts
Surface Transportation	$13.3 billion
Water/wastewater	$3.9 billion
Electricity	$5.2 billion
Airports	$508 million
Inland waterways/marine ports	$182 million
Dams	$472 million
Hazardous and solid waste	$36 million
Levees	$847 million
Public parks and recreation	$1.2 billion
Rail	$2.5 billion
Schools	$4.6 billion
Gas distribution pipelines—leak repairs only	$2.2 billion
Broadband	$4.2 billion
TOTALS	$39.2 billion

B) Land Restoration and Agriculture: $22.6 billion per year

	Spending amounts
Agriculture	
Regenerative agriculture	$5.0 billion
Farmland conservation	$3.0 billion
Organic Agriculture	$182 million
Resources for Marginalized Farmers	$11.0 billion
Agriculture R&D	$302 million
Land Restoration	
Pollution Cleanup	$1.5 billion
Closing Orphaned Oil and Gas Wells	$1.5 billion
Ecosystem restoration	$121 million
TOTALS	$22.6 billion

Source: https://static1.squarespace.com/static/5f53b5996b708446acb296c5/t/5f5a2a6dc21f38271ec5629b/1599744622100/THRIVE+--+PERI+Jobs+Analysis+FINAL.pdf, pp. 6 and 12.

TABLE 4.2
Job Creation in California through Manufacturing and Public Infrastructure Investments:
Job creation per $1 million in manufacturing and infrastructure investments

	Direct jobs	Indirect jobs	Direct + indirect jobs	Induced jobs	Direct, indirect + induced jobs
Surface transportation	9.6	1.4	11.0	2.4	13.4
Water/wastewater	4.9	1.8	6.7	2.7	9.4
Electricity	1.6	0.7	2.3	0.9	3.2
Airports	2.8	1.1	3.9	1.6	5.5
Inland waterways/marine ports	3.0	1.9	4.9	1.9	6.8
Dams	6.8	1.9	8.7	3.3	12.0
Hazardous and solid waste	5.9	2.0	7.9	2.7	10.6
Levees	6.9	2.0	8.9	3.4	12.3
Public parks and recreation	11.0	2.3	13.3	3.7	17.0
Rail	2.4	1.3	3.7	1.5	5.2
Schools	10.4	1.4	11.8	3.5	15.3
Gas distribution pipelines—leak repairs only	0.8	1.2	2.0	1.2	3.2
Broadband	1.8	1.8	3.6	1.6	5.2

Sources: Authors' calculations using IMPLAN 3.1. See Appendix 1.

TABLE 4.3
Manufacturing and Public Infrastructure Investments for California, 2021 – 2030
Overall program at $39.2 billion per year
12.1 percent of U.S. THRIVE program

	Spending amounts	Direct jobs	Indirect jobs	Direct+ indirect jobs	Induced jobs	Direct, indirect+ induced jobs
Surface transportation	$13.3 billion	127,680	18,620	146,300	31,920	178,220
Water/wastewater	$3.9 billion	19,110	7,020	26,130	10,530	36,660
Electricity	$5.2 billion	8,320	3,640	11,960	4,680	16,640
Airports	$508 million	1,422	559	1,981	813	2,794
Inland waterways/ marine ports	$182 million	546	346	892	346	1,238
Dams	$472 million	3,210	897	4,107	1,558	5,665
Hazardous and solid waste	$36 million	212	72	284	97	381
Levees	$847 million	5,844	1,694	7,538	2,880	10,418
Public parks and recreation	$1.2 billion	13,200	2,760	15,960	4,440	20,400
Rail	$2.5 billion	6,000	3,250	9,250	3,750	13,000
Schools	$4.6 billion	47,840	6,440	54,280	16,100	70,380
Gas distribution pipe-lines—leak repairs only	$2.2 billion	1,760	2,640	4,400	2,640	7,040
Broadband	$4.2 billion	7,560	7,560	15,120	6,720	21,840
TOTALS	**$39.2 billion**	**242,704**	**55,498**	**298,202**	**86,474**	**384,676**

Source: Tables 4.1 and 4.2.

Job Creation through Land Restoration and Agriculture

In Table 4.4, we show the job creation figures for our eight investment areas in this category: regenerative agriculture; farmland conservation; organic agriculture; resources for marginalized farmers; agriculture R&D; pollution cleanup; closing orphaned oil and gas wells; and ecosystem restoration. For these projects, we see that direct and indirect jobs ranges between 1.6 per $1 million in expenditure for closing orphaned wells and 14.9 jobs for ecosystem restoration. Adding induced jobs brings the range to 2.4 per $1 million for closing orphaned wells to 18.6 for ecosystem restoration.

Based on these proportions, we see in Table 4.5 the levels of job creation in California generated by spending an average of $22.6 billion per year between 2021 – 2030 in these areas of land restoration and agriculture at the levels assigned to each area within the THRIVE Agenda, as we reported in Table 4.1. Following from these budgetary assumptions, we see that total job creation generated in California by these investments will be about 188,000 direct and indirect jobs and 241,000 if we include induced jobs.

Table 4.6 summarizes our employment creation estimates for the full range of investments in the areas of manufacturing/infrastructure and land restoration/agriculture. As we see, direct and indirect jobs totals to over 486,000, equal to 2.5 percent of California's 2019 workforce. When induced jobs are included, the total comes to roughly 626,000 jobs, equal to 3.2 percent of the 2019 California workforce.

TABLE 4.4
Job Creation in California through Agriculture and Land Restoration Investments
Job creation per $1 million in agriculture and land restoration investments

	Direct jobs	Indirect jobs	Direct+ indirect jobs	Induced jobs	Direct, indirect+ induced jobs
Agriculture					
Regenerative agriculture	4.9	1.6	6.5	1.8	8.3
Farmland conservation	7.5	2	9.5	2.9	12.4
Organic agriculture	4.9	1.6	6.5	1.8	8.3
Resources for marginalized farmers	7.9	1.7	9.6	2.6	12.2
Agriculture R&D	4.4	1.8	6.2	2.7	8.9
Land restoration					
Pollution cleanup	7.1	2	9.1	3.2	12.3
Closing orphaned oil and gas wells	0.7	0.9	1.6	0.8	2.4
Ecosystem restoration	12.6	2.3	14.9	3.7	18.6

Sources: Authors' calculations using IMPLAN 3.1. See Appendix 1.

TABLE 4.5
Land Restoration and Agriculture Investment Program for California, 2021 – 2030
Overall program at $22.6 billion per year

12.1 percent of U.S. THRIVE program

	Spending amounts	Direct jobs	Indirect jobs	Direct+ indirect jobs	Induced Jobs	Direct, indirect+ Induced jobs
Agriculture						
Regenerative agriculture	$5.0 billion	24,500	8,000	32,500	9,000	41,500
Farmland conservation	$3.0 billion	22,500	6,000	28,500	8,700	37,200
Organic agriculture	$182 million	892	291	1,183	328	1,511
Resources for marginal-ized farmers	$11.0 billion	86,900	18,700	105,600	28,600	134,200
Agriculture R&D	$302 million	1,329	544	1,873	815	2,688
Land restoration						
Pollution cleanup	$1.5 billion	10,650	3,000	13,650	4,800	18,450
Closing orphaned oil and gas wells	$1.5 billion	1,050	1,350	2,400	1,200	3,600
Ecosystem restoration	$121 million	1,525	278	1,803	448	2,251
TOTALS	**$22.6 billion**	**149,346**	**38,163**	**187,509**	**53,891**	**241,400**

Source: Tables 4.1 and 4.4.

TABLE 4.6
Annual Job Creation in California through Manufacturing/Infrastructure and Land Restoration/Agriculture Investment Programs
Average annual figures for 2021-2030; average investment level = $61.8 billion

Industry	Number of direct and indirect jobs created	Number of direct, indirect, and induced jobs created
$39.2 billion in manufacturing development and public infrastructure	298,202	384,676
$22.6 billion in land restoration and agriculture	187,509	241,400
TOTALS	485,711	626,076
TOTAL AS SHARE OF 2019 CALIFORNIA LABOR FORCE *(Labor force at 19.4 million)*	2.5%	3.2%

Source: Tables 4.3 and 4.5.

Indicators of Job Quality

In Table 4.7 and 4.8, we provide some basic measures of job quality for the jobs that will be generated through both the manufacturing/infrastructure and the land restoration/agriculture investment projects in California. As with our discussion on clean energy investment jobs, the basic indicators again are: 1) average total compensation (including wages plus benefits); 2) the percentage of workers receiving health insurance coverage; 3) the percentage having retirement plans through their employers; and 4) the percentage that are union members. In addition, as before, we focus here only on the *direct* jobs that will be created through manufacturing/infrastructure and land restoration/agriculture investments in California.

Starting with the manufacturing and infrastructure figures in Table 4.7, we see first that compensation figures range widely. At the lower end are the jobs in surface transportation, in which average pay is around $40,000. At the high end are the relatively small number of jobs repairing gas pipelines that pay nearly $190,000 on average. As a whole, the other 11 industries also provide a wide range of pay levels.

TABLE 4.7
Indicators of Job Quality in California Manufacturing Development and Public Infrastructure Industries: Direct Jobs Only

	Manufacturing/Infrastructure						
	1. Surface transportation *(127,680 workers)*	**2. Water/ Wastewater** *(19,110 workers)*	**3. Electricity** *(8,320 workers)*	**4. Airports** *(1,422 workers)*	**5. Inland waterways/ marine ports** *(546 workers)*	**6. Dams** *(3,210 workers)*	**7. Hazardous and solid waste** *(212 workers)*
Average total compensation	$39,800	$85,400	$82,900	$87,500	$80,800	$76,700	$69,800
Health insurance coverage, percentage	34.0%	47.3%	41.6%	46.8%	45.8%	40.1%	36.2%
Retirement plans, percentage	19.9%	35.6%	27.1%	32.7%	33.2%	26.8%	24.3%
Union membership, percentage	17.5%	17.4%	16.6%	22.5%	18.6%	17.3%	9.6%

	Manufacturing/Infrastructure					
	8. Levees *(5,844 workers)*	**9. Public parks and recreation** *(13,200 workers)*	**10. Rail** *(6,000 workers)*	**11. Schools** *(47,840 workers)*	**12. Gas distribution pipelines-leak repairs only** *(1,760 workers)*	**13. Broadband** *(7,560 workers)*
Average total compensation	$77,300	$52,900	$87,900	$59,400	$189,400	$93,900
Health insurance coverage, percentage	40.4%	43.0%	51.8%	43.0%	63.4%	48.5%
Retirement plans, percentage	27.1%	30.5%	36.3%	39.6%	72.9%	34.7%
Union membership, percentage	17.1%	5.5%	32.0%	19.6%	32.0%	16.9%

Sources: See Appendix 2.

TABLE 4.8

Indicators of Job Quality in Agriculture and Land Restoration Industries: Direct Jobs Only

	Agriculture				
	1. Regenerative agriculture *(24,500 workers)*	**2. Farmland conservation** *(22,500 workers)*	**3. Organic farming** *(892 workers)*	**4. Resources for marginalized farmers** *(86,900 workers)*	**5. Agricul-tural R&D** *(1,329 workers)*
Average total compensation	$55,800	$60,200	$55,800	$50,300	$92,800
Health insurance coverage, percentage	31.2%	46.5%	31.2%	27.9%	39.7%
Retirement plans, percentage	18.1%	32.1%	18.1%	19.3%	26.5%
Union membership, percentage	7.4%	5.9%	7.4%	6.9%	3.2%

	Land Restoration		
	6. Pollution cleanup *(10,650 workers)*	**7. Closing orphaned wells** *(1,050 workers)*	**8. Ecosystem restoration** *(1,525 workers)*
Average total compensation	$70,200	$153,000	$46,900
Health insurance coverage, percentage	43.3%	64.0%	35.1%
Retirement plans, percentage	30.4%	64.4%	25.5%
Union membership, percentage	6.6%	23.2%	5.7%

Sources: See Appendix 2.

The figures for workers receiving health insurance from their employers also are more consistent across the 13 industries. Again, workers repairing gas pipelines are at the high end, with over 63 percent receiving employer-sponsored health care. About 52 percent of the rail industry workers have health coverage through their employer. But with the remaining 11 industries, employer-sponsored health care coverage is below 50 percent, with surface transportation workers again having the low figure of only 34 percent coverage.

With employer-sponsored pensions, once again, the situation for the workers repairing gas pipelines is well above the norm at 73 percent. Otherwise, only a minority of workers in the other 12 industries receive this benefit, with the percentages ranging from 20 – 40 percent.

Union membership among the manufacturing/public investment industries is relatively high. For the most part, the range of union membership is between 17 – 32 percent. The one significant exception is the public parks and recreation workers, in which only 6 percent are supported by union representation.

Turning now in Table 4.8 to the job quality measures for the eight land restoration and agriculture industries, again we see a wide range of compensation levels. On average, ecosystem restoration workers earn about $47,000 at the low end, while workers closing orphaned wells receive an average of $153,000. The workers closing orphaned wells also have the highest level of both health care and pension support from their employers, at about 64 percent in both cases. They also have a much higher level of union representation than the other seven industries, at 23 percent.

With the other seven industries in the land restoration and agriculture investment categories, between 28 – 47 percent receive employer-sponsored health insurance and between 18 – 32 percent receive employer-sponsored pensions. Union membership ranges between about 3 – 7 percent, within range of the 6.3 percent figure for private sector workers overall.

Overall, as indicated by our four measures, we see in Table 4.7, job quality standards in California for workers in the areas of manufacturing and infrastructure are broadly comparable to those in the various clean energy activities. But job quality is generally lower for California workers employed in the areas of land restoration and agriculture, with the exception of the jobs engaged in plugging orphaned wells. As such, the measures that should be employed for clean energy investments to raise job quality, including support for unionization as well as accessible and effective job training programs, will be equally important, if not more so, for advancing the quality of employment as well as the number of jobs available in the areas of manufacturing/infrastructure and land restoration/agriculture.

Implementing a $15 minimum wage standard for these jobs would also be important. Of the direct jobs created by manufacturing/infrastructure spending, 22 percent pay less than $15.00 per hour. The figure for agriculture/land restoration investments is significantly higher: nearly two-fifths—39 percent—of direct jobs created by such spending pay wage rates below $15.00 per hour. Raising the pay rates of these jobs would entail a modest one percent increase in manufacturing/infrastructure investment spending and just under a two percent increase in agriculture/land restoration investment spending.[131]

Educational Credentials and Race/Gender Composition

In Table 4.9, we present data on the educational credentials and the racial and gender compositions for workers in jobs that are directly employed in the areas of manufacturing/infrastructure. Table 4.10 presents these figures for workers in the land restoration and agriculture industries.

Educational Credentials

With respect to educational credentials, the critical overall result is that credential levels vary widely across the various industries, both in manufacturing/infrastructure as well as land restoration/agriculture. In manufacturing/infrastructure, over half of those employed in 8 of the 13 industries have high school degrees or less whereas around 20 percent have Bachelor's degrees or higher. With land restoration/agriculture, there are more industries where a third or more workers have Bachelor's degrees, including in agricultural R&D, pollution clean-up and ecosystem restoration. Overall, the investments in manufacturing/infrastructure and land restoration/agriculture will generate a substantial expansion in employment opportunities for workers at all credential levels.

Race and Gender Composition

In 12 of the 13 industries within manufacturing/infrastructure, a large majority of the jobs are held by BIPOC. The only exception is with parks and recreation, in which the BI-

TABLE 4.9

Educational Credentials and Race/Gender Composition of Workers in Manufacturing/ Public Infrastructure Industries: Direct Jobs Only

	Manufacturing/Infrastructure						
	1. Surface transportation *(127,680 workers)*	**2. Water/ wastewater** *(19,110 workers)*	**3. Electricity** *(8,320 workers)*	**4. Airports** *(1,422 workers)*	**5. Inland waterways/ marine ports** *(546 workers)*	**6. Dams** *(3,210 workers)*	**7. Hazardous and solid waste** *(212 workers)*
Share with high school degree or less	43.6%	51.2%	57.4%	53.1%	52.9%	54.6%	50.3%
Share with some college or Associate degree	33.8%	26.8%	25.5%	26.2%	27.1%	24.4%	19.1%
Share with Bachelor's degree or higher	22.7%	21.9%	17.1%	20.8%	20.0%	21.0%	30.6%
Racial and gender composition of workforce							
Pct. Black, Indigenous and People of Color	64.3%	60.9%	62.4%	60.3%	61.7%	59.8%	62.9%
Pct. female	19.1%	18.5%	11.0%	14.1%	13.4%	14.6%	20.3%

	Manufacturing/Infrastructure					
	8. Levees *(5,844 workers)*	**9. Public parks and recreation** *(13,200 workers)*	**10. Rail** *(6,000 workers)*	**11. Schools** *(47,840 workers)*	**12. Gas distribu-tion pipelines-leak repairs only** *(1,760 workers)*	**13. Broadband** *(7,560 workers)*
Share with high school degree or less	53.8%	35.4%	56.3%	22.9%	31.5%	48.9%
Share with some college or Associate degree	24.3%	24.6%	28.9%	23.3%	37.8%	26.4%
Share with Bachelor's degree or higher	21.9%	39.9%	14.8%	53.8%	30.7%	24.7%
Racial and gender composition of workforce						
Pct. Black, Indigenous and People of Color	59.5%	46.8%	62.3%	52.1%	55.8%	61.9%
Pct. female	14.8%	43.0%	10.8%	53.8%	31.5%	14.8%

Sources: See Appendix 2.

POC share of the workforce totals to 47 percent of employment. The same general pattern is also true with land restoration/agriculture. With these industries, the lowest share of workers that are BIPOC is 45 percent in farmland conservation. Overall, as with the expansion of California's clean energy economy, investments in California's infrastructure/manufacturing and land restoration/agriculture will continue to create increasing opportunities on a large scale for workers that are BIPOC in the state.

By contrast, the representation of women in these investment areas is generally low. In manufacturing/infrastructure, the only area where women constitute the majority of the workforce is with schools. With parks and recreation, female employment is at 43 percent.

TABLE 4.10
Educational Credentials and Race/Gender Composition of Workers in Agriculture and Land Restoration Industries: Direct Jobs Only

	Agriculture				
	1. Regenerative agriculture *(24,500 workers)*	**2. Farmland conservation** *(22,500 workers)*	**3. Organic farming** *(892 workers)*	**4. Resources for marginalized farmers** *(86,900 workers)*	**5. Agricultural R&D** *(1,329 workers)*
Share with high school degree	69.8%	31.3%	69.8%	45.2%	49.0%
Share with some college or Associate degree	16.5%	25.0%	16.5%	20.3%	16.2%
Share with Bachelor's degree or higher	13.7%	43.7%	13.7%	34.5%	34.7%
Racial and gender composition of workforce					
Pct. Black, Indigenous and People of Color	73.2%	44.9%	73.2%	59.1%	67.1%
Pct. female	25.6%	47.9%	25.6%	42.2%	37.3%

	Land Restoration		
	6. Pollution cleanup *(10,650 workers)*	**7. Closing orphaned wells** *(1,050 workers)*	**8. Ecosystem restoration** *(1,525 workers)*
Share with high school degree	40.4%	37.4%	31.5%
Share with some college or Associate degree	19.7%	34.9%	22.2%
Share with Bachelor's degree or higher	39.9%	27.6%	46.3%
Racial and gender composition of workforce			
Pct. Black, Indigenous and People of Color	58.3%	51.7%	48.3%
Pct. female	30.9%	23.8%	46.7%

Sources: See Appendix 2.

In the other 11 industries, the share of female employment is between 11 – 32 percent. In land restoration/agriculture, the female share is close to half in farmland conservation and ecosystem restoration. But in the other six industries, women make up between 24 – 42 percent of the workforce.

In short, for the most part, there remains a large disparity in the current gender composition of the workforce in in manufacturing/infrastructure and land restoration/agriculture. Yet, again as with clean energy, the large-scale expansion of investments in these areas will provide a major opportunity to expand job opportunities for women. As we have discussed with respect to clean energy, an initiative focused on equal opportunity in the growing manufacturing/infrastructure and land restoration/agriculture investment areas could be readily integrated into the broader investment project.

Prevalent Job Types in Manufacturing/Infrastructure and Land Restoration/Agriculture

Table 4.11 reports on the prevalent job types associated with investments in manufacturing/infrastructure and Table 4.12 provides comparable figures for land restoration/agriculture. As previously, in all cases, we report on the job categories in which we estimate that 5 percent or more of the new jobs will be created through these investment areas.

TABLE 4.11
Manufacturing Development and Infrastructure: Prevalent Job Types in California Industry
(Job categories with 5 percent or more employment)

Job category	Percentage of direct jobs	Representative occupations
Transportation and material moving	32.2%	Freight movers; first-line supervisors; bus drivers
Construction	23.5%	Pipelayers; painters; carpenters
Management	10.9%	General managers; chief executives; education administrators
Education	8.9%	Secondary school teachers; teacher assistants; postsecondary teachers
Office and administrative support	6.2%	Bookkeeping clerks; dispatchers; general office clerks

Source: See Appendix 2.

TABLE 4.12
Agriculture and Land Restoration: Prevalent Job Types in California Industry
(Job categories with 5 percent or more employment)

Job category	Percentage of direct jobs	Representative occupations
Farming, fishing, and forestry	24.7%	Logging workers; conservation workers; agricultural products graders and sorters
Management	15.2%	Construction managers; education administrators; farmers
Education	12.2%	Teacher assistants; training and library workers; postsecondary teachers
Construction	8.1%	Plumbers; first-line supervisors; construction laborers
Office and administrative support	7.3%	Accounting clerks; customer service representatives; secretaries

Source: See Appendix 2.

It is clear from these tables that job opportunities will expand in a wide range of areas. In the manufacturing/infrastructure areas, more than 32 percent of all employment in manufacturing/infrastructure will be in transportation and moving materials, and another 24 percent the construction industry, including jobs for pipelayers, painters and carpenters. The investments in schools will create jobs for teachers and teaching assistants. Expanding job opportunities will also expand across-the-board in office and administrative support, including for bookkeepers, dispatchers, and general office clerks. With land restoration/agriculture, the largest expansion of employment will be in the areas of farming, fishing and forestry, including for logging workers, conservation workers, and agricultural product graders and sorters. Employment opportunities will also expand for farmers, who are classified as managers, along with other types of managers, such as those in construction. These will be in addition to the expansion of jobs in the areas of education, construction, and office support.

As with the clean energy investments, what emerges generally from Tables 4.11 – 4.12 is that investments in manufacturing/infrastructure and land restoration/agriculture will certainly generate a wide range of new employment opportunities. We again also note that this broad range of new opportunities will be available for workers in California that will have been displaced by the contraction of the state's fossil fuel industry activities.

Public Sector Job Creation

As with the job creation figures we presented for clean energy investments, we now present more focused results on the public sector jobs that will be generated through the infrastructure/manufacturing and land restoration/agriculture investment programs we have outlined here. Again, we focus on *direct j*ob creation, as we have with our results on job quality, educational credentials and the racial and gender composition of the manufacturing/infrastructure and agriculture/land restoration workforce.

As we see in Table 4.13, of the approximately 393,000 total direct jobs that will be created on average in California through the infrastructure/manufacturing and land restoration/agriculture investment programs, about 53,000 of the jobs will be in the public sector.

TABLE 4.13
Public Sector Jobs Created through Manufacturing/nfrastructure Development and Land Restoration/Agriculture Land Restoration Investments: Direct Jobs Only
Average annual figures for 2021 – 2030

	Public sector direct jobs created	Total direct jobs created	Public sector share of total direct jobs created
Infrastructure/manufacturing development	43,444	242,704	17.9%
Land restoration/agriculture	9,926	150,396	6.6%
TOTAL	53,370	393,100	13.6%

Source: See Appendix 2.

These public sector jobs will therefore account for nearly 14 percent of all the jobs created through California's infrastructure/manufacturing and land restoration/agriculture investment programs. This percentage is well above the 3.9 percent share for public sector jobs that would be generated through clean energy investments.

As Table 4.13 shows, the main explanation for the much higher share of public sector job creation is the employment that will result through the infrastructure/manufacturing investment programs. With investments in these areas, we estimate that nearly 18 percent of all jobs created will be in California's public sector. This results because, with infrastructure sectors, virtually all of the jobs associated with management and maintenance—including managing any new construction or repair work of roads, water treatment plants, airports, dams, levees, parks, rail systems, and schools—will be performed by public sector workers. This will be the case even when the construction work to expand or upgrade the state's infrastructure is performed by private firms working on public procurement projects. We therefore provide brief profiles here in two areas of public sector employment that will result through investments to expand or maintain the state's existing infrastructure, water/wastewater treatment plant operator and recreation workers.

Some Specifics on Prevalent Infrastructure, Land Restoration and Agriculture Jobs

Water/Wastewater Treatment Plant Operator

Water and liquid waste treatment plant and system operators run the equipment, control the processes, and monitor the plants responsible for managing water systems. Fresh water is pumped from wells, rivers, streams, and reservoirs to water treatment plants, where it is treated and distributed to customers. Wastewater travels through sewage pipes to treatment plants where it is treated and either returned to streams, rivers, and oceans, or reused for irrigation. Operators in both types of plants control equipment and monitor processes that remove or destroy harmful materials, chemicals, and microorganisms from the water. They also run tests to make sure that the processes are working correctly and keep records of water quality and other indicators.[132]

Drinking water treatment and distribution operators work with equipment and processes used to clarify, purify, and disinfect surface or ground water for human consumption. Wastewater treatment operators use various filtration equipment such as microstrainers and backwash filters as well as dechlorination equipment, disinfection chlorinators, ion exchangers, agitators, and aerators. Operators operate and maintain the pumps and motors that move water and wastewater through physical, mechanical, biological, and chemical treatment systems. They monitor the indicators, read meters and gauges, and make adjustments as necessary to make sure that plant equipment is working properly.

Additionally, operators may add chemicals such as ammonia, chlorine, or lime to disinfect and deodorize water and other liquids. They inspect equipment or monitor operating conditions to determine load requirements and detect malfunctions, and may collect and test water and sewage samples, using test equipment and color analysis standards. They may operate and adjust controls on equipment to purify and clarify water, process or dispose of sewage, and generate power, maintain, repair, and lubricate equipment, as well as clean and maintain tanks and filter beds.

Job Quality. The median wage in 2020 for water and liquid waste treatment plant Workers in California was $74,083 annually, or $35.62 hourly. Water and wastewater treatment operators usually receive benefits that may include health and life insurance, a retirement plan, and educational reimbursement for job-related courses. Holidays, vacation, and sick leave are also provided.[133]

Water and wastewater treatment operators work indoors and outdoors. Work is often physically demanding and performed in unclean locations, and operators may be exposed to noise from machinery and unpleasant odors. Operators must pay close attention to safety procedures because of the presence of hazardous conditions, such as dangerous gases and chemicals, and malfunctioning equipment. Operators must sometimes work during emergencies, as weather conditions may cause large amounts of storm water and wastewater to flow into sewers, exceeding a plant's capacity. Emergencies also may be caused by malfunctions within a plant, such as chemical leaks or oxygen deficiencies. Operators are trained in emergency management procedures and use safety equipment to protect their health as well as that of the public.

Union Status and Training. Operators have the opportunity to become members of various unions including Stationary Engineers, International Brotherhood of Electrical Workers, or International Union of Operating Engineers.[134] Many employers require an associate degree or certificate in water quality and wastewater treatment. These programs are offered by community colleges, technical schools, and trade associations. In some cases, a degree or certificate program can be substituted for experience, allowing a worker to become licensed at a higher level more quickly. Trainees usually start as attendants or operators-in-training and acquire skills on the job under the direction of an experienced operator. They learn by observing and doing routine tasks such as recording meter readings, taking samples of wastewater and sludge, and performing simple maintenance and repair work on pumps, electric motors, valves, and other plant equipment. Larger treatment plants often combine this on-the-job training with formal classroom or self-paced study programs.

Water treatment plant operators are required to have the proper certification which is offered by the State Water Resources Control Board (SWRCB).[135] There are five levels of certification for water treatment operators and distribution operators, and operators may be cross-certified for both treatment and distribution. The certification process requires operators to have specific amounts of on-the-job training, complete training courses, and pass a competency examination for each grade level of certification. Certification renewal for water operators is every three years and requires completion of continuing education units or contact hours. In addition, both tap water and wastewater are highly regulated by the U.S. Environmental Protection Agency and other state and local agencies. Operators should be aware of and keep current with state and federal regulations as well as Occupational Safety and Health Association (OSHA) standards.

Farmers

Farmers oversee and direct the daily activities on farms throughout California. Farmers mainly operate family-owned farms or lease farmlands that are smaller in size and production output than corporate-owned farms. Certain specialized farming methods are integral to California's green economy, such as regenerative and organic farming, which both fall under the broader rubric of "sustainable agriculture." Farms may also recycle animal and plant byproducts for other uses, such as composting or biogas generation, or specialize in growing energy specific crops like switchgrass.[136]

Sustainable farmers—both in regenerative and organic farming—manage the day-to-day business operations of farms according to sustainable standards of practice. Soil and water conservation and the use of clean renewable energy sources are fundamental to sustainable farming. Additional sustainable farming methods include the use of mushroom composting systems that can improve soil quality and plant growth, implementing tailwater retention systems that collect water runoff in collection ponds for irrigation use, and natural pest control methods like pheromone traps and interplanting crops with beneficial species that avoid reliance on toxic chemicals. Organic farmers, in particular, must meet strict certification guidelines set forth by such governing bodies as the California Certified Organic Farmers (CCOF).

Job Quality. The median income in 2020 for farmer owners in California was $86,622 annually, or $41.65 hourly, and farmers are typically responsible for providing their own insurance and benefits.[137] Farming incomes generally vary from year to year due to changing weather conditions and other factors that influence the price of farm products. Farmers do often also receive government subsidies or other payments that supplement their incomes and reduce some of the risk of farming.

Working conditions for farmers vary depending on the size of the farm and the type of crop or animal that is raised. Farmers who grow crops typically work from sunrise to sunset during the planting and harvesting seasons, while farmers at nurseries, greenhouses, and farms with livestock generally have work year-round and employees that work eight-hour shifts. Additionally, farm work can be dangerous, risking injury from machinery and exposure to toxic pesticides.

Union Status and Training. Union membership is not typical for farmers. Most farmers learn their jobs by growing up on a farm or through years of work experience, though completion of associate or bachelor's degree at a college of agriculture is becoming more common with the increasing sophistication of modern farming techniques. An organic farming apprenticeship is available at the College of Marin's Indian Valley campus, where apprentices can earn college credits while completing paid hands-on training at a local organic farm.[138] Farmers who specialize in sustainable and organic farming methods will need to stay current on federal and state laws as well as the most recent products and practices in their specialty. Certification is available for both sustainable and organic farming.[139]

Farm Workers and Laborers

Farmworkers and laborers play a crucial role in supplying the nation and world's food supply. The job can include planting, watering, pruning, and harvesting crops, and packaging fruits and vegetables. Farmworkers and laborers often identify diseased plants and markings left by pests or insects in order to remove them, and may use pesticides and herbicides to eliminate pests, insects, and weeds. Farmworkers and laborers may also perform general upkeep duties, such as repairing fencing or maintaining irrigation systems. In orchards or farms, farmworkers and laborers may operate large farm vehicles, such as tractor-trailers and combine harvesters. In nurseries and greenhouses, they may prepare land or greenhouse beds for growing horticultural products, such as trees, plants, flowers, and sod, and may also interact with customers.[140]

Job Quality. The median wage in 2020 for farmworkers and laborers in California was $26,104 annually ($12.55 hourly).[141] Benefits are uncommon, although some employers may offer sick leave, paid vacation, and health benefits. Working conditions may vary depending on the type of farm or nursery where they work, but generally farmworkers and laborers spend most of their time outside under a wide range of weather conditions. They may spend long periods of time bent over and may be required to lift and carry heavy items. Long periods of time working in direct sun can pose serious health risks, especially during very hot weather conditions when they can face the risk of dehydration and other illnesses. When working under industrial farming practices, as opposed to sustainable methods, farmworkers and laborers may be exposed to herbicides, pesticides, and other hazardous chemicals that are sprayed on crops or plants.

Work schedules vary by type of workplace. Work in nurseries and greenhouses is often year-round, whereas crop farmworkers and laborers are employed seasonally. Long hours and working on weekends is common, and farmworkers and agricultural equipment operators often work six or seven days a week during planting and harvesting seasons.

Union Status and Training. Union membership is uncommon but some farmworkers may belong to unions such as the United Farm Workers of America.[142] A high school diploma and formal training is typically not required for farmworkers and laborers, and workers without high school diplomas are particularly common in the crop production sector. Most learn on the job, and may need one month to one year of on-the-job training depending on the job's responsibility level.

Recreation Workers

Recreation workers plan, organize, and direct people in a variety of activities, such as arts and crafts, camping, hiking, swimming, and sports. They promote and facilitate participation in recreational activities and programs, while taking into consideration the abilities and needs of individual participants. A recreation worker's job may include setting up and laying out materials or equipment for the day's activities, scheduling the use of the facility, keeping records, and making sure the recreation equipment and facilities are used properly. Recreation workers enforce rules and regulations of recreational facilities to ensure safety, and manage the daily operations of recreational facilities. They also explain principles, techniques, and safety procedures to participants in recreational activities, and demonstrate use of materials and equipment.[143]

Job Quality. The median wage in 2020 for recreation workers in California was $30,511 annually ($14.67 hourly).[144] Most public and private recreation agencies provide full-time recreation workers with health and life insurance, vacation, sick leave, and pension plans; although part-time workers receive few benefits. Recreation workers may work in various settings, such as community centers, playgrounds, and parks, and most of these workers spend their time outdoors in a variety of weather conditions. They may work 40 hours a week, although, the majority work part-time, nights, weekends, irregular hours, and seasonally. Public recreation agencies depend upon state and local government funding, and there may be fewer employment opportunities during economic downturns.

Union Status and Training. Unionization is not common in this occupation. However, recreation workers who work for government agencies usually join a union. Recreation workers with formal training and prior work experience or graduate degrees may have better opportunities for job placement. Full-time professional positions generally require a bachelor's degree in parks and recreation or leisure studies. A part-time or summer job may only require a high school diploma (or equivalent), along with a short period of on-the-job training.

Some employers may require previous volunteer or work experience in the recreational field. Participation and leadership experience in Scouting, 4-H Clubs, and other community activities may provide valuable skills and experience for this occupation. Additionally, some recreation occupations may require certifications, such as Certified Park and Recreation Professional, Computer Fundamentals, Lifeguard, Safety-Certified Riding Instructor, and Standard First Aid. Continuing education is necessary for recreation workers to keep their certifications valid.[145]

5. TOTAL JOB CREATION IN CALIFORNIA THROUGH COMBINED INVESTMENT PROGRAMS

We include this brief Section 5 in order to bring together and highlight our estimates of the overall employment impacts of the full set of investment programs we have presented in Sections 3 and 4. These include:

- Investments in energy efficiency and clean renewable energy, targeted at bringing down CO_2 emissions in California by 50 percent as of 2030;
- Investments in manufacturing and public infrastructure that will raise productivity throughout the state and also advance new areas of industrial opportunity.;
- Investments in land restoration and agriculture that will create new opportunities for family farms, marginalized farmers, and plugging orphaned oil and gas wells, while also reducing energy use and pollution.

As we have shown in Sections 3 and 4, we have scaled these investment projects at an average of $137.5 billion per year over 2021 – 2030, equal to about 3.8 percent of California's projected midpoint GDP for 2021 – 2030, i.e. the state's GDP between 2025 and 2026 (assuming the state's average growth rate is 2.5 percent per year). The proposed budget allocations include an average of $75.8 billion per year for clean energy, including $66.4 billion in clean renewable energy and $9.3 billion in energy efficiency. This is the figure that we have estimated will be needed to achieve a 50 percent reduction in California's CO_2 emissions by 2030. Working from the national THRIVE Agenda, we have also budgeted $39.2 billion per year for manufacturing/public infrastructure investments along with $22.6 billion per year for land restoration/agriculture investments.

We summarize the impact of these investment projects in Table 5.1. As the table shows, we estimate that these projects, in combination, will generate about 780,000 direct and indirect jobs per year in California, amounting to about 4.0 percent of California's labor force as of 2019. When we include induced job creation (i.e. "multiplier effects"), total job creation rises to 1,043,986 jobs, equal to about 5.4 percent of California's 2019 labor force.

As a simple exercise to illustrate the potential impact of this level of job creation in California, let us assume that these investments are undertaken in the state, and all else about the state's economy were to remain equal. Under such an "all else equal" assumption, this level of job creation would result, for example, in the state's unemployment rate falling from, say, its December 2020 level of 9 percent to roughly 3.6 percent. A reduction in California's unemployment rate at this scale would, of course deliver a major expansion in job opportunities throughout the state. It would also provide a foundation for a corresponding improvement in living conditions for most people in the state.

TABLE 5.1

Annual Job Creation in California through Combined Investment Programs

- Clean Energy
- Manufacturing/Infrastructure
- Land Restoration/Agriculture

Estimates are annual averages for 2021 – 2030

Overall Investments at $137.6 billion/year; 3.8% of California $3.61 trillion mid-point GDP

	Number of direct and indirect jobs created	Number of direct, indirect and induced jobs created
1) $66.4 billion/year in clean renewable energy	241,240	347,560
2) $9.3 billion/year in energy efficiency	53,421	70,350
3) $39.2 billion/year in manufacturing/public infrastructure	298,202	384,676
4) $22.6 billion/year in land restoration/agriculture	187,509	241,400
5) Total for all investment areas *(= rows 1 – 4)*	780,372	1,043,986
13) TOTAL AS SHARE OF 2019 CALIFORNIA LABOR FORCE *(labor force at 19.4 million)*	**4.0%**	**5.4%**

Sources: See Tables 3.5 and 4.6.

6. CONTRACTION OF CALIFORNIA'S FOSSIL FUEL INDUSTRIES AND JUST TRANSITION FOR FOSSIL FUEL WORKERS

As we have shown above, in order for California to bring total CO_2 emissions down from its 2018 level of 389 million tons to no more than about 193 million tons by 2030, we have developed a 10-year program for reducing the consumption of natural gas, oil, and high-emissions bioenergy by 50 percent as of 2030, and to phase out coal consumption completely. As we have seen, oil and natural gas provided 83 percent of California's overall energy supply in 2018 including electricity imports from other states. High-emissions bioenergy plus coal contributed another 4 percent.[146] That is, oil and natural gas are the predominant sources of energy supply in California at present.

The issue on which we focus in this section is what the impact will be on workers in industries in California that are dependent on statewide consumers continuing to purchase fossil fuels. We assume that, through 2030, production activity and employment in the oil and gas industries will also decline at approximately the same rates as fossil fuel energy consumption in the state—i.e. by 50 percent.[147] In particular, we develop here a just transition program for the workers in these fossil fuel related sectors who will face displacement as a result of the statewide contraction in the consumption of CO_2-producing energy sources.

Our primary focus in this section is on the *direct* jobs that will be lost in California through the contraction of the state's fossil fuel-based and bioenergy industries. Our reasoning for focusing on the contraction of direct jobs is the same as we discussed above with respect to the job quality issues regarding clean energy investments in the state. That is, the direct jobs that will be lost in California through the cuts in CO_2-generating energy sources are the jobs that are, at present, most closely associated with the state's fossil fuel-based industry activities. The workers currently employed in these jobs will therefore be the ones that will be most in need of just transition support as California phases out these CO_2-generating activities. The jobs that will be lost through the indirect and induced channels will be more diffuse in their characteristics. A high proportion of the jobs lost through the indirect channels are likely to match up reasonably well with those in the clean energy economy, including in areas such as administration, clerical, professional services, and transportation services. The characteristics of the induced jobs created will simply reflect the overall characteristics of California's present-day workforce. The job losses that will result through the indirect and induced channels can therefore be appropriately managed through the same set of policies that are available to all workers in California who experience unemployment. We return to this issue below, after we first review here job figures and policies to support a just transition as they apply to the direct jobs that will be lost.

Measuring Direct Employment Levels

In Table 6.1, we show employment levels for the 14 fossil-fuel and ancillary industries in California as of 2018.[148] As we see, as of 2018, there are 112,482 people employed in the fossil fuel and ancillary industries in California. Of these, 32,290 (29 percent) are employed in natural gas distribution, 27,720 (25 percent) work in oil and gas extraction, 11,203 (10.0 percent) are in petroleum refining and 10,259 (9.1 percent) are in support activities for the oil and gas industry. Thus, these four sectors—natural gas distribution, extraction, refining, and support activities—together account for over 73 percent of total employment in all of California's fossil fuel-based industries. Taken as a whole, the 112,482 people employed in California's fossil fuel-based industries account for only 0.6 percent—a bit more than one-half of one percent—of all employment in the state.

TABLE 6.1
Number of Workers in California Employed in Fossil Fuel-Based Industries, 2018

Industry	2018 Employment levels	Industry share of total fossil fuel-based employment
Natural gas distribution	32,290	28.7%
Oil and gas extraction	27,720	24.6%
Petroleum refining	11,203	10.0%
Support activities for oil/gas	10,259	9.1%
Wholesale -petroleum and petroleum products	8,751	7.8%
Fossil fuel electric power generation	8,658	7.7%
Drilling oil and gas wells	5,288	4.7%
Pipeline transport	2,660	2.4%
Construction of other new residential structures	2,309	2.1%
Other nonmetallic minerals services	1,571	1.4%
Coal mining	971	0.9%
Oil and gas field machinery and equipment manufacturing	693	0.6%
Mining machinery and equipment manufacturing	74	0.07%
All other petroleum and coal products manufacturing	35	0.03%
Fossil fuel industry total	**112,482**	**100.0%**
TOTAL FOSSIL FUEL EMPLOYMENT AS SHARE OF CALIFORNIA STATE EMPLOYMENT *(California 2018 employment = 18,460,725)*	**0.61%**	

Source: IMPLAN 3.1, U.S. Department of Labor.

Characteristics of Fossil Fuel-Based Industry Jobs

Table 6.2 provides basic figures on the characteristics of the direct jobs in California for workers in fossil fuel-based sectors. We first see that, on average, these are high-paying jobs. The average overall compensation is a bit less than $129,800, about 34 percent more than the $97,000 average pay level for solar industry workers, who, on average, are the highest paid in California's clean energy sectors.

In terms of private health insurance coverage, the fossil fuel industries are, for the most part, providing coverage for their workers, with 70 percent of workers receiving employer-based insurance. This level of health insurance coverage is consistently much higher than is generally the case with the industries that would expand as a result of clean energy investments. As we saw in Table 3.6, the extent of health insurance coverage in the clean energy industries generally ranges between 34 – 48 percent. Nearly 65 percent of the fossil fuel-based workers also receive retirement benefits from their jobs. This is in contrast with the various clean energy industries, in which between about 24 – 33 percent of workers receive retirement benefits. Union membership is at about 23 percent. This is higher than all of the various clean energy industries, in which union membership ranges between 7 – 19 percent. It is also much higher than the figure for the overall private U.S. economy, at 6.2 percent.

Table 6.2 also reports figures on educational credential levels for workers in the fossil fuel-based sectors, as well the percentages of workers who are women and people of color. With respect to educational credentials, the overall level of attainment is relatively high, with about 35 percent having Bachelor's degree or higher, and another 35 percent have some college or an Associate degree. The remaining 30 percent have high school degrees only or less.

TABLE 6.2
Characteristics of Workers Employed in California's Fossil Fuel-Based Sectors

	Fossil fuel-based industries
Average total compensation	$129,800
Health insurance coverage*	70.0%
Retirement benefits*	64.7%
Union membership coverage	22.7%
Educational credentials	
Share with high school degree or less	29.5%
Share with some college or Associate degree	35.3%
Share with Bachelor's degree or higher	35.2%
Racial and gender composition of workforce	
Pct. Black, Indigenous and People of Color	44.6%
Pct. female workers	21.5%

Source: See Appendix 2.

Note: *Due to small sample sizes, these figures are based on the Pacific region rather than California only.

Women account for only 22 percent of the workforce. The percentage of Black, Indigenous and People of Color (BIPOC), is high, at 45 percent, but still lower than the share for California's overall population, which is 63 percent, including Latinx, Asian Americans, African Americans and people with multiracial backgrounds.

In Table 6.3, we gain further detailed information on workforce and employment conditions for workers in California's fossil fuel-based industries. We show the most prevalent job categories and the representative occupations in each job category.

The key finding that emerges from these tables is that the fossil fuel-based industries in California provide a wide range of employment opportunities for the nearly 113,000 workers currently employed in these industries. As we see, the largest share of jobs, at roughly 18 percent, are in construction, including, as examples, laborers, electricians and equipment operators. The next largest category is "production," including jobs for power plant operators, inspectors and first-line supervisors. But other job categories—including engineering, management, extraction, installation and office support—each account for 8 percent or more of total employment.

Overall, from the data presented in Table 6.3, we see that there are a large number of jobs, probably a majority, that match up well with new types of employment that will be generated through clean energy investments in California, as well as expanded investments in public infrastructure. But this will not be the case with *all occupations* in which workers are now employed in California's fossil fuel-based activities. As such, any just transition program to support displaced workers in California's fossil fuel related industries will need to be focused on the specific background and skills of each of the impacted workers. We now turn to estimating the magnitude of this problem as California transitions out of CO_2-generating energy sources.

TABLE 6.3
Prevalent Job Types in California's Fossil Fuel-Based Industries
(Job categories with 5 percent or more employment)

Job category	Percentage of direct jobs	Representative occupations
Construction	17.5%	Construction equipment operators, laborers; electricians
Production	12.4%	Power plant operators; inspectors; first-line supervisors
Architecture and engineering	12.4%	Engineering technicians; material engineers; chemical engineers
Management	10.4%	Financial managers; engineering managers; marketing managers
Extraction	9.9%	Earth drillers; roustabouts; mining machine operators
Installation and maintenance	9.4%	Home appliance repairers; electric powerline installers; control and valve repairers
Office and administrative support	7.9%	Secretaries; production clerks; office clerks

Source: See Appendix 2.

Features of a Just Transition Program

We present here a just transition program for workers who will directly face job losses through the 50 percent contraction of the state's oil and gas industries. Our discussion here is in alignment with the proposals on just transition and related measures for California development in the extensive 2020 study *Putting California on the High Road*.[149] Thus, in this study's chapter focused specifically on just transition policies (Chapter 4), J. Mijin Cha writes the following:

> The state could work to identify the most vulnerable industries, firms and localities through research and engagement of business, labor, and community, and develop a set of the most likely job disruption scenarios through 2030. For each scenario, the task force could develop cost estimates for a transition plan, incorporating a variety of assistance packages, options for retraining and job displacement, and considerations regarding the speed of industry transition, and firm and worker characteristics such as the health of pension plans and the age of workforce (2020, pp. 167 – 168).

The specific policy measures we consider here, consistent with these priorities highlighted by Cha, include three major elements:

1. Guaranteeing the pensions for the workers in affected industries who will retire up until the year 2030;
2. Guaranteeing re-employment for workers facing displacement;
3. Providing income, retraining, and relocation support for workers facing displacement.

We describe each feature of this program in what follows, as well as provide estimates of the costs of effectively operating each measure within the overall program.

To translate these general principles of a just transition into specific policies, and to estimate the costs of providing these policies, we now examine a basic policy package. We present the provisions of this policy package in Table 6.4.

TABLE 6.4
Policy Package for Displaced Workers in California's Fossil Fuel-Based Industries

Pension guarantees for workers (65+) voluntarily retiring	– Legal pension guarantees
Employment guarantee	– Jobs provided through clean energy and public infrastructure investment expansions
Wage insurance	– Displaced workers guaranteed 3 years of total compensation at levels of fossil fuel-based industry jobs
Retraining support	– 2 years of retraining, as needed
Relocation support	– $75,000 for one-half of displaced workers

Source: Assumptions described in text.

As we see in Table 6.4, the detailed policy package includes five components. These are:

1. Pension guarantees for retired workers who are covered by employer-financed pensions, starting at age 65;
2. Re-employment for displaced workers through an employment guarantee, with 100 percent wage insurance. With wage insurance, workers are guaranteed that their total compensation in their new job will be supplemented to reduce any losses relative to the compensation they received working in the fossil fuel-based industry;
3. Retraining, as needed, to assist displaced workers to obtain the skills required for a new job;
4. Relocation support for 50 percent of displaced workers, assuming only 50 percent will need to relocate; and
5. Full just transition support for workers 65 and over who choose not to retire.

Steady versus Episodic Industry Contraction

We will provide further details and cost estimates for each of these measures within the overall policy package. But before moving into the discussion of these cost estimates, it is first necessary to understand how any such policy measures will be affected by the conditions under which the fossil fuel-based industries contraction occurs in California. Specifically, the scope and cost of any set of just transition policies will depend substantially on whether the contraction is steady or episodic.

Under a pattern of steady contraction, there will be uniform annual employment losses between 2021 – 2030 in the affected industries. But it is not realistic to assume that the pattern of industry contraction will necessarily proceed at a steady rate. An alternative pattern would entail relatively large episodes of employment contraction, followed by periods in which no further employment losses are experienced. This type of pattern would occur if, for example, one or more relatively large firms were to undergo large-scale cutbacks at one point in time as the industry overall contracts, or even for such firms to shut down altogether.

The costs of a 10-year just transition will be much lower if the transition is able to proceed steadily rather than through a series of episodes. One reason is that, under a steady transition, the proportion of workers who will retire voluntarily in any given year will be substantially greater than if several large businesses were to shut down abruptly and lay off their full work force at a given point in time. Related to this, through a series of large-scale episodic contractions, significant numbers of workers who are approaching retirement age but are not yet 65 will be included in the pool of laid-off workers when any given episode of layoffs occurs. It would not be reasonable to expect these workers in, say, the 60 – 64 age cohort to have to retrain and possibly relocate to take up new occupations. Under an episodic contraction, these workers will therefore need to be offered the option of income support at their existing pay level until they are able to start receiving income from their pension funds.

In what follows, we first describe how a steady transition pattern would proceed. We then examine the transition conditions while assuming that the industry phase-down occurs in episodes.

Steady Contraction

Estimating Attrition by Retirement and Job Displacement Rates

In Table 6.5, we show figures on annual employment reductions in California's fossil fuel-based industries over 2021 – 2030 that would result from a steady contraction of these industries. [150] We also then show the proportion of workers who will move into voluntary retirement at age 65 by 2030. Once we know the share of workers who will move into voluntary retirement at age 65, we can then estimate the number of workers who will be displaced through the 50 percent contraction in oil and gas. As described above, the just transition program will provide support for all displaced workers through a re-employment guarantee along with wage insurance, retraining, and relocation support.

All forms of just transition support will also be fully available to those workers 65 and over who choose to continue working. We therefore need to estimate how many workers 65 and older are likely to choose to remain employed. For the fossil fuel sector taken as a whole, we approximate that about 20 percent of workers who are 65 and over choose to continue on their jobs.[151] We therefore assume that this same 20 percent of older workers will choose to continue working while the fossil fuel-based sectors undergo their contractions between 2021 – 2030. Specifically, we incorporate into our calculations in Table 6.5 an estimate that, of the total number of workers reaching age 65 in any given year, 80 percent will retire voluntarily while 20 percent will choose to continue working.

TABLE 6.5
Attrition by Retirement and Job Displacement for Fossil Fuel Workers in California
STEADY TRANSITION

	Fossil fuel workers
1) Total workforce as of 2018	112,482
2) Job losses over 10-year transition, 2021 – 2030	57,548
3) Average annual job loss over 10-year production decline *(= row 2/10)*	5,755
4) Number of workers reaching 65 over 2021 – 2030 *(=row 1 x % of workers 54 and over in 2019)*	31,720 *(28.2 % of all workers)*
5) Number of workers per year reaching 65 during 10-year transition period *(=row 4/10)*	3,172
6) Number of workers per year retiring voluntarily	2,538 *(80% of 65+ workers)*
7) Number of workers requiring re-employment *(= row 3 - row 6)*	3,217

Source: Table 6.1.

Note: The 80 percent retirement rate for workers over 65 derived from U.S. Bureau of Labor Statistics data: https://www.bls.gov/cps/cpsaat03.htm. According to these BLS data, 20 percent of 65+ year-olds remain in the workforce.

We can see, step-by-step, how these various considerations come into play through the figures we show in Table 6.5. As we again see in column 2 of Table 6.5, there were, as of the most recent 2018 figures, 112,482 workers in California employed in all fossil fuel-based industries. We assume that all the oil and natural gas-based industries will contract by 50 percent. As we see in row 2 of the table, this means that total employment in these sectors will fall by 57,648 as of 2030, which means that there will be same number of jobs, 57,648, retained. If we then assume that the contraction in these industries proceeds at a steady rate between 2021 – 2030, this means that 5,755 jobs in these industries will be lost each year, as we see in row 3 (i.e. 57,548 job losses in total/10 years of industry contraction = 5,755 job losses per year).

We see in row 4 that, of the workers presently employed in these sectors in California, 31,720, or 28 percent, will be between 55 – 65 over 2021 – 2030. If all these workers were to voluntarily retire at a steady rate over 2021 – 2030, this would mean that 3,172 workers will move into retirement every year over the 10-year period. However, we are assuming that only 80 percent of these workers will retire once they reach 65. That is, as we see in row 6, we estimate that 2,538 workers employed in these sectors will retire voluntarily every year between 2021 – 2030.

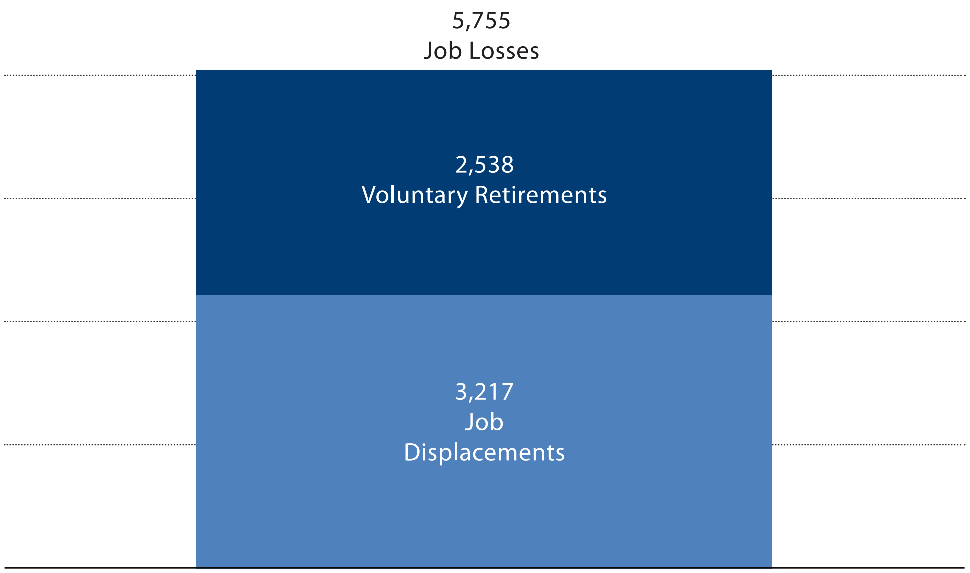
Given that total job losses each year will average 5,755 over the 2021 – 2030 period, that in turn means that the total number of workers currently employed in California's fossil fuel-based sectors that will require re-employment will be 3,217 per year. We show this figure in row 7 of Table 6.5.

This is a critical result. The immediate point it establishes is that the just transition program will need to focus in two areas: 1) Guaranteeing the pensions for the 2,538 workers per year moving into voluntary retirement; and 2) Providing all the forms of re-employment support, including the re-employment guarantee, for the 3,217 workers per year facing displacement. Of course, these figures are not meant to be understood as precise estimates, but rather to provide broadly accurate magnitudes. Among other factors beyond what these figures themselves show, we again have to recognize that the pattern of contraction is not likely to be as smooth as is being assumed in our calculations. We therefore do consider below an alternative scenario, in which the fossil fuel industry phase out is episodic.

Nevertheless, precise details aside, it is the overall finding from this steady contraction pattern that is most central: that the number of workers in California who are likely to experience job displacement through the state's transitioning away from CO_2-generating energy sources will be small—indeed, the number of workers facing displacement should be in the range of 3,000 – 3,500 per year. Given that there are over 112,000 people employed presently in California's fossil fuel-based industries, we acknowledge that it may appear implausible that there should be only about 3,000 workers per year who would be displaced through a program to cut consumption from CO_2-generating energy sources by 50 percent as of 2030. But as we saw in Table 6.5, this finding is not due to any kind of unreasonable assumptions or incomprehensible mathematical manipulations.

In Figure 1, we illustrate the main results of our calculations in Table 6.5.

FIGURE 1: Estimated Annual Job Losses, Voluntary Retirements and Workers Displaced in California's Fossil Fuel-Based Industries, 2021–2030



Source: Table 6.5.

Cost Estimates for a Just Transition Program with Steady Contraction

Pension Guarantees for Retiring Workers

What becomes clear from the patterns we have presented on the steady contraction of California's fossil fuel industry over 2021 – 2030 is that guaranteeing workers' pension funds must be a centerpiece of the state's overall just transition program. The fossil fuel firms that employ the workers and manage their pension funds will certainly experience significant financial challenges during all phases of their phase-out through 2045.

In Table 6.6, we provide evidence on the status of the pension funds for the 17 fossil fuel firms currently that account for 94 percent of California's oil production, 95 percent of its gas production, and 89 percent of its operating wells. The table shows the names of the 17 firms operating in the state as well as, in parentheses, these firms' parent companies, where applicable.

We have divided the 17 firms into three groups:

- 4 publicly traded firms that provide pensions to their employees;
- 3 publicly traded firms that do not provide pension plans; and
- 10 private firms for which there is no publicly available information on pensions or other financial data.

Of these three groups, the publicly listed firms with pension plans account for 46 percent of oil and 36 percent of gas that is produced in California. The publicly listed firms without pension plans produce 30 percent of the state's oil and 59 percent of gas. The private companies account for 18 percent of California's oil and 4 percent of its gas production.

TABLE 6.6
Status of Pension Funds of Major Oil and Gas Companies in California
Parent companies in parentheses

A) Public firms with pension data

Property	Unfunded pension liabilities, 2019	Net income, 2017-2019	Dividends, 2017-2019*	Share buybacks, 2017-2019
Aera Energy, LLC (Royal Dutch Shell, PLC)	$0 *(overfunded by $1.1 billion)*	$17.9 billion	$13.9 billion	$4.7 billion
Chevron USA, Inc. (Chevron Corporation)	$1.5 billion	$9 billion	$ 8.5 billion	$1.9 billion
Seneca Resources Company, LLC (National Fuel Gas Company)	$60 million	$326.4 million	$143.2 million	$3.0 million***
Southern California Gas Company (Sempra Energy)**	$203.5 million	$1.3 billion	$952.0 million	$20.7 million

Notes: *Distribution to non-controlling interests not included in dividends. Includes common and preferred dividends. **Sempra Energy 10-K SEC filings also include separate financial statements for Southern California Gas Company. The parent company is reported here. ***National Fuel Gas Company reports net issuance/repurchase of stock. In 2017 and 2018, this resulted in negative net values of dividends paid of -$7.78 and -$4.11 million, respectively.

B) Public firms without pension data

Property	Net income, 2017-2019	Dividends, 2017-2019*	Share buybacks, 2017-2019
Berry Petroleum Company, LLC (Berry Corporation (bry))**	$56.5 million	$19.3 million	$7.9 million
California Resources Corporation***	$88.7 million	$0	$0
Carbon California Operating Company, LLC (Carbon Energy Corporation)	$6.1 million	$0	$0

Notes: *Distribution to non-controlling interests not included in dividends. Includes common and preferred dividends. **Berry Corporation 2017 data excludes first two months of the year. ***California Resources Corporation is the parent of the following top 20 oil and gas producers in CA: California Resources Elk Hills, LLC; California Resources Production Corporation; Thums Long Beach Company; Tidelands Oil Production Company.

C) Private firms with no public data

Property
Bridge Energy, LLC
Breitburn Operating, LP (EIG Global Energy Partners)
Crimson Resource Management Corporation
E & B Natural Resources Management Corporation (Rotterdam Ventures, Inc.)
Holmes Western Oil Corporation
Macpherson Oil Company (Macpherson Energy Corporation)
Sentinel Peak Resources California, LLC
Signal Hill Petroleum, Inc.
Vaquero Energy, Inc.
Warren E & P, Inc. (Warren Resources)

Given that we have information on only 7 of these 17 firms, and that only 4 of those 7 firms operate pension plans for their workers, it is difficult to generalize about how best to protect pensions for the workers of all 17 firms. Focusing first on the 4 publicly traded firms in panel A which do provide pensions for their workers, we see that, in 2019, 3 of these firms were carrying unfunded liabilities, while only one, Aera Energy, whose parent company is Royal Dutch Shell, is holding an overfunded pension account. Of the three with unfunded liabilities, none of the unfunded liabilities are large relative to the firms' other financial indicators. Thus, Chevron has the largest unfunded liability, at $1.51 billion. However, its net income for 2017 – 2019 was $9 billion. Chevron also distributed $8.5 billion in dividends and bought back $1.93 billion of its own shares in 2017 – 2019. Southern California Gas, whose parent company is Sempra Energy, is carrying the next largest unfunded liability, at $204 million as of 2019. But it received $1.3 billion in income over 2017 – 2019. It also paid out $952 million in dividends and bought back $21 million of its own shares over 2017 – 2019. Seneca Resources held $60 million in unfunded liabilities in 2019, while earning $326 million in income over 2017 – 2019. It also paid out $143 million in dividends and bought back $3 million of its own shares over 2017 – 2019. With these 4 firms, it is reasonable to conclude that all of their pension funds were financially sound as of 2019. This status needs to be guaranteed through financial regulations as California's fossil fuel industry contracts.

Considering now the 3 publicly-traded firms shown on panel B which do not provide pensions for their employees, we see from the available data that two, Berry Petroleum and California Resources, generated significant profits—$57 million and $89 million respectively—over 2017 – 2019 while the third, Carbon California, received a modest $6.1 million in income.[152] But only Berry Petroleum distributed dividends or engaged in stock buybacks over 2017 – 2019. The workers employed by these firms will not face any threat of losing their pensions, since they have not been provided with pension plans to begin with. But given their lack of pension fund support, it will be critical that the workers at these firms be provided with the full range of additional just transition support as they face displacement.

We cannot generalize about the 10 private firms listed in panel C, since we have no financial data on their operations. But it is likely that, like the 10 firms listed in panel B, they are not providing pensions for their workers.

Because of the large differences in the situations facing these 17 firms according to the three main categories in which they fall, it would be most useful to focus on some general points on the issue of pension fund protection as a feature of a just transition program. The first point is that, since, overall, these firms will need to contract by 50 percent as of 2030, we cannot expect those that are carrying pension funds are planning to replenish them over this period as a matter of course. It should therefore be a priority of California state policy to mandate full funding, to the extent that this is possible within existing state law or through establishing new regulations. This could also be achieved in coordination with federal government regulators, at the Pension Benefit Guarantee Corporation (PBGC). One way to enforce this would be to prohibit the relevant companies from paying dividends or financing share buybacks until their pension funds have been brought to full funding and then maintained at that level. As needed, the state government, again in coordination with the PBGC, could consider placing liens on company assets when pension funds are underfunded. Through such measures, the pension funds for most of the affected workers can be protected through a regulatory intervention alone, without the government having to provide financial infusions to sustain the funds.

At the same time, it is likely that one or more of these firms have already experienced severe financial difficulties during the 2020 COVID-induced recession and will continue to struggle even as a recovery begins, since the market for their products will be contracting substantially through 2030 and beyond. As a roughly comparable case in point, some coal companies operating throughout the U.S. do now already face critical conditions with their pension funds, due to cutbacks in U.S. coal demand. Under such conditions, the pension commitments to the affected coal industry workers will still need to be fully honored.

In addressing the longstanding crisis with coal industry pensions, the Obama administration had proposed in 2015 a measure to support the pensions, under its "Power Plus" program that aimed broadly to support coal communities and workers.[153] This proposal was blocked in the U.S. Congress by the Republican majority. But the broader point is that the equivalent of such a measure must be understood as a centerpiece for any just transition program for California. Without having further detailed information on the current status of the pension plans for all 17 firms listed in Table 6.6, we cannot estimate what the funding would need to be for a California oil and gas-specific equivalent of the Obama administration's Power Plus proposal for the U.S. coal industry. But, in general, a pension insurance-type policy is a measure that deserves careful attention in ongoing work to develop specifics of California's just transition program.

Major new employment opportunities will certainly open up as a result of the large-scale investments in the areas of clean energy, infrastructure/manufacturing, and land restoration/agriculture. As we have presented in Sections 2 – 4, we estimate that clean energy investments in California, budgeted at about $76 billion per year, will generate about 300,000 direct and indirect jobs within the state. Investments in infrastructure/manufacturing and land restoration/agriculture, budgeted at about $62 billion per year, in alignment with the national THRIVE Agenda, will generate about 490,000 direct and indirect jobs. Total direct and indirect employment creation through these combined investment programs would therefore amount to about 780,000 jobs (see summary Table 5.1). The clean energy investments will be partially financed through public-sector funding while the infrastructure/manufacturing and land restoration/agriculture jobs will be predominantly financed through public funds. Because of this high level of public funding, the state will have the leverage to require job preference provisions for the displaced workers. Again, our estimate of the number of displaced workers that will need re-employment is about 3,200 per year in total. It will not be difficult for the state to set aside 3,200 guaranteed jobs per year for these displaced workers.

Income Support through Wage Insurance

Overall then, it should not be difficult to find new employment opportunities for the roughly 3,200 fossil fuel-based workers that, through a steady contraction rate, will be displaced annually on average. But there is a high likelihood that, for workers currently employed in the fossil fuel-based industries and re-employed in clean energy activities, their new jobs will be at lower pay levels than their previous jobs. We report the relevant figures in Table 6.7. As we see there, we estimate that the average compensation for displaced workers will be $129,800. This compares with the average compensation for all the clean energy investment sectors, which, as Table 6.7 shows, is $85,300. That is, the difference in average pay is $44,500 between workers currently employed in California's fossil fuel-based industries versus those in the various clean energy sectors. It will therefore be necessary for the fossil fuel-based sector workers to be provided with wage insurance so that they experience no income losses in their transition from fossil fuel industry jobs into new positions.

TABLE 6.7
Estimating Costs of 100 Percent Compensation Insurance for Displaced Workers in California's Fossil Fuel-Based Sectors

1. Number of fossil fuel-based displaced workers per year requiring re-employment	3,217
2. Average compensation for displaced workers	$129,800
3. Average compensation for clean energy sector jobs	$85,300
4. Average compensation difference between fossil fuel-based and clean energy jobs *(= row 2 – row 3)*	$44,500
5. Annual cost of compensation insurance for 2,317 workers *(= row 4 x row 1)*	$143.2 million
6. Total cost of compensation insurance for 3 years *(= row 5 x 3)*	$429.5 million

Sources: See Tables 3.6, 6.4 and 6.5.

To provide some specifics on the costs of providing wage insurance for displaced workers who move into jobs at lower pay levels, we propose that all displaced workers facing pay cuts receive 100 percent compensation insurance for three years. That is, they will be paid the full difference between any disparities in the compensation they receive in their new jobs relative to what they received in their previous jobs in the fossil fuel-related industries—that is, as an average, $44,500 per worker for three years. From this difference in average compensation levels, we then calculate that the annual cost of compensation insurance for 3,217 displaced workers to be about $430 million.

Retraining Support

As we have seen above (Tables 3.7-3.13), the range of new jobs that are being generated through clean energy investments vary widely in terms of their formal educational credentials as well as special skill requirements. Some of the jobs will require skills closely aligned with those that the displaced workers used in their former fossil fuel-based industry jobs. These include a high percentage of construction-related jobs for efficiency investments as well as most management, administrative and transportation-related positions throughout the clean energy industries. In other cases, new skills will have to be acquired to be effective at the clean energy industry jobs. For example, installing solar panels is quite distinct from laying oil and gas pipelines. This is why a just transition program must include a provision for retraining for the displaced fossil fuel-based industry workers. The just transition program will also need to serve as a job placement clearinghouse for all displaced workers.

There will be two components of this job retraining program for displaced workers. The first will be to finance the actual training programs themselves. We can estimate this with reference to the overall costs of providing community college education. An average figure for annual non-housing costs for community college in California is around $1,330.[154] We then also allow an additional $665 per year per worker (50 percent of $1,330) to cover other expenses during their training program, such as purchases of textbooks and equipment. We assume that workers would require the equivalent of two full years of training, which they would most likely spread out on a part-time basis, as they move into their guaranteed jobs. By this measure, the average costs of the training program for 3,217 workers would be about $6.4 million per year.

Relocation Support

Some of the displaced workers will need to be relocated to begin their new jobs. For the purposes of our discussion, we assume that one-half of the 3,217 displaced workers per year will need relocation allowances, at an average of $75,000 per displaced worker.[155] That would bring the annual relocation budget to about $121 million for 1,609 workers each year.

Overall Costs for Supporting Displaced Workers under Steady Contraction

In Table 6.8, we show estimates of the full costs of providing this set of wage insurance, retraining and relocation support for 3,217 workers per year. As Table 6.8 shows, the total level of annual spending will vary, depending largely on the number of cohorts of displaced workers that are receiving just transition benefits.

TABLE 6.8
Total and Annual Average Costs for Just Transition Support for Displaced Fossil Fuel-Based Workers in California, 2021 – 2032
STEADY TRANSITION

Year	Income support *(3 years of support for 3,217 workers)*	Retraining support *(2 years of support for 3,217 workers)*	Relocation support *(1 year of support for 1,609 workers)*	Total *(cols. 1+2+3)*
2021	$143.2 million (1 cohort)	$6.4 million (1 cohort)	$120.7 million	$270.3 million
2022	$286.3 million (2 cohorts)	$12.8 million (2 cohorts)	$120.7 million	$419.9 million
2023	$429.5 million (3 cohorts)	$12.8 million (2 cohorts)	$120.7 million	$563.0 million
2024	$429.5 million (3 cohorts)	$12.8 million (2 cohorts)	$120.7 million	$563.0 million
2025	$429.5 million (3 cohorts)	$12.8 million (2 cohorts)	$120.7 million	$563.0 million
2026	$429.5 million (3 cohorts)	$12.8 million (2 cohorts)	$120.7 million	$563.0 million
2027	$429.5 million (3 cohorts)	$12.8 million (2 cohorts)	$120.7 million	$563.0 million
2028	$429.5 million (3 cohorts)	$12.8 million (2 cohorts)	$120.7 million	$563.0 million
2029	$429.5 million (3 cohorts)	$12.8 million (2 cohorts)	$120.7 million	$563.0 million
2030	$429.5 million (3 cohorts)	$12.8 million (2 cohorts)	$120.7 million	$563.0 million
2031	$286.3 million (2 cohorts)	$6.4 million (1 cohort)		$292.8 million
2032	$143.2 million (1 cohort)			$143.2 million
Total	**$4.3 billion**	**$128.4 million**	**$1.2 billion**	**$5.6 billion**
Average annual costs	**$357.9 million** *(12 years of support)*	**$11.7 million** *(11 years of support)*	**$120.7 million** *(10 years of support)*	**$469.2 million** *(12 years of support)*

Sources: Tables 6.4, 6.5 and 6.7.

For example, in 2021, the first cohort of 3,217 displaced workers will receive support through the just transition program, including wage insurance, retraining and relocation support, as needed. As we can see in column 4, these full costs will amount to $270 million in 2021. Costs increase in 2022, since we now have two cohorts of displaced workers receiving income and retraining support, as well as one cohort receiving relocation support. Thus, total costs in 2022 rise to $420 million. In 2023, there are now three cohorts of displaced workers receiving income support, along with 2 cohorts receiving retraining support and, again, one cohort receiving relocation support. This totals to $563 million, the figure that then prevails through 2030. In 2031 and 2032, with smaller cohorts eligible for income and retraining support, and no further cohorts receiving relocation support, the costs of the program fall correspondingly, to $293 million, then to $143 million.

In total, assuming a steady contraction, just transition benefits provided to 3,217 displaced workers per year in California will total to $5.6 billion, or an average of $469.2 million per year over 12 years, in total costs and about $175,000 per worker.

Episodic Contraction

Under this alternative scenario, we assume that California's fossil fuel-based industries do not contract at a steady annual rate over 2021 – 2030. They rather contract in three large episodes, in 2021, 2026 and 2030 respectively. Of course, the total number of job losses in the state will remain constant, at 57,548. That is, 50 percent of all fossil-fuel based jobs in California will be eliminated as of 2030 regardless of whether this occurs through a steady or episodic contraction pattern. Under this episodic contraction scenario, one-third of this total number of jobs will be lost in each of the three episodes. This means that 19,183 (=57,548/3) jobs will be lost in 2021, 2026, and 2030 respectively. It also means that there will be no job losses in the remaining years, i.e. 2022, 2023, 2024, 2025, 2027, 2028, and 2029.

For most workers, the just transition support policies available to them will be identical to those under the steady contraction scenario. More specifically, first, all workers moving into voluntary retirement in each of the three years of industry contraction will have their pensions guaranteed. Workers who are not retiring will then receive the full package of the reemployment guarantee, along with income, retraining and relocation support, as discussed above.

But under the episodic scenario, we need to also consider an additional cohort of workers. These are older workers who are approaching, but not yet at, retirement age. For the most part, these will be workers between the ages of 60 – 64. For these workers who are close to retirement age, it is not reasonable to assume that they will have to move into new occupations, including perhaps facing retraining and relocation. Therefore, under the episodic scenario, when these workers are laid off, they should be provided with a glide-path to retirement. That would consist of income replacement at 100 percent of the income they were receiving before their jobs were eliminated. Of course, for these older workers who choose to accept this option, they would not then receive either retraining or relocation support in addition to this 100 percent level of income support.

In Table 6.9, we calculate how this episodic contraction would proceed in 2021, through considering the impact of 19,183 layoffs in which we divide the full set of laid off workers into three cohorts according to age: 1) workers 65 or older moving into voluntary retirement; 2) workers between ages 60 – 64 who voluntarily accept the glide-path option into

TABLE 6.9
Attrition by Retirement and Job Displacement for Fossil Fuel Workers in California
EPISODIC TRANSITION — Episode 1: 2021

	Fossil fuel workers
1) Total workforce as of 2018	112,482
2) Job losses over 10-year transition, 2021 – 2030	57,548
3) Job loss per episode *(= row 2/3)*	19,183
4) Number of workers reaching 65 during 2021 *(% of workers at least 65 years old in 2021 x row 1)*	4,949 *(4.4% of workers)*
5) Number of workers retiring voluntarily in 2021 *(= 80% x row 4)*	3,959 *(80% of 65+ workers)*
6) Number of near-retirement workers laid-off *(= row 3 x % of workers between 60 and 64 years old in 2021)*	2,762 *(14.4 % of job losses)*
7) Number of workers requiring re-employment *(= row 3 – row 5 – row 6)*	12,462

Source: Table 6.1.

Note: The 80 percent retirement rate for workers over 65 is derived from U.S. Bureau of Labor Statistics data: https://www.bls.gov/cps/cpsaat03.htm. According to these BLS data, 20 percent of 65+ year-olds remain in the workforce.

retirement; and 3) workers 59 and younger who are facing displacement. As the table shows, under this episodic contraction scenario in 2021, there will be 2,762 workers retiring voluntarily, 3,959 workers moving onto the glide-path to retirement, and 12,462 workers facing displacement who will require the full package of re-employment, retraining, and relocation support.

This same breakdown into three cohorts will also occur in 2026 and 2030, when the second and third episodic contractions of California's fossil fuel industry would occur under this episodic contraction scenario between 2021 – 2030.[156]

In Table 6.10, we then calculate the costs of the just transition program under this episodic scenario. As we see, the program now includes income, retraining and relocation support for displaced workers, all of whom will be guaranteed new jobs. It also includes glide-path income support for the workers between ages 60 – 64 who will be choosing to retire once they turn 65. As before, we assume that the pensions of workers ages 65 and over will be guaranteed through regulatory policies.

The results in Table 6.10 make clear that the episodic contraction will entail a much more costly level of just transition support than with the steady contraction. Based on the Table 6.10 results, in Table 6.11, we then directly compare the overall costs of the steady contraction scenario with those of the episodic contraction scenario. As Table 6.11 shows, the total costs for the 12 years of the just transition program are $4.4 billion higher under the episodic scenario, at $10.0 billion. Overall, the just transition program under the episodic contraction will be nearly 80 percent more expensive than the program under a steady contraction—$10.0 billion under the episodic scenario versus $5.6 billion under the steady scenario. On an annual average basis, the cost differences amount to $833 million per year

TABLE 6.10
Total and Annual Average Costs for Just Transition Support for Displaced Fossil Fuel-Based Workers in California, 2021 – 2032
THREE EPISODES OF LAYOFFS

Year	Income support *(3 years of support)*	Retraining support *(2 years of support)*	Relocation support *(1 year of support)*	Glide-path income support *(3 years of support)*	Total *(cols. 1+2+3+4)*
2021	$540.9 million (1 cohort of 12,462 workers)	$24.9 million (1 cohort of 12,462 workers)	$467.3 million (1 cohort of 6,231 workers)	$358.5 million (1 cohort of 2,762 workers)	$1.4 billion
2022	$540.9 million (1 cohort)	$24.9 million (1 cohort)		$358.5 million (1 cohort)	$924.2 million
2023	$540.9 million (1 cohort)			$358.5 million (1 cohort)	$899.4 million
2024					
2025					
2026	$570.1 million (1 cohort of 13,137 workers)	$26.2 million (1 cohort of 13,137 workers)	$492.7 million (1 cohort of 6,569 workers)	$358.5 million (1 cohort of 2,762 workers)	$1.4 billion
2027	$570.1 million (1 cohort)	$26.2 million (1 cohort)		$358.5 million (1 cohort)	$954.9 million
2028	$570.1 million (1 cohort)			$358.5 million (1 cohort)	$928.7 million
2029					
2030	$599.4 million (1 cohort of 13,812 workers)	$27.6 million (1 cohort of 13,812 workers)	$518.0 million (1 cohort of 6,906 workers)	$358.5 million (1 cohort of 2,762 workers)	$1.5 billion
2031	$599.4 million (1 cohort)	$27.6 million (1 cohort)		$358.5 million (1 cohort)	$985.5 million
2032	$599.4 million (1 cohort)			$358.5 million (1 cohort)	$957.9 million
Total	**$5.1 billion**	**$157.2 million**	**$1.5 billion**	**$3.2 billion**	**$10.0 billion**
Average annual costs	**$427.6 million** *(12 years of support)*	**$14.3 million** *(11 years of support)*	**$147.8 million** *(10 years of support)*	**$268.9 million** *(12 years of support)*	**$832.8 million** *(12 years of support)*

Sources: Tables 6.4, 6.7 and 6.9.

TABLE 6.11
Comparative Just Transition Program Costs under Steady versus Episodic Contraction Scenarios, 2021 – 2032
Support for 57,548 workers

	Steady contraction	Episodic contraction	Transition program costs under episodic versus steady contraction
Total costs over 12 years	$5.6 billion	$10.0 billion	+ $4.4 billion *(= +78.6%)*
Average costs per year over full 12-year period *(with 11 years of retraining and 10 years of relocation support)*	$469.2 million	$832.8 million	+ $363.6 million per year *(= +77.5%)*

Sources: See Tables 6.8 and 6.10.

under the episodic scenario versus $469 million per year under the steady scenario, with the episodic scenario therefore adding more than 77 percent to the overall costs of providing just transition support to California's fossil fuel industry dependent workers.

These large differences in cost result from the fact that, with the steady contraction, the transition program is well-designed to operate in tandem with the pattern at which older workers will move voluntarily into retirement. Under the episodic contraction, the transition program needs to provide for support for a much larger number of laid-off workers when the industry contraction in the 2021, 2026 and 2030 episodes—that is, considering the 2021 episode, 2,762 workers moving onto the retirement glide path in addition to the 12,462 workers requiring re-employment versus a steady annual figure of 3,217 workers per year requiring re-employment under the steady contraction.

Of course, both the steady and episodic contraction patterns that we present here are both stylized examples only. The actual fossil fuel industry contraction pattern will almost certainly fall somewhere in between what we have described under either the steady or episodic contraction pattern. Nevertheless, this exercise illustrates why policymakers should aim to manage the fossil fuel industry phase out in a pattern that proceeds as smoothly as possible.

Transitional Support for Workers Facing Indirect and Induced Job Losses

It should not be a challenge, either administratively or financially, to provide transition support for the relatively small number of workers facing displacement through indirect and induced job channels. This is especially the case because, on balance, there should be no jobs lost in California through the induced employment channel after we take account of the just transition program for workers who experience displacement through the direct employment channel. This is because, as we have described above, induced employment effects refer to the expansion of employment that results when people in any given industry—such as clean energy or fossil fuels—spend money and buy products. This increases overall demand in the economy, which means more people are hired into jobs to meet this increased demand. It follows that the loss of incomes through a contraction of employment will create a reverse induced employment effect. People will have less money to spend, overall demand for goods and services will contract, and therefore the demand for employees will decline correspondingly. However, our proposed just transition program provides that workers facing displacement through the direct jobs channel will be guaranteed re-employment at a compensation level equal to what they were earning before they became displaced. It follows that implementing the just transition program will mean that there will also be no reverse induced employment effects in California even as the fossil fuel-based industries themselves contract.

7. COUNTY-LEVEL JOB CREATION, JOB DISPLACEMENT AND JUST TRANSITION

As we have seen, the total amount of employment in the fossil fuel and ancillary industries in California is about 112,000 (rounded from 112,482) jobs. This amounts to about 0.6 percent of total statewide employment. As such, only a relatively small number of communities in the state will experience job losses that will significantly affect the overall level of economic activity in these respective communities. Other than in these communities, the impact of the fossil fuel industry contraction in the state will mostly be minimal. In addition, the losses experienced in these relatively hard-hit communities will be partially offset by the job guarantee and wage insurance features of our proposed just transition program. Like the rest of the state, they will also benefit from the state's clean energy, infrastructure/manufacturing, and land restoration/agriculture investment programs. Still, we need to give some focused attention to those communities that will experience negative impacts from the fossil fuel industry contraction to a disproportionate extent.

In fact, there are only three counties in California in which the impact of the fossil fuel phase-down between 2021 – 2030 will be substantial, either in terms of total number of jobs that will be lost or the share of jobs that will be lost relative to total countywide employment. These are Kern, Contra Costa and Los Angeles Counties. Table 7.1 shows the 2018 figures for fossil fuel-based employment in these three counties as well as the share of total employment in these counties represented by the fossil fuel-based industry jobs. These three counties combined account for roughly 50 percent of all employment in the fossil fuel and ancillary industries in California.

As we see, the county whose employment conditions are most heavily dependent on the fossil fuel-based industries is Kern County, both in terms of the absolute number of fossil fuel-based jobs in Kern and as a share of the state's total employment. As Table 7.1 shows,

TABLE 7.1
Fossil Fuel-Based Employment in Kern, Contra Costa and Los Angeles Counties, 2018

	Fossil fuel-based employment	Share of statewide fossil fuel employment *(total fossil fuel-based employment = 112,482)*	Share of total county employment
Kern County	13,651	12.1%	3.2%
Contra Costa County	12,972	11.5%	2.2%
Los Angeles County	29,003	25.8%	0.4%
TOTALS	**55,626**	**49.5%**	---

Source: IMPLAN 3.1.
Note: County employment levels are as follows: Kern County: 427,257; Contra Costa County: 584,726; and Los Angeles County: 6,515,598.

there are 13,651 people employed in the fossil fuel-based industries in Kern. This amounts to 12.1 percent of all statewide employment in the fossil fuel-based industries. It also totals to 3.2 percent of total employment in Kern County.

Contra Costa is the other county in California in which the share of fossil fuel employment is significant, with total fossil fuel-based employment at 12,972, amounting 11.5 percent of all statewide employment in the fossil fuel-based industries as well as 2.2 percent of total employment in the county. Los Angeles County has the largest number of people employed in the fossil fuel-based industries, at 29,003, comprising 28 percent of all statewide fossil fuel-based employment. But overall employment in LA county is 6.5 million, so that fossil fuel-based employment amounts to only 0.4 percent of countrywide employment.

In what follows, we present various perspectives on the impact of California's clean energy transition on these three counties. We first show data on the employment effects of the clean energy, public infrastructure/manufacturing, and land restoration/agriculture investments along with the corresponding employment impacts of the 50 percent reduction in fossil fuel-based activity in the three counties. We then focus on the situation for Kern County specifically, in terms of both its fossil fuel-based industry activities as well as recent clean energy industry developments in the county. Finally, we evaluate the experiences with transition policies more broadly, both in California and elsewhere, to the extent that these previous experiences can help identify the types of transition policies that might be most effective for California's current transition project.

Statewide Investment Program Budget Allocations by County

As we have seen, investments in California would total to an average of $137.6 billion per year in the four areas of energy efficiency ($9.3 billion), clean renewable energy ($66.4 billion), manufacturing/infrastructure ($39.2 billion) and land restoration/agriculture ($22.6 billion). We derived the energy efficiency and renewable energy investment figures through the program to achieve a 50 percent emissions reduction in California by 2030. The investment figures for manufacturing/infrastructure and land restoration/agriculture represent California's share of the proposed national THRIVE Agenda, assuming California's share reflects its proportion of the U.S. population.

In considering the allocation throughout the state of the full $137.6 billion per year, we will work with the assumption that Kern and Contra Costa Counties will receive a larger share of the total funds relative to an allocation based strictly on their population share. This larger allocation reflects the fact that these counties will face much more difficult transition challenges than will be experienced throughout the rest of the state. Thus, Kern County accounts for 2.3 percent of California's population, but we assign Kern a 4.6 percent share of the overall investment budget—i.e. an investment share that is twice as large as its population share. This 4.6 percent investment share would amount to an average of $6.3 billion per year. For Contra Costa County, its population accounts for 2.9 percent of California's population. We have assigned Contra Costa a 4.0 share of the overall California investment budget. This amounts to an average of $5.5 billion per year between 2021 – 2030. We assigned to Contra Costa County a somewhat smaller share of the total statewide investment budget than Kern County because Contra Costa's economy is not as dependent as Kern on its fossil fuel industry activities.

As we have seen, Los Angeles County employs about 29,000 fossil fuel industry-based workers, nearly 26 percent of all fossil fuel industry based workers in the state. But these 29,000 workers account for only 0.4 percent of overall employment in LA County. As such, we have assigned to LA County 25 percent of the state's overall investment budget between 2021 – 2030, a share roughly proportional to its share of statewide population. This investment budget would then come to an average of $34.4 billion per year between 2021 – 2030.

Employment Estimates by County

From these investment figures, we then estimate the employment effects of the combined investment programs in each of the three counties. For each county, we then review the pattern of fossil fuel industry contraction, working with the assumption that each county will experience the same 50 percent contraction of its fossil fuel industry as will occur in California overall. We also consider the pattern of the fossil fuel industry contraction under both the steady and episodic contraction patterns that we have developed in Section 6 for the state overall.

Table 7.2 shows the job creation figures for Kern County and Table 7.3 shows the fossil fuel-based industry contraction patterns under both the steady and episodic contraction scenarios. As we see in Table 7.2, in assuming that Kern will receive 4.6 percent of the state's overall investment spending over 2021 – 2030 in clean energy, manufacturing/infrastructure and land restoration/agriculture, that amounts to an average of $6.3 billion in new investment spending per year. The table also shows the distribution of these funds in our four specific investment areas—energy efficiency, clean renewable energy, manufacturing/infrastructure, and land restoration/agriculture. As the table shows, investing $6.3 billion per year in these four areas in Kern will generate an increase of overall employment in the

TABLE 7.2

Kern County 1: Job Creation Summary through Clean Energy, Manufacturing/ Infrastructure and Land Restoration/Agriculture Investment Programs

- Kern County share of California population = 2.3%
- Kern County share of overall $137.6 billion investment budget = 4.6%

Average Annual Job Creation, 2021 – 2030

	Annual investment budget	Annual total job creation: *direct, indirect and induced jobs*
Energy efficiency	$330 million	1,992
Clean renewable energy	$3.8 billion	12,416
Manufacturing/infrastructure	$1.4 billion	7,760
Land restoration/agriculture	$770 million	5,543
TOTALS	**$6.3 billion**	**29,711**

Source: Table 5.1. U.S. Census.

county—including direct, indirect, and induced employment—of nearly 30,000 jobs per year between 2021 – 2030.

Table 7.3 then shows the job contraction pattern in Kern County through the 50 percent reduction in fossil fuel-related activity in the county. Beginning in panel A, the steady contraction scenario, we see that the county will lose 6,963 jobs over 2021 – 2030, averaging 696 jobs per year. We then estimate that 308 workers per year will retire voluntarily. As a result, we estimate that 388 workers per year in Kern County will be displaced through the 50 percent fossil fuel contraction in the county. Of course, this figure of 388 workers displaced every year contrasts dramatically with the nearly 30,000 new jobs that will be generated in the county through the clean energy, manufacturing/infrastructure, and land restoration/agriculture investment programs.

TABLE 7.3

Kern County 2: Job Losses through Fossil Fuel-Based Industry Contraction

A) Steady Contraction

	Fossil fuel workers
1) Total workforce as of 2018	13,651
2) Job losses over 10-year transition, 2021 – 2030	6,963
3) Average annual job loss over 10-year production decline *(= row 2/10)*	696
4) Number of workers reaching 65 over 2021 – 2030 *(= row 1 x % of workers 54 and over in 2019)*	3,850 *(28.2% of all workers)*
5) Number of workers per year reaching 65 during 10-year transition period *(= row 4/10)*	385
6) Number of workers per year retiring voluntarily	308 *(80% of 65+ workers)*
7) Number of workers requiring re-employment *(= row 3 – row 6)*	388

B) 2021 Episodic Contraction

	Fossil fuel workers
1) Total workforce as of 2018	13,651
2) Job losses over 10-year transition, 2021 – 2030	6,963
3) Job loss per episode *(= row 2/3)*	2,321
4) Number of workers reaching 65 during 2021 *(% of workers at least 65 years old in 2021 x row 1)*	601 *(4.4% of workers)*
5) Number of workers retiring voluntarily in 2021 *(= 80% x row 4)*	481 *(80% of 65+ workers)*
6) Number of near-retirement workers laid-off *(= row 3 x % of workers between 60-64 years old in 2021)*	334 *(14.4 % of job losses)*
7) Number of workers requiring re-employment *(= row 3 – row 5 – row 6)*	1,506

Source: Tables 6.5, 6.9 and 7.1.

As we saw for California overall, the transition out of fossil fuels in Kern will certainly be more challenging under an episodic contraction pattern. The panel B in Table 7.3 shows the 2021 episodic contraction in Kern. The episodic contractions in 2026 and 2030 will follow similar patterns. In this 2021 contraction episode scenario, job contraction will amount to 2,321 jobs. Of this total level of job loss, we estimate that 481 workers will retire voluntarily. We also estimate that 334 will be between ages 60 – 64 and will therefore be eligible for the glide-path to retirement support that we have described in Section 6. This leaves 1,506 workers who will experience displacement in the 2021 contraction episode. This is a much larger number than the 388 workers who will be displaced under the steady contraction scenario for Kern. But it is also the case that, under the episodic scenario, Kern wouldn't experience further layoffs until 2026, with another hiatus in displacements until 2030.

Overall for Kern, under either the steady or episodic scenarios, the nearly 30,000 jobs that will be created through investments in clean energy, manufacturing/infrastructure and land restoration/agriculture will be far greater than either the roughly 400 workers facing displacement under the steady contraction scenario or the roughly 1,500 workers displaced under the 2021, 2026 or 2030 contraction episodes. As we have seen for California overall, the large-scale expansion of job opportunities will establish a strong foundation for operating an effective just transition program in Kern County. This just transition program in Kern will include, as we have reviewed in Section 6, pension, job, and income guarantees, along with retraining and relocation support as needed. We consider the transition process for Kern County in more specific and qualitative terms below.

For Contra Costa and Los Angeles Counties, the patterns for job creation through the clean energy, manufacturing/infrastructure infrastructure, and land restoration/agriculture investment programs and job contraction through the fossil fuel industry phase-out are broadly similar to those for Kern County. In Table 7.4, we see that for Contra Costa County,

TABLE 7.4

Contra Costa County 1: Job Creation Summary through Clean Energy, Manufacturing/ Infrastructure and Land Restoration/Agriculture Investment Programs

• Contra Costa County share of California population = 2.9%

• Contra Costa County share of overall $137.6 billion investment budget = 4.0%

Average Annual Job Creation, 2021 – 2030

	Annual investment budget	Annual total job creation: *direct, indirect and induced jobs*
Energy efficiency	$370 million	2,084
Clean renewable energy	$2.7 billion	8,522
Manufacturing/infrastructure	$1.5 billion	11,575
Land restoration/agriculture	$900 million	5,877
TOTALS	**$5.5 billion**	**28,058**

Source: Table 5.1. U.S. Census.

the average investment level of $5.5 billion per year will generate an average of about 28,000 additional jobs in the county. At the same time, Table 7.5 shows the extent of fossil fuel based industry job displacements will be 370 workers under a steady contraction scenario and 1,432 under the 2021 episodic contraction scenario. The 2026 and 2031 contraction episodes would generate similar levels of job displacement in Contra Costa County, while there would be no additional displacements in the non-episodic years between 2021 – 2030. For Los Angeles County, we estimate that the $34.4 billion in investments per year will generate about 318,000 jobs in the county between 2021 – 2030 (see Table 7.6). We also estimate that

TABLE 7.5
Contra Costa County 2: Job Losses through Fossil Fuel-Based Industry Contraction

A) Steady Contraction

	Fossil fuel workers
1) Total workforce as of 2018	12,972
2) Job losses over 10-year transition, 2021 – 2030	6,618
3) Average annual job loss over 10-year production decline *(= row 2/10)*	663
4) Number of workers reaching 65 over 2021 – 2030 *(= row 1 x % of workers 54 and over in 2019)*	3,657 *(28.2% of workers)*
5) Number of workers per year reaching 65 during 10-year transition period *(= row 4/10)*	366
6) Number of workers per year retiring voluntarily	293 *(= 80% of 65+ workers)*
7) Number of workers requiring re-employment *(= row 3 – row 6)*	370

B) 2021 Episodic Contraction

	Fossil fuel workers
1) Total workforce as of 2018	12,972
2) Job losses over 10-year transition, 2021 – 2030	6,618
3) Job loss per episode *(= row 2/3)*	2,206
4) Number of workers reaching 65 during 2021 *(% of workers at least 65 years old in 2021 x row 1)*	571 *(4.4% of workers)*
5) Number of workers retiring voluntarily in 2021 *(= 80% x row 4)*	456 *(80% of 65+ workers)*
6) Number of near-retirement workers laid-off *(= row 3 x % of workers between 60-64 years old in 2021)*	318 *(14.4 % of job losses)*
7) Number of workers requiring re-employment *(= row 3 – row 5 – row 6)*	1,432

Source: Tables 6.5, 6.9 and 7.1.

TABLE 7.6
Los Angeles County 1: Job Creation Summary through Clean Energy, Manufacturing/ Infrastructure and Land Restoration/Agriculture Investment Programs
• Los Angeles County share of California population = 25.3%
• Los Angeles County share of overall $137.6 billion investment budget = 25.0%

Average Annual Job Creation, 2021 – 2030

	Annual investment budget	Annual total job creation: *direct, indirect and induced jobs*
Energy efficiency	$2.4 billion	15,554
Clean renewable energy	$16.1 billion	168,462
Manufacturing/infrastructure	$10.1 billion	93,798
Land restoration/agriculture	$5.8 billion	40,331
TOTALS	**$34.4 billion**	**318,145**

Source: Table 5.1. U.S. Census.

about 800 fossil fuel industry-based workers will be displaced every year between 2021 – 2030 under a steady contraction scenario and about 3,200 would be displaced in 2021, 2026 and 2030 respectively under the episodic contraction scenarios (see Table 7.7).

Once again, we therefore see that the clean energy, infrastructure, and land restoration/ agriculture investment program will provide a major source of job creation in Contra Costa and Los Angeles Counties. As such, this combined investment program will establish a strong foundation for a viable just transition program for workers in Contra Costa and LA Counties, as well as throughout California.

Transition Developments and Prospects for Kern County

Status of Oil and Gas Industry

Kern is a county of 900,000 people about 130 miles northeast of Los Angeles in the San Joaquin Valley. It is one of the most oil-rich counties in the U.S. and is the state's top petroleum producer. Oil development in Kern began with the 1894 discovery of the Midway-Sunset Oil Field. At present, the Midway-Sunset field is the largest in California and the third-largest in the United States.[157] Along with Midway-Sunset, four additional fields in Kern make up the five most productive oil fields in the state.[158] As of 2018, 70 percent of California's oil and nearly 80 percent of its natural gas were produced in Kern.[159]

At present, Kern County's own assessed value of all assets in the county tied to fossil fuels, including land and mineral rights, is nearly $15 billion. The oil industry accounts for about 14 percent of Kern's total economic activity and property tax base, generating about $330 million in property tax revenue annually.[160] More than $100 million of this oil tax rev-

TABLE 7.7
Los Angeles County 2: Job Losses through Fossil Fuel-Based Industry Contraction

A) Steady Contraction

	Fossil fuel workers
1) Total workforce as of 2018	29,003
2) Job losses over 10-year transition, 2021 – 2030	14,847
3) Average annual job loss over 10-year production decline *(= row 2/10)*	1,485
4) Number of workers reaching 65 over 2021 – 2030 *(= row 1 x % of workers 54 and over in 2019)*	8,179 *(28.2% of workers)*
5) Number of workers per year reaching 65 during 10-year transition period *(= row 4/10)*	818
6) Number of workers per year retiring voluntarily	654 *(= 80% of 65+ workers)*
7) Number of workers requiring re-employment *(= row 3 – row 6)*	831

B) 2021 Episodic Contraction

	Fossil fuel workers
1) Total workforce as of 2018	29,003
2) Job losses over 10-year transition, 2021 – 2030	14,847
3) Job loss per episode *(= row 2/3)*	4,949
4) Number of workers reaching 65 during 2021 *(% of workers at least 65 years old in 2021 x row 1)*	1,276 *(4.4% of workers)*
5) Number of workers retiring voluntarily in 2021 *(= 80% x row 4)*	1,021 *(80% of 65+ workers)*
6) Number of near-retirement workers laid-off *(= row 3 x % of workers between 60-64 years old in 2021)*	713 *(14.4% of job losses)*
7) Number of workers requiring re-employment *(= row 3 – row 5 – row 6)*	3,215

Source: Tables 6.5, 6.9 and 7.1.

enue contributes to financing Kern's public school system. Another $80 million funds the operations of the county itself.[161]

While the current level of tax revenues generated by Kern's fossil fuel industry is substantial, it is also the case that the industry has experienced a long-term decline as a source of the county's total property tax value. In 1980, fossil fuel assets accounted for more than 50 percent of the county's total property tax value.[162] The sharp decline in global oil prices, first in 2015, then again in 2019- 2020, have led to an overall declining level of investment activity in the industry.[163] Kern County, along with other fossil fuel-dependent areas in the

U.S., has experienced serious revenue shortfalls as a result. Thus, in 2015, the Kern County Supervisors declared a state of emergency when declining oil revenue caused a budgetary shortfall of $61 million.[164] In 2020, California Resource Corporation, one of the state's major oil and gas producers, filed for bankruptcy. Kern County is listed in the bankruptcy paperwork as an unsecured creditor. California Resource Corporation is reported to owe the county more than $25 million in tax revenues.[165]

In short, since 2015, the Kern County economy has already been experiencing major economic disruptions resulting from its heavy dependence on conditions in the fossil fuel industry, and the negative impact of the global oil price decline and COVID-induced recession on the industry.

Wind, Solar and Energy Efficiency Developments

In addition to the fossil fuel industry's ongoing major presence in Kern, the county has also been successful in beginning to develop a major renewable energy industry. Since 2009, more than $60 billion has been invested in the county's renewable energy projects. Kern is now home to both the nation's largest wind farm, Alta Wind Energy Center, and its largest solar facility, BHE Renewable's Solar Star Project.

Private investment in creating wind power supply in Kern has produced about 4 Gigawatts of power-generating capacity, with more turbines operating within Kern than in the entire northeastern region of the U.S.[166] Kern County supplies 54 percent of California's 128 T-BTUs of wind energy. But after significant increases in wind energy capacity from 2005-2015, new capacity has leveled off since 2015.[167]

The bulk of the more recent private investment in renewable energy in Kern County has been channeled into solar development, amounting to about $50 billion since 2009.[168] There is also a significant rooftop solar industry with over 24,000 distributed generation systems, making three zip codes in Kern County in the top-five for solar saturation in the state.[169] At the same time, the expansion of the solar industry in Kern has not led to a significant increase in the county's tax revenues. This is because of the longstanding property tax exemption provided to the state's solar industry. The California state legislature has extended this provision at least until the end of 2025.[170]

The San Joaquin Valley, which includes most of Kern County, has the highest per capita energy use in the state. Kern County is therefore also positioned to gain disproportionate benefits through investments to raise its energy efficiency standards through efficiency investments. According to a 2015 study by Next 10, energy customers in the San Joaquin Valley had received a total of $257 million in rebates for purchases including energy efficient lighting, appliances, and HVAC upgrades, as well as other incentives including direct install services, between 2010-2015. Additional spending associated with program administration and marketing, combined with customer investments, brought the total investment in energy efficiency in the region through programs administered by investor-owned utilities to $846 million. According to the Next 10 study, these investments generated over $1.1 billion in economic benefits to the San Joaquin region.[171]

Orphaned Wells

Orphaned wells are abandoned oil and gas wells for which no viable responsible party can be located. Idle oil and gas wells emit pollutants into the air, including hydrogen sulfide and organic compounds that contribute to ground-level ozone.[172] According to a 2018 study by the California Council on Science and Technology on idle and orphan wells in the state, more than 5,500 oil and gas wells are orphaned or highly likely to become orphaned. It would cost $550 million to plug and abandon just these old wells. Almost 70,000 other wells are either currently idle or economically marginal and at increased risk of becoming orphaned, bringing the total cost to $5 billion.

Most of the state's idle or orphaned wells are located in Kern County, given that most of the state's oil production is concentrated in Kern. One major concentration is the Elk Hills oil field in Kern. Elk Hills is the largest gas-producing field in the state. It includes 1,400 of the more than 7,600 wells owned by recently bankrupt California Resource Corporation. On average, these wells haven't produced oil or gas for 14 years. This field is riddled with contaminants left behind by fossil fuel extraction. At present, the federal government is paying the state to remediate 131 areas of concern here that contain arsenic, metals such as chromium and lead, and carcinogenic chemicals called polycyclic aromatic hydrocarbons.[173] The U.S. Navy previously managed Elk Hills.

While oil companies in California are required to post bonds against future remediation costs of their wells, the bonds posted by the operators legally obligated to pay for the work total just over $100 million. [174] The California Council on Science and Technology estimated that the State of California overall is liable for more than $500 million in cleanup costs for more than 5,500 orphaned wells in the state.[175] The average remediation cost is $68,000 per well, though the range of costs is large, with a minimum value of $1,200 and a maximum of $391,000. [176]

Additionally, wells that have been plugged prior to 1953 are not considered effective with respect to controlling their environmental impacts. This is because, prior to 1953, wells either were orphaned or plugged and abandoned with very little cement, since plugging was mainly focused on protecting the oil reservoirs from rain infiltration, as opposed to minimizing environmental impacts. Roughly 30 percent of plugged wells in the state are listed as having been plugged without the use of cement. Kern County, in turn, has more than half of the total plugged wells in the entire state.[177]

In short, plugging all of Kern's orphaned wells, and doing so according to stringent environmental regulatory standards, needs to be a major transition project for the county.

Support for Disadvantaged Kern Communities

California's Greenhouse Gas Reduction Fund invests funds into disadvantaged areas as legislated by the state's 2012 Global Warming Solutions Act. The legislature specifically included provisions to direct investment toward the most disadvantaged communities. Kern has been a major beneficiary of the provision. The San Joaquin Valley represents about 12 percent of the state's population but has received 35 percent, amounting to $320 million, of the total funds provided by the Fund GGRF. The money has been spent on a variety of projects including the construction of high-speed rail, methane digesters, community solar facilities and affordable housing projects. The majority of the construction jobs generated by these investments have been covered under union-negotiated Project Labor Agreements.[178]

Moving Forward with Transition Program

To date, Kern County has demonstrated a viable path forward in transitioning the region's economy away from its longstanding dependence on fossil fuels. At the same time, issues have emerged that will need to be addressed moving forward. For example, solar panels that are located on farmlands are being used to pump groundwater independently from electricity supply provided by utilities. This has provided the farmers with a degree of welcome energy autonomy. But it has also enabled them to avoid facing rising water prices during drought periods. The higher prices have been the state's main tool for promoting water conservation during these drought periods.[179]

In addition, to date, Kern County has allocated few resources to investments in land reclamation and restoration, infrastructure resiliency, or responsive capacity to wildfires or other disasters.[180] These are areas that will be targeted in the overall package of projects within the state's clean energy, manufacturing/infrastructure and land reclamation/agricultural investment program.

Community Transition Programs throughout California

In addition to the community transition measures that focus on Kern County, a broader set of initiatives will need to be implemented to assist other communities in California that will be negatively impacted by the state's fossil fuel phase-down. As with Kern County, such initiatives will fall under two broad categories. The first is land reclamation, beginning with plugging the oil wells that are located in communities other than Kern. The other is land repurposing, comparable to the projects already underway in Kern to expand the area's clean energy production capacity. There are valuable lessons to extract from previous experiences with land repurposing, both within the U.S. and elsewhere. We note a few such examples here.[181]

One important example of a federal government-directed repurposing project was the Worker and Community Transition program that operated through the Department of Energy from 1994 – 2004. Its mission was "to minimize the impacts on workers and communities caused by changing Department of Energy missions." This program, along with related initiatives, was targeted at 13 communities which had been heavily dependent on federal-government operated nuclear power and weapons facilities but subsequently faced retrenchment due to nuclear decommissioning.

The conditions faced by the nuclear power-dependent communities and the aims of the repurposing program for them have useful parallels with the challenges that will be faced by many fossil fuel-dependent communities. To begin with, for security reasons, the nuclear facilities were located in rural areas. Most fossil fuel extraction sites are also in rural areas, as determined by the location of the fossil fuel deposits. As a result, in most cases, with both the nuclear weapons facilities and the fossil fuel production sites, the surrounding communities and economies became heavily dependent on these single activities. Finally, both with the nuclear and fossil fuel-dependent communities, the opportunities are limited to directly repurpose much of the physical infrastructure in place, since that infrastructure was built to meet the specific needs of each of the industries.[182]

Operating with such constraints, the Worker and Community Transition program provided grants as well as other forms of assistance in order to promote diversification for these 13 nuclear energy-dependent communities and to maintain jobs or create new employment opportunities. The program targeted sites where job losses exceeded 100 workers in a single year. It encouraged voluntary separations, assisted workers in securing new employment, and provided basic benefits for a reasonable transition period. The program also provided local impact assistance and worked with local economic development planners to identify public and private funding and assist in creating new economic activities and replacement employment. Annual appropriations for the program totaled around $200 million in its initial years but became much smaller—in the range of $20 million—in the final years of operation.

Lynch and Kirshenberg, writing in the *Bulletin of the Energy Communities Alliance*, provide a generally favorable assessment of the program. They conclude as follows:

> Surprisingly, the 13 communities, as a general rule, have performed a remarkable role in attracting new replacement jobs and in cushioning the impact of the cutbacks at the Energy-weapons complex across the country … The community and worker adjustments to the 1992 – 2000 DOE site cutbacks have been strong and responsive, especially when compared with any other industrial adjustment programs during the same decade (2000).

The experience in Piketon, Ohio provides a good case study of how this program has operated in one community. Piketon had been the home of a plant producing weapons-grade uranium that closed in 2001. The workers in the plant were represented by the Oil Chemical and Atomic Workers union (OCAW—which merged in 1999 with the United Steel Workers). The union leadership was active in planning the plant's repurposing project. The closure could have been economically devastating for the region, but the federal government provided funding to clean up the 3,000 acre complex. The clean-up operation began in 2002, and is scheduled to take 40 years to complete.[183] Currently 1,900 workers are employed decontaminating the site at a cost of $300-$400 million a year. The contractor hired to clean up the site employs union workers and the president of the USW local union is enthusiastic about the long-term prospects for the project and the site (Hendren 2015).

Despite the positive achievements with projects such as Piketon, Lynch and Kirshenberg also note more generally that "The most serious problem facing the energy-impacted communities…was the lack of a basic regional economic development and industrial diversification capacity for most of the regions affected by the cutbacks…"

To address this problem directly, community assistance initiatives could encourage the formation of new clean energy businesses in the affected areas, as has already been happening in Kern County. One large-scale example of a successful diversification program was the repurposing of a nuclear test site in Nevada to what is now a solar proving ground. More than 25 miles of the former nuclear site are now used to demonstrate concentrated solar power technologies and help bring them to commercialization.[184]

There are also important cases of successful repurposing projects in other countries. Most prominent has been the experience in Germany's Ruhr Valley, which has been the traditional home for its coal, steel and chemical industries. Since the 1990s, the region has advanced industrial policies to develop new clean energy industries.[185] As one important example of this repurposing project in the Ruhr region, RAG AG, a German coal-mining firm, is in the process of converting its Prosper-Haniel coal mine into a 200-megawatt pumped-storage hydroelectric reservoir that acts like a giant battery. The capacity is enough to power more than 400,000 homes in North-Rhine Westphalia.[186] In addition to hydroelectric power storage, the company is also erecting wind turbines on the top of tall waste heaps and installing solar panels on the slopes. Other firms in the region have branched into producing wind and water turbines. This regional transition project has succeeded through mobilizing the support of the large coal, steel and chemical companies and their suppliers, along with universities, trade unions and government support at all levels.

Beginning with Kern County but throughout California more generally, the most critical challenge will be to effectively integrate transition programs with the state's coming wave of public and private investments in clean energy, manufacturing/infrastructure and land restoration/agriculture.

8. ACHIEVING A ZERO EMISSIONS ECONOMY BY 2045

If California is able to bring overall CO_2 emissions in the state down to approximately 195 million tons by 2030—a 50 percent decline relative to the 2018 level of 389 million tons—it should also be able to establish a zero emissions economy by 2045.

In fact, enabling California to meet its 2045 emissions reduction target as set out in the 2018 Executive Order B-55-18 will not require fossil fuel energy consumption in the state, and thereby CO_2 emissions, to fall precisely to zero. This is because perhaps as much as 20 million tons of CO_2 emissions can be absorbed through afforestation and the expansion of organic agricultural practices within California itself. These are projects that will be supported through the land restoration and agriculture programs we have described in Section 4. Nevertheless, as a means of simplifying the analysis here, we assume that the goal will be for California to reach zero emissions within the state by 2045. The global climate stabilization project would then be further strengthened as afforestation and the expansion of organic farming in the state contribute toward absorbing the accumulated stock of CO_2 in the atmosphere.

California should be able to establish a zero-emissions energy infrastructure as of 2045 basically through continuing the clean energy investment project that would have proceeded from 2021 – 2030. Moreover, on an annual basis, the scale of the investments in energy efficiency and clean renewable energy between 2031 – 2045 that will be needed to reach zero emissions by 2045 will be significantly more modest than what we have described above for the project through 2030.

As we saw in Table 2.11, our estimate of the clean energy investment costs for bringing emissions down to 195 million tons by 2030 was about 2.1 percent of California's GDP per year between 2021 – 2030. Over 2031 – 2045, as we will see, we estimate that the average annual clean energy investment costs necessary to bring emissions down to zero to be about 1.3 percent of California's average GDP. The impact of the smaller investment project on job opportunities throughout the state is therefore likely to also be more modest than during 2021 – 2030, though still strongly in the positive direction.

We do not attempt to develop here a full assessment as to the technical requirements for achieving a zero emissions economy in California by 2045. However, many researchers, focused on a range of different regions and countries, have concluded that conversion to an economy relying on clean renewable sources to meet 100 percent of energy demand is technically feasible within a few decades or less. One important study reaching this conclusion is by the Harvard University physicist Mara Prentiss. Prentiss concludes in her 2015 book, *Energy Revolution: The Physics and the Promise of Efficient Technology,* that "Electricity generated by renewable energy can easily provide 100 percent of the average energy consumption of the United States during those next 50 years, virtually eliminating the negative environmental consequences associated with fossil fuel consumption," (2015, p. 304).[187]

Within a framework that recognizes the technical feasibility of bringing CO_2 emissions to zero by 2045, our focus here is to assess the economic trajectory of how this goal can be accomplished while the state's economy and job opportunities continue to grow. Of course, considering how such a trajectory is likely to proceed entails making a series of assumptions about the economy's long-term growth path. This exercise necessarily becomes increasingly speculative the further out one moves in time. To keep our discussion as realistic as possible, we rely on a small number of assumptions that are credible within the body of knowledge that is available to us at present.

The assumptions on which we will rely are as follows:

1. *Economic growth.* We assume that average economic growth in California proceeds at the same rate as we have assumed for 2021 – 2030, i.e. at 2.5 percent per year.
2. *Energy efficiency.* We have already assumed that California will have achieved major gains in energy efficiency between 2021 – 2030, specifically that the state's energy intensity ratio will have fallen from 2.7 to 2.0 Q-BTUs per $1 trillion of GDP—a 26 percent improvement. We assume that further efficiency gains are possible through continued investments, and that the costs of achieving these efficiency gains will remain at $35 billion per Q-BTU, the same cost figure for our 2021 – 2030 scenario. We make this assumption of stable overall costs, based on two ideas: 1) technological improvements will occur in raising efficiency standards; but 2) the "low-hanging fruit" possibilities for efficiency gains will have dissipated. We assume that these two factors will roughly counteract each other.
3. *Clean renewable energy.* Technological advances in generating, storing and transmitting renewable energy will certainly occur between 2031 – 2045, especially given that these industries will have scaled up dramatically over 2021 – 2030. But to proceed cautiously, we assume only a modest rate of average technological improvement for renewables overall—that the average costs of creating 1 Q-BTU of renewable capacity falls at an average rate of 1 percent per year between 2031 – 2045. This means, specifically, that average costs for expanding renewable energy supply will fall from the 2030 level of $200 billion per Q-BTU to an average of $186 billion over 2031 – 2045.
4. *Job creation.* We assume that labor productivity in all clean energy investment activity improves at an average annual rate of 1 percent per year. These gains in productivity will proceed concurrent with the 2.5 percent average annual GDP growth rate. As such, the net increase in employment will be 1.5 percent per year.

Working from these assumptions on 1) economic growth; 2) the costs of achieving energy efficiency gains and an expanded clean renewable energy supply; and 3) labor productivity, we then develop projections as to how California could become a zero emissions economy by 2045. We present these results in Tables 8.1 – 8.6.

In Table 8.1, we show California's GDP projection for 2045 based on a 2.5 percent average annual growth rate for 2031 – 2045. This growth path begins at the 2030 GDP baseline of $4.03 trillion. This figure is itself a projection, of course, which we derived through assuming that California's GDP would grow at an average annual rate of 2.5 percent between 2018 – 2030, starting from the 2018 actual GDP level of $3.0 trillion. Based on these assumptions, as we see in Table 8.1, California's GDP will be $5.84 trillion in 2045. We then calculate the midpoint GDP level between 2031 – 2045 under this scenario. As we see, this midpoint figure is $4.94 trillion.

In Table 8.2, we then estimate the investment costs necessary to bring California's energy intensity ratio down from the 2030 figure of 2.0 to 1.5 Q-BTUs of energy/$1 trillion in

TABLE 8.1
California Average Economic Growth Projection for 2030 – 2045
Assumption is 2.5% average GDP growth

Projected 2030 GDP level *(from Table 2.9)*	$4.03 trillion
Projected 2045 GDP level	$5.84 trillion
Midpoint GDP level for investment spending estimates *(= (2031 GDP + 2045 GDP)/2)*	$4.94 trillion

Source: See Table 2.9; authors' calculations.

TABLE 8.2
Energy Efficiency Investments Needed to Bring California Energy Intensity Ratio to 1.5 by 2045
Energy Intensity Ratio = Q-BTUs of energy/GDP in trillions of dollars
2.5% average GDP growth

1) 2045 GDP assumption *(from Table 8.1)*	$5.8 trillion
2) Total 2045 energy consumption at 2.0 energy intensity ratio *(=2.0 x $5.8 trillion)*	11.6 Q-BTUs
3) Total energy consumption at 1.5 energy intensity ratio *(= 1.5 x $5.8 trillion)*	8.7 Q-BTUs
4) Gains in energy efficiency through 2031 – 2045 efficiency investments *(= rows 2 – 3)*	2.9 Q-BTUs
5) Costs of achieving energy efficiency gains *(= row 4 x $35 billion)*	$102 billion
6) Costs per year over 15-year investment cycle *(= row 5/15)*	$6.8 billion

Sources: Table 8.1 and authors' projections.

GDP. This would represent a 25 percent improvement in average energy efficiency throughout the California economy, i.e. a roughly 1.9 percent improvement per year between 2030 – 2045. We had projected in Table 2.10 that California would be at the 2.0 intensity ratio by 2030 under the clean energy investment program we outlined for 2021 – 2030. Table 8.2 shows that to arrive at a 1.5 energy intensity ratio by 2045 will require $102 billion in new energy efficiency investments between 2031 – 2045 under the 2.5 percent growth scenario. Considered on an annual basis, these total costs amount to an average of $6.8 billion per year under the 2.5 percent growth scenario.

In Table 8.3, we perform a comparable set of calculations for clean renewable energy investments between 2031 – 2045. We begin these calculations with the assumption of a 1.5 energy intensity ratio for 2045. This then entails that, in 2045, overall energy consumption in California will be at 8.7 Q-BTUs. This total level of energy demand will then need to be supplied in full by clean renewable energy sources. As of 2030, clean renewable energy supply will be at 4.2 Q-BTUs. This means that the net expansion of clean renewables by 2045 will need to be 4.5 Q-BTUs. As we see in rows 4 – 7 of Table 8.3, achieving this higher level of productive capacity in clean renewables will require a level of investment averaging $55.8 billion per year.

In Table 8.4, we then summarize these results for achieving zero emissions in California as of 2045. As we see, we estimate these overall costs to be $939 billion, which averages to $62.6 billion per year over 2031 – 2045. As a share of California's projected midpoint GDP over 2031 – 2045, these annual cost figures would amount to 1.3 percent of GDP. As mentioned above, these figures are significantly below the cost level we have estimated for the initial 2021 – 2030 investment period that would be necessary to bring California's CO_2 emissions down to 195 million tons by 2030. We estimated those costs to amount to about 2.1 percent of the state's average GDP between 2021 – 2030.

TABLE 8.3
Clean Renewable Energy Investments Needed to Reach Zero Emissions in California by 2045

1) 2045 Energy consumption level with 1.5 energy intensity ratio *(from Table 8.2)*	8.7 Q-BTUs
2) Total clean renewable energy supply required *(= 100% clean energy supply)*	8.7 Q-BTUs
3) Clean renewable energy supply as of 2030 *(from Table 2.11)*	4.2 Q-BTUs
4) Renewable energy expansion needed by 2045 *(= rows 2 – 3)*	4.5 Q-BTUs
5) Midpoint cost per Q-BTU of expanding clean renewable supply *(assumes average costs decline at 1% per year relative to 2030)*	$186 billion
6) Total costs of reaching 8.7 Q-BTUs in renewable supply *(= rows 4 x 5)*	$837 billion
7) Average annual costs over 15-year investment cycle *(= row 6/15)*	$55.8 billion

Sources: Tables 2.5, 2.11 and 8.2 and authors' projections.

TABLE 8.4
Overall Estimated Costs of Achieving Zero Emissions in California by 2045

1) Total energy efficiency investment costs *(from Table 8.2)*	$102 billion
2) Total renewable energy investment costs *(from Table 8.3)*	$837 billion
3) Total clean energy investment costs *(= rows 1 + 2)*	$939 billion
4) Average annual costs per year for 15-year investment cycle *(= row 3/15)*	$62.6 billion
5) Average annual costs per year as percentage of midpoint GDP *(= row 4/Table 8.1 figure)*	1.3%

Sources: See Tables 8.1 – 8.3.

Employment Creation through 2031 – 2045 Investment Project

In Table 8.5, we provide rough estimates as to the level of employment creation that would be generated by the clean energy investment levels necessary to bring California's CO_2 emissions down to zero by 2045. We have estimated these employment figures based on two assumptions: 1) the overall clean energy investment spending levels for 2031- 2045 as a proportion of the 2021 – 2030 spending level; and 2) our assumption of a 1 percent average annual increase in labor productivity in these clean energy investment projects, while clean energy investments increase at the same rate as GDP growth, i.e. at 2.5 percent per year.

We saw in Table 3.5 that, over 2021 – 2030, our estimate of total employment—direct, indirect and induced employment—generated through clean energy investments at $75.8 billion per year would be about 418,000 jobs. This rounded figure of 418,000 jobs is repeated in row 1 of Table 8.5. In row 2, we then calculate average annual clean energy investment spending for 2031 – 2045 as a share of average spending over 2021 – 2030. That figure is 81.8 percent. From this figure, we then generate an estimate of 318,000 jobs being created each year on average within the 2031 – 2045 labor force, after assuming that labor productivity grows by 1 percent per year between 2031 – 2045.

TABLE 8.5
Average Annual California Employment Creation through Clean Energy Investments, 2031 – 2045

1) Estimated annual average job creation through 2021 – 2030 clean energy investments (rounded) *(from Table 3.5)*	418,000 jobs
2) Approximate average annual investment spending 2031 – 2045 as pct. of 2021 – 2030 spending *(from Tables 2.11 and 8.4)*	81.8%
3) Average annual employment creation 2031 – 2045 with fixed productivity *(= row 1 x row 2)*	342,000 jobs
4) Average annual employment creation 2031 – 2045 with 1% labor productivity growth *(= row 3 x 0.93, midpoint productivity relative to 2030)*	318,000 jobs

Sources: Tables 2.11, 3.5, and 8.4.

Just Transition Program

In Table 8.6, we provide estimates for the just transition program for 2031 – 2045. The figures we present in Table 8.6 are derived from the material we have developed for the 2021 –2030 period in Section 6 of this paper, including in Tables 6.1 and 6.5.

With the 2021 – 2030 analysis, we reported in Table 6.1 that a total of 112,482 workers were employed in California as of 2018 at jobs in the state's fossil fuel-based industries. In Table 6.5, we provide the estimate that by 2030, a total of 57,548 of these jobs, equal to just over 50 percent of the jobs, will be lost. This results from our assumption that, by 2030, oil and gas production activity in the state will decline by 50 percent, while the state's tiny coal industry will be entirely closed down. This result also implies that, as of 2030, the remaining nearly 50 percent of jobs—i.e. another 57,548—will remain intact in these industries across California.

Starting from the goal that California is going to achieve zero emissions by 2045, this means that all 57,548 jobs will be phased out between 2031 – 2045. We first consider this phase out process within the framework of a steady contraction scenario, as described in Section 6. Under the steady contraction scenario, the job losses would amount to an average of 3,837 per year as an average figure over this 15-year period. Working from the age profile of workers in the industry, we estimate that 1,074 workers per year will voluntarily retire over this same period. This then means that an average of 2,763 workers per year in California's fossil fuel-based industries will face displacement.

From the figures we report in Table 6.8, we assume that the total costs per worker of the just transition program—including compensation insurance, retraining, and relocation support—will be about $175,000 per worker. Thus, the average costs of just transition support for 2,763 California workers will be $160 million per year under a steady contraction scenario. As we note in row 8 of Table 8.6, this figure amounts to about 0.003 percent of California's average GDP between 2031 – 2045 of $4.9 trillion. In short, under a steady contraction scenario, covering the full costs of just transition for all of California's displaced fossil fuel-based industry workers comes to a trivial figure relative to the overall level of economic activity in the state.

In Section 6, we estimated that the costs of an episodic contraction scenario between 2021 – 2030 would be about 80 percent higher than those under a steady contraction scenario. For the 2031 – 2045 period, even if we assume that the costs of a just transition would double under an episodic scenario relative to those of a steady scenario, this would raise the average costs to about $320 million per year. This annual just transition spending figure under an episodic contraction scenario would still amount to well below 0.01 percent of California's average GDP between 2030 – 2045.

TABLE 8.6
Costs of Just Transition Program for Displaced Workers in Fossil Fuel Sectors: *2031 – 2045 Scenario*

1) Projected number of workers employed in fossil fuel industries in 2030 *(from Table 6.5)*	57,548
2) Employment contraction, 2031 – 2045 *(100% contraction)*	57,548
3) Average employment contraction per year *(= row 2/15)*	3,837
4) Projected number of workers reaching retirement between 2031 – 2045 *(workers 50 years and over in 2031; assume 35%)*	20,142
5) Average annual attrition through voluntary retirement *(= row 4 x 80%/15)*	1,074
6) Average number of workers displaced annually, 2031 – 2045 *(= row 3 – row 5)*	2,763
7) Average annual costs of 100% just transition: compensation insurance, retraining and relocation support *(= row 6 x $58,000 per worker per year)*	$160 million
8) Average annual costs of just transition as share of average 2031 – 2045 GDP *(= row 7/ $4.94 trillion)*	0.003%

Source: Projections based on figures from Tables 6.5, 6.8, and 8.1.

9. FINANCING CALIFORNIA'S RECOVERY AND SUSTAINABLE TRANSITION PROJECTS

In Sections 2 – 6 of this study, we developed investment and just transition programs for California whose total costs come to an average of $138 billion per year between 2021 – 2030. These overall costs include the following:

- $75.7 billion per year for clean renewable energy and energy efficiency;
- $61.8 billion per year for public infrastructure/manufacturing and land reclamation/agriculture;
- $470 million per year in just transition support for displaced workers in fossil fuel-based industries.

However, as we discussed in Section 2, of this $138 billion total, we assume that roughly half of the funds would be provided by private investors. Specifically, we assume that with the $75.7 billion in clean energy investments, $1 dollar of public funds would be capable of leveraging $9 in private investment. Based on this assumption, it follows that annual *public spending* on clean renewable energy and energy efficiency will amount to $7.6 billion per year (i.e. $75.7 billion x .10 = $7.6 billion). Private clean energy investment spending will total to about $68.1 billion (i.e. $75.7 billion - $7.6 billion = $68.1 billion), with the overall public plus private clean energy investment level at $75.7 billion.

Thus, the total annual *public sector budget* for these programs would be $70 billion (rounded from $69.9 billion), including:

- $7.6 billion per year for public funding of clean energy investments
- $61.8 billion per year for public infrastructure/manufacturing and land restoration/agriculture
- $470 million per year for just transition support

This $70 billion overall public spending figure would amount to an average of 1.9 percent of California's average GDP between 2021 – 2030 of $3.61 trillion, assuming the economy grows at an average rate of 2.5 percent per year.

Federal Support

How would a spending program at this level be financed in California? We can begin by considering funds that would be available from the federal government. In December 2020, the federal government, still under former President Trump, passed a $900 billion economic recovery bill, the COVID-19 Economic Relief Bill. As we discussed in Section 1, most of the funds provided in this bill are targeted to provide various forms of short-term support over the remaining course of the COVID-induced recession. This includes $600 in direct payments for individuals earning less than $75,000 per year, $300 a week in supplemental unemployment insurance benefits, $285 billion for small business loans, $82 billion for public education, $70 billion for production and distribution of vaccines, and smaller amounts for child-care workers, rental assistance, and food security. The overall package does also allocate a relatively small but still significant amount, $35 billion, to fund wind, solar and other clean energy projects.[188]

In addition to these already allocated funds from the federal government, the Biden administration introduced in mid-January 2021 the American Rescue Plan. This is an additional short-term recovery program, budgeted at $1.9 trillion beyond the $900 billion already allocated through the December bill. Most of the funding priorities in Biden's American Rescue Plan are similar to those included in the December measure, but with higher levels of spending attached. These include an additional $1,400 in direct payments to individuals, $400 per week in additional supplemental unemployment insurance, along with major support for state and local governments, a major increase in spending for distributing COVID vaccines and expanding the tax credit for families with children.[189]

These funds will provide an important short-term boost to the California economy as well as to the U.S. economy overall. According to the California Legislative Analyst's Office, California will be receiving between $60 – $70 billion from the December 2020 COVID-19 recovery bill and about $180 billion from the American Rescue Plan.[190] In combination then, the December COVID-19 Economic Relief Bill and the proposed American Rescue Plan would deliver about $250 billion to California. This amount is nearly 4 times greater than the $70 billion annual public figure we are proposing for the clean energy, infrastructure/manufacturing and land restoration/agriculture investment programs and the just transition support for displaced fossil fuel industry workers. However, almost none of the funds from these two measures will have been allocated to directly support the investment and just transition programs we have proposed here. For example, of the $35 billion total allocated for clean energy investments in the December bill, California would receive $4.2 billion, assuming funds are allocated based on relative population size. Nevertheless, these stimulus funds will certainly provide indirect support through strengthening the economic recovery.[191]

Federal Public Investment Initiatives: American Jobs Plan and THRIVE

In March 2021, the Biden Administration introduced its American Jobs Plan. This measure includes a range of investment programs. These investment areas include traditional infrastructure, such as roads, bridges and water management systems, broadband development, as well as clean energy and climate resilience programs. Broadly speaking, the investment areas in the American Jobs Plan match up substantially with those we have proposed in Sections 2 – 4 in the areas of energy efficiency, renewable energy, infrastructure, manufacturing, land restoration and agriculture.

The overall level of spending proposed in the American Jobs Plan is $2.7 trillion over 8 years. This would amount to an average of $340 billion per year over these 8 years. If California were allocated its share of American Jobs Plan funding based on its 12.1 percent population share, the state would receive roughly $40 billion per year.

The Biden plan is similar in its aims to the Markey-Dingell THRIVE program that was introduced in Congress in February 2021, and that we have summarized in Section 4. Our funding levels for California in the areas of infrastructure/manufacturing and land restoration/agriculture investments are based directly on the national THRIVE program and budget allocations, with California's share of the proposed national THRIVE program proportional to its population share.

Within the full THRIVE program, the areas of investment on a national level that correspond closely with the investment programs we present in this study for California are as follows:

- $354 billion per year for clean energy investments;
- $324 billion per year for manufacturing and infrastructure investments;
- $186 billion per year for land restoration and agriculture investments.

These budget allocations total to $864 billion per year.[192] If California were to receive funding from the THRIVE program based on its 12.1 percent population share, it would receive about $104 billion per year from THRIVE. Thus, on an annual basis, the THRIVE Agenda allocates roughly $60 billion more in annual investment spending in these areas than the amounts provided in the Biden American Jobs Plan.

As of this writing in May 2021, we do not know what, if any, version of the American Jobs Plan or the THRIVE Agenda may get enacted into law. Let us assume that federal funding support will be at the lower-end Biden American Jobs Plan as opposed to the Congressional THRIVE Agenda. Even this lower-end $40 billion annual figure from the Biden proposal would still cover nearly 60 percent of the total $70 billion annual public spending budget that we have proposed for the full set of clean energy, infrastructure/manufacturing, and land restoration/agriculture investments, along with the just transition program for displaced fossil fuel industry workers. Under the Congressional THRIVE proposal, our estimate of a $70 billion annual public investment requirement would be more than fully covered through the $104 billion THRIVE-based budget allocation. Overall, the prospects are favorable that at least half of the public funding to support the full set of initiatives that we have introduced will be provided by the federal government.

State Government Support for Capital Investment Projects

In addition to this potential federal funding support, the California state government is also capable of making significant contributions to the clean energy, manufacturing/infrastructure, land restoration/agriculture and just transition programs. By statute, the state does have the legal authority as well as the capacity to issue bonds to support capital projects.[193] Such capital projects could, for example, be in the areas of traditional infrastructure such as roads or school buildings. Capital projects could also include public-sector led clean energy investments to, for example, raise energy efficiency standards in public buildings through retrofitting projects. In fact, between the fiscal years 2000/2001 and 2019/2020, the California state budget did run deficits of varying amounts in 13 of the 19 years.[194]

Moreover, coming out of the COVID recession, the state's fiscal situation has improved substantially relative to the projections built into the state budget in June 2020. As of May, 2021, the state projects a $75 billion surplus for the fiscal 2020 – 2021 year on revenues of $154 billion.[195] General state revenues are forecast to further increase 5.2 percent, to $161.6 billion in fiscal year 2021 – 2022, $39 billion (32 percent) higher than the June 2020 estimate.

The bond ratings agency Fitch Ratings explains the State of California's significantly improved fiscal situation as follows:

> The state attributes the improved revenue performance to the unusual nature of the coronavirus-related downturn, in which higher-wage taxpayers have both been protected from job losses and have benefitted from the strong stock market. This has allowed the state's progressive personal income tax structure and taxing of capital gains to generate the higher than anticipated tax revenue. It also reflects a less severe economic downturn than was assumed in the fiscal 2021 budget.[196]

As described in Section 1, Governor Newsom and the state legislature agreed on February 17 to implement a $9.6 billion statewide stimulus program. Its major provisions include $600 in cash support for low-income households; $2 billion in grants for small businesses; and $400 million for child-care support.[197] Governor Newsom then also proposed in May a second stimulus program for the state. This second stimulus proposal includes an additional round of $600 direct payments, to be provided to those who will not have received a payment through the February stimulus program. In combination, the first- and second-round individual payments should provide support for two-thirds of Californians. Newsom's second round proposal also includes an additional $500 payment for families with children, along with $5 billion in total funds to assist renters and $2 billion to subsidize utility bills.[198]

These state-based programs are in addition to the $900 billion federal stimulus program enacted in December 2020 under President Trump and as well as the $1.9 trillion in further funds provided under President Biden's American Rescue Plan. But, as with these federal government programs, these California measures do not allocate any funding for public investments in the areas we have targeted in this study—i.e. clean energy, infrastructure/manufacturing and land restoration/agriculture. State-level support for these investment programs would have to be provided through separate initiatives focused on long-term capital expenditures.

In fact, in his 2021 – 2022 preliminary budget, Governor Newsom has proposed a "California All" 5-year infrastructure plan for the state.[199] Under this proposal, California would invest a total of $52 billion over the next five years—i.e. an average of about $10 billion per year in infrastructure projects throughout the state. Funds would be provided for climate resilience and broadband development as well as the traditional infrastructure projects in transportation and construction. In fact, $22 billion—nearly half of the total budget—would be allocated to state highway repair and rehabilitation projects within the State Highway Operations and Protection Program. The level of funding proposed in key areas that would support a clean energy transformation remain modest in the proposal, such as "up to $1 billion" to accelerate rate of adoption of zero-emissions vehicles and $250 million for ecosystem restoration and coastal protection. In short, the California All infrastructure program, will provide financial support to a statewide clean energy transition program along the lines we have described here, but, in its current version, only to a modest extent.

At the same time, the state does have the capacity to significantly increase the scale of funding support it can provide to this investment project. It is important to recognize that, at present, bonds issued by the state and municipalities in California are being marketed at very low rates. As of 5/6/21, the yield on California newly-marketed state and municipal bonds ranged between 0.4 and 2.3 percent.[200] Depending on Federal Reserve policy over the coming year, these rates could remain within this range or perhaps even fall further.[201] Low interest rates, in turn, will keep the financing costs of the investment program low as well. For example, if the state were to issue $20 billion in public investment bonds with a 2 percent interest rate, the annual debt servicing on this bond would be $400 million, equal to about 0.2 percent of the state's 2022 general revenues and about 0.01 percent of average state GDP over 2021 – 2030.

It also follows from these figures that the State of California is well-positioned to provide a significant share of the funding for the overall investment program in energy efficiency, renewable energy, infrastructure/manufacturing, and land restoration/agriculture. For example, let's assume that federal funding from an enacted version of the American Jobs Plan ends up providing only $30 billion per year for California. In this case, the State of California would need to provide $40 billion per year in order for the total public sector contribution to remain at $70 billion per year. In this case, with a 2 percent interest rate on California state bonds, annual debt servicing would rise to $1 billion per year. This is still equal to only 0.4 percent of California's 2022 revenues and 0.02 percent of average state GDP over 2021 – 2030 (assuming 2.5 percent average annual GDP growth rate).

In short, with California's state and municipal governments being able to borrow at low rates, the prospects are highly favorable for the state to provide a significant share of funding in behalf of moving California onto a robust recovery path and a sustainable long-term growth trajectory.

Appendix 1
Employment Estimating Methodology

The employment estimates for California were developed using an input-output model. Here we used IMPLANv3.1, an input-output model that uses data from the U.S. Department of Commerce and other public sources. The data set used for the estimates in this report is the 2018 California data. An input-output model traces linkages between all industries in the economy and institutional sources of final demand (such as households and government). A full discussion of the strengths and weaknesses of input-output (I-O) models and their application to estimating employment in the energy sector can be found in Appendix 4 of Pollin et al. (2014).

One important point to note here is that I-O models to date do not identify, for example, renewable energy industries such as wind, solar, or geothermal, or energy efficiency industries such as building retrofits, industrial efficiency, or grid upgrades.[202] However, all of the components that make up each of these industries are contained in existing industries within the models. For example, the hardware, glass production, and installation industries that are all activities within "solar" are an existing industry in the I-O model. By identifying the relevant industries and assigning weights to each, we can create "synthetic" industries representing each of the renewable energy and energy efficiency industries within the model as well as the manufacturing/infrastructure and land restoration/agriculture industries. A full discussion of the methodology for creating synthetic industries can be found in Garrett-Peltier (2017). The synthetic industries and weight of each component industry used in this study are shown in Table A1.1, below.

Scaling Manufacturing Activity

The employment estimates produced in the IMPLAN model are disaggregated into over 500 sectors. The expansion of clean energy that we propose in this report is significant and occurs relatively rapidly. While it may be possible for construction and service activities to keep pace with the rapid scaling up of clean energy consumption in California, we assume that manufacturing facilities will take longer to develop. While manufacturing activity will expand within the state, some clean energy manufacturing will develop out of state in the first ten years of clean energy expansion. Here we make the conservative assumption that all sectors will expand at their existing local (within state) content. Thus, the employment multipliers will be lower in this constrained case than if we assume that all sectors, including manufacturing, will be produced within California. In the IMPLAN model, we reduce the regional purchasing content to the existing levels to incorporate this change.

To err on the side of underestimating rather than overestimating in this study, we use the constrained employment numbers in the right-hand column of Table A1.2 in our estimates.

TABLE A1.1
Composition and Weights for Modelling Industries within the I-O Model

A) Clean renewable and energy efficiency sectors

Sectors	Composition and Weights of Industries within the I-O Model
Building Retrofits	50% maintenance and repair construction of residential structures, 50% maintenance and repair construction of nonresidential structures.
Industrial efficiency with CHP	20% environmental and technical consulting services, 10% repair construction of nonresidential structures, 5% air purification and ventilation equipment manufacturing, 5% heating equipment manufacturing, 5% A/C, refrigeration, and warm air heating equipment manufacturing, 10% all other industrial machinery manufacturing, 25% turbine and turbine generator set units manufacturing, 7.5% power boiler and heat exchanger, 2.5% electricity and signal testing instruments, 10% architectural and engineering services.
Grid upgrades	25% construction of new power and communication structures, 25% mechanical power transmission equip¬ment manufacturing, 25% commercial and industrial machinery and equipment repair and maintenance, 25% other electronic component manufacturing.
Public transport/ rail	30% construction of other new nonresidential structures, 21% motor vehicle body manufacturing, 6% railroad rolling stock manufacturing, 43% transit and ground passenger transportation.
Expanding electric/ hybrid vehicles	30% automobile manufacturing, 20% light truck manufacturing, 12.5% storage battery manufacturing, 5% motor vehicle electrical and electronic equipment manufacturing, 10% other motor vehicle parts manufacturing, 2% motor vehicle metal stamping, 8% motor vehicle body manufacturing, 12.5% motor vehicle gasoline engine and engine parts manufacturing.
Wind (onshore)	26% construction of new power and communication structures, 12% plastic and resin manufacturing, 12% fabricated structural metal manufacturing, 37% turbine and turbine generator manufacturing, 3% mechanical power transmis¬sion equipment manufacturing, 3% electronic connector manufacturing, 7% Scientific research and development services.
Solar PV	30% construction of new power and communication structures, 17.5% hardware manufacturing, 17.5% mechanical power transmission equipment manufacturing, 17.5% capacitor, resistor, coil, transformer, and other inductor manufacturing, 17.5% Scientific research and development services.
Geothermal	15% drilling wells, 35% construction of new nonresidential structures, 10% pump and pumping equipment manufacturing, 10% power boiler and heat exchanger, 30% scientific research and development services.
Low-emissions bio-energy	15% grain farming, 10% sugarcane and sugar beet farming, 15% industrial process variable instruments manufacturing, 20% construction of nonresidential structures, 10% construction of new commercial structures,10% wet corn milling, 5% sugarcane refining, 15% power boiler and heat exchanger .
Small-scale hydro	50% construction of new nonresidential structures, 10% concrete pipe manufacturing, 10% architectural and engineering services, 15% turbine and turbine generator, 5% mechanical power transmission equipment manufacturing, 5% motor and generator manufacturing, 5% copper rolling.

TABLE A1.1 *(cont.)*
Composition and Weights for Modelling Industries within the I-O Model

B) Manufacturing/Infrastructure Sectors

Sectors	Composition and Weights of Industries within the I-O Model
Broadband	10% Cable subscription programming, 25% construction of new power structures, 20% wired telecommunication services, 20% wireless telecommunication services, 10% fiber optic cable manufacturing, 15% miscellaneous electrical equipment.
Surface transportation	15% construction of new nonresidential structures, 15% construction of new highway and streets, 10% maintenance and repair of highways, streets, bridges, 33% transit ground transportation, 17% automobile manufacturing, 10% heavy duty truck manufacturing.
Water and wastewater Infrastructure	30% water and sewage, 25% construction of other new nonresidential structure, 10% plastic pipe, 5% concrete pipe, 5% iron and steel pipe, 5% fabricated pipe, 10% other support services, 10% waste management.
Electricity	14% power, distribution, and specialty transformer manufacturing, 14% motor and generator manufacturing, 14% relay and industrial control manufacturing, 14% fiber optic cable manufacturing, 14% energy wire manufacturing, 30% construction of new power and communication structures.
Airports	30% air transportation, 25% aircraft manufacturing, 5% aircraft engine and engine parts manufacturing, 5% other aircraft parts manufacturing, 10% maintenance and repair construction of nonresidential structures, 25% construction of new commercial structures.
Inland waterways/ marine ports	30% Water transportation, 10% maintenance of nonresidential structures, 25% construction of new commercial structures, 25% ship building, 10% boat building.
Dams	12% architectural and engineering services, 10% other support services, 50% construction of new nonresidential structures, 15% concrete block and brick manufacturing, 5% iron and steel pipe manufacturing, 5% fabricated pipe manufacturing, 3% elevator and moving stairway manufacturing.
Levees	15% architectural and engineering services, 10% other support services, 50% construction of new nonresidential structures, 15% concrete block and brick manufacturing, 5% iron and steel pipe manufacturing, 5% fabricated pipe manufacturing.
Hazardous and solid waste	20% environmental consulting services, 20% waste management, 10% landscape and horticultural services, 25% maintenance and repair of nonresidential structures, 25% maintenance and repair of residential structures.
Public parks and Recreation	10% environmental consulting services, 70% museums, historical sites, zoos and parks, 20% landscape and horticultural services.
Rail	40% Rail transportation, 25% construction of new commercial structures, 25% railroad rolling stock manufacturing, 10% overhead cranes, hoists manufacturing.
Schools	30% construction of educational and vocational structures, 10% maintenance and repair of nonresidential structures, 30% elementary and secondary schools, 20% junior colleges, colleges, universities and professional schools, 10% other educational services.
Repairing leaks in gas pipelines	60% natural gas distribution; 40% pipeline transportation.

TABLE A1.1 *(cont.)*
Composition and Weights for Modelling Industries within the I-O Model

C) Agriculture/land restoration sectors

Sectors	Composition and Weights of Industries within the I-O Model
Regenerative agriculture/ organic farming	15% grain farming, 10% fruit farming, 5% greenhouse, nursery and floriculture production, 20% all other crop farming, 20% animal production other than beef, 10% beef cattle ranching and farming, 5% labor and civic organization, 15% construction of new farm structure.
Resources for marginalized farmers	8% grain farming, 5% fruit farming, 7% all other crops, 2% animal production, 5% beef cattle ranching, 3% poultry and egg, 10% support activities for agriculture, 10% construction of new farm structure, 5% construction of educational structures, 15% other educational services, 15% farm machinery, 5% other real estates, 5% architectural services, 5% office administrative services.
Agriculture research and development	5% grain farming, 4% fruit farming, 3% all other crops, 3% beef ranching, 3% poultry and egg, 2% animal production, 10% support activity for agriculture, 5% construction of farm structures, 5% farm machinery, 60% scientific research and development services.
Farmland conservation	5% grain farming, 4% fruit farming, 3% all other crops, 3% beef ranching, 3% poultry and egg, 2% animal production, 5% support activity for agriculture, 5% construction of farm structures, 10% farm machinery, 15% environmental and other technical services, 40% museums, historical sites, 5% grantmaking and social advocacy.
Pollution cleanup	30% environmental consulting services, 10% zoos and parks, 50% waste management and remediation services, 10% landscape and horticultural services.
Closing orphan wells	30% natural gas distribution, 40% pipeline transportation, 30% support activities for oil and gas operations.
Ecosystem restoration	10% environmental consulting services, 50% museums, zoos, parks, 20% other education services, 20% landscape and horticultural services.

TABLE A1.2
Employment Multipliers per $1 Million in Unconstrained and Constrained Cases: Clean Renewable Energy Sectors

	Direct, indirect, and induced jobs per $1 million	
	If all sectors expanded 100 per cent	Constrained: All sectors expand at existing local content
Wind (Onshore)	6.6	3.9
Solar PV	8.0	4.3
Geothermal	10.8	8.8
Small-scale hydro	12.2	10.3

Appendix 2
Estimating Job Characteristics for Clean Energy, Manufacturing/Infrastructure, Agriculture/Land Restoration, and Fossil Fuel Industry Jobs

Characteristics of Jobs Created by Clean Energy Investments

Our strategy for identifying the types of jobs that would be added to the economy due to an investment involves two steps.

The first step is to calculate, for each specific investment program, the level of employment generated in each of the over 500 industries through our input-output model (IMPLAN) as explained in Appendix 1.

Next, we apply this information on the industry composition of the new employment created by an investment with data on workers currently employed in the same industrial mix of jobs. We use the characteristics of these workers to create a profile of the types of jobs and the types of workers that will likely hold the jobs created with each investment. These characteristics include types of occupations, gender, race/ethnicity, union status, credential requirements, and job-related benefits. Compensation data for these workers come directly from IMPLAN and are reported in 2020 dollars.

Our information about the workers currently employed in the industrial mix of jobs created by an investment comes from the Current Population Survey (CPS). The CPS is a household survey administered by the U.S. Census Bureau, on behalf of the Bureau of Labor Statistics of the U.S. Labor Department. The basic monthly survey of the CPS collects information from about 60,000 households every month on a wide range of topics including basic demographic characteristics, educational attainment, and employment status. Among a subset of its monthly sample—referred to as the outgoing rotation group (ORG)—respondents are asked more detailed employment-related questions, including about their wages and union status. The CPS' survey in March includes a supplement, referred to as the Annual Social and Economic survey (ASEC) that asks additional questions, particularly about income, poverty status, and job-related health insurance and retirement benefits. We pool data from 2015-2019 for our analyses.[203]

To create a profile of the types of jobs and the types of workers that will likely hold the jobs created with each investment, we weight the CPS worker data with the industry shares generated by IMPLAN. This creates a sample of workers with an industry composition that matches that of the jobs that we estimate will be added by investing in a clean energy, manufacturing/infrastructure, or agriculture/land restoration sector.

Specifically, we use the IMPLAN industry shares to adjust the sampling weights provided by the CPS. The CPS-provided sampling weights weight the survey sample so that it is representative at various geographic levels, including nation and state. We adjust the CPS-provided sampling weights by multiplying each individual worker's sampling weight with the following:

$$S \times \frac{\text{IMPLAN's estimate of the share of new jobs in worker i's industry j}}{\sum \text{CPS sampling weights of all workers in industry j}}$$

where S is a scalar equal to the number of direct jobs produced overall by the level of investment being considered. For example, say California's investment in solar power of \$35 billion would generate 70,000 direct jobs, then S is equal to 70,000.

Some of IMPLAN's over 500 industries had to be aggregated to match the industry variable in the CPS, which has 242 categories, and vice versa. For example, among IMPLAN's sectors, there are 13 construction sectors while the CPS has only one construction industry. In the end, 194 industry sectors are common to both IMPLAN and the CPS.

We use these adjusted sampling weights to estimate the job-related health insurance and retirement benefits, and union membership among workers in the specific industrial mix of jobs associated with each type of investment. We also estimate demographic characteristics, such as percent female and percent non-white, as well as, workers' educational attainment. Finally, we determine what are the most prevalent occupations held by workers in the industrial mix of jobs associated with each type of investment.

Public sector workers. To determine the share of public sector workers represented among the jobs created by the various investment spending programs, we use the same basic methodology as what we describe above. That is, we use the characteristics of the workers currently employed in the types of jobs that we estimate will be created to estimate the share of workers we expect will be employed in the public sector. This involves two steps.

First, we model job creation for each type of investment using IMPLAN's input-output model based on private sector firms. We do this only to generate the *industry composition* of the types of jobs that will be produced.

Second, as with the demographic characteristics, we can then use the industry shares of the jobs created and weight CPS worker data with these industry shares. This creates a sample of workers with an industry composition that matches that of the jobs that we estimate will be added by investing in a clean energy, manufacturing/ infrastructure, or agriculture/land restoration sector. Note that these worker samples include both public sector and private sector workers.

We can then use the information about whether a worker works in the public or private sector available in the CPS worker data. That is, we can estimate, based on the *industry composition* of the jobs created by a specific investment program (e.g., energy efficiency), what share we expect to be public sector workers. Once we have identified these public sector workers—again, based on the industry composition of the jobs created by a specific investment program—we can next examine the demographic characteristics of these public sector workers.

Characteristics of Jobs in Fossil Fuel Related Industries

We use the same methodology for identifying fossil fuel related jobs and worker characteristics as we did for the clean energy, manufacturing/ infrastructure, or agriculture/land restoration sectors. The only difference here is that IMPLAN's I-O models have well-defined sectors for fossil fuel related activities, i.e., we do not have to create "synthetic" industries.

We can therefore use IMPLAN's sectors directly to model the industry distribution of the jobs that will be lost as the fossil fuel related sectors in California contract. We use IMPLAN's estimates to create an industry profile of the types of jobs that will be lost as this combination of industries contract. As above with jobs created by the various investment programs, we weight the CPS worker data with the industry shares generated by IMPLAN. This creates a sample of workers with an industry composition that matches that of the jobs that we estimate will be lost as fossil fuel sectors contract.

Note that because the CPS ASEC—which asks about job-related retirement and health benefits—is only administered in March, the sample sizes for the variables in the supplement are substantially smaller than for the basic monthly or ORG data files of the CPS. Due to this feature of the ASEC survey, the sample sizes for the health and retirement benefits measures of fossil fuel workers were too small for a California-only analysis, despite pooling five years of data (2015-2019). As a result, we estimated these job features using data from the entire Pacific region. This region includes California, as well as, Alaska, Hawaii, Oregon, and Washington.

Definition of Jobs in IMPLAN

The employment figures in IMPLAN are based on the employment concept used by the Bureau of Economic Analysis. The BEA's concept of employment includes:

- wage and salaried workers
- self-employed workers in incorporated businesses, and
- proprietors employment which includes self-employed workers in unincorporated businesses.

The BEA's concept of employment is more expansive than what it typically used by the U.S. Labor Department's Bureau of Labor Statistics (BLS). Well-known BLS employer-based data on employment, such as from the Quarterly Census of Employment and Wages (QCEW), for example, do not include the unincorporated self-employed. The BLS' CPS data, on the other hand, does include the unincorporated self-employed. However, the CPS data on employment are based on household surveys and only counts the employment of the unincorporated self-employed if their self-employment is their primary job. Moreover, each person can only represent one job. The BEA's concept of proprietor's employment allows for the unincorporated self-employed to represent multiple units of employment. For example, if an individual has various different businesses operating during the year, each business would count as a unit of employment.

To ensure that we use a consistent measure of employment effects in terms of both job *creation* from clean energy, energy efficiency, and other types of investments, and job *losses* from the contraction of fossil fuel industry contractions, we use IMPLAN's (i.e., the BEA's) concept of employment throughout this report.

Appendix 3
Detailed Sources for Pension Fund and Income Data

Methodology

California is a significant fossil fuel producer, ranking seventh in oil production and fourteenth in natural gas production. There is no coal production in the state.[204] It was impossible to identify and analyze pension and income data for every single firm within the fossil fuel and ancillary industries in California due to data limitations and the large number of fossil fuel firms There are over 900 in oil and gas production alone.[205] For Table 6.6, we narrowed our analysis to include the top twenty oil and gas producing companies.

We included the oil and gas production companies for the following reasons. Firstly, about 23 percent of fossil fuel industry wage and salary jobs (as defined by the Department of Labor's QCEW survey) fall under NAICS code categories 21112 ("Crude petroleum extraction"), 21113 ("Natural gas extraction"), and 213112 ("support activities for oil and gas operations").[206] While ranked lists of companies specific to each NAICS code are unavailable, ShaleXP provides a list of the top twenty oil and gas producing companies in California, which together account for 94% of oil production and 95% of gas production in the state.[207] Thus, we can assume that these companies make up a considerable percentage of workers that will be affected by a clean energy transition. To our knowledge, a similar list for companies providing support for oil and gas operations (NAICS code 213112)—a much broader category—does not exist.

Of the twenty companies, ten are publicly traded companies, and ten are privately held. Pension and income data are unavailable for all of the privately held companies.

Sources for Pension Data

The pension plan data come from the Department of Labor ERISA Form 5500 series, including these specific forms[208]:

- Form 5500, the main form filed by employee benefit plans with at least 100 participants;
- Form 5500 SF, filed by plans with fewer than 100 participants;
- Schedule SB, which contains information on assets and liabilities for single-employer pension plans;
- Schedule MB, which contains similar information as Schedule SB, for multiemployer plans.

Sources for Income Data by Company (parent companies in parentheses)

Aera Energy, LLC (Royal Dutch Shell, PLC): SEC filings (10-Ks)
https://www.sec.gov/Archives/edgar/data/0001306965/000130696520000014/0001306965-20-000014-index.html

Berry Petroleum Company, LLC (Berry Corporation (bry)): SEC filings (10-Ks)
https://www.sec.gov/Archives/edgar/data/0001705873/000170587320000014/0001705873-20-000014-index.html

California Resources Elk Hills, LLC (California Resources Corporation): SEC filings (10-Ks)
https://www.sec.gov/Archives/edgar/data/0001609253/000160925320000066/0001609253-20-000066-index.html

California Resources Production Corporation (California Resources Corporation): SEC filings (10-Ks) https://www.sec.gov/Archives/edgar/data/0001609253/000160925320000066/0001609253-20-000066-index.html

Carbon California Operating Company, LLC (Carbon Energy Corporation): SEC filings (10-Ks) https://www.sec.gov/Archives/edgar/data/0000086264/000121390020007986/0001213900-20-007986-index.html

Chevron USA, Inc. (Chevron Corporation): SEC filings (10-Ks) https://www.sec.gov/Archives/edgar/data/0000093410/000009341020000010/0000093410-20-000010-index.html

Seneca Resources Company, LLC (National Fuel Gas Company): SEC filings (10-Ks) https://www.sec.gov/Archives/edgar/data/0000070145/000007014519000030/0000070145-19-000030-index.html

Southern California Gas Company (Sempra Energy): SEC filings (10-Ks) https://www.sec.gov/Archives/edgar/data/0000086521/000103220820000006/0001032208-20-000006-index.html

Thums Long Beach Company (California Resources Corporation): SEC filings (10-Ks) https://www.sec.gov/Archives/edgar/data/0001609253/000160925320000066/0001609253-20-000066-index.html

Tidelands Oil Production Company (California Resources Corporation): SEC filings (10-Ks) https://www.sec.gov/Archives/edgar/data/0001609253/000160925320000066/0001609253-20-000066-index.html

Other Sources:

For general information about the twenty companies, we used subsidiary and parent company web-sites, www.shalexp.com, and https://www.dnb.com.

Appendix 4
Job Attrition Figures for Episodic Transition of Fossil Fuel Sectors: Episodes 2 and 3

In this appendix we provide job attrition figures in the case of an episodic transition in California's fossil fuel-based industries, as described in Section 6 above. Specifically, Tables A4.1 and A4.2 provide job attrition figures for the second and third episodes of contraction. Tables A4.1 and A4.2 both provide figures analogous to those presented in Table 6.9 above, including the numbers of job losses per episode, number of workers retiring voluntarily, number of near-retirement workers, and number of workers needing re-employment in 2026 and 2030, respectively. These figures, along with those presented for the first episode of contraction in Table 6.9, underlie the just transition programs costs presented in Table 6.10.

In Table A4.1, we show the total workforce as of 2026 is 93,299 (row 1), equal to the total workforce that we estimate for 2021 (112,482) minus the job losses in 2021 (19,183). In rows 2 and 3, we show how we assume that the number of layoffs occurring in this second episode will be the same as in the first episode (19,183). We then assume that the age profile will be the same as in 2021, since workers will age between the two episodes and we assume that employers will maintain basically the same type of workforce between episodes. As a result, we estimate that about 3,300 will voluntarily retire in 2026, just over 2,700 near retirement age workers will be laid off, and just over 13,100 will require re-employment in 2026. In Table A4.2, repeats the same calculations as A4.1, starting this time with a total workforce of 74,116.

TABLE A4.1
Attrition by Retirement and Job Displacement for Fossil Fuel Workers in California
EPISODIC TRANSITION — Episode 2: 2026

	Fossil fuel workers
1) Total workforce as of 2026 *(2018 workforce of 112,482 – Episode 1 contraction of 19,183 jobs)*	93,299
2) Job losses over 10-year transition, 2021 – 2030	57,548
3) Job loss per episode *(= row 2/3)*	19,183
4) Number of workers reaching 65 during 2026 *(% of workers at least 65 years old in 2026 x row 1)*	4,105 *(4.4% of workers)*
5) Number of workers retiring voluntarily in 2026 *(= 80% x row 4)*	3,284 *(80% of 65+ workers)*
6) Number of near-retirement workers laid-off *(= row 3 x % of workers between 60-64 years old in 2026)*	2,762 *(14.4% of job losses)*
7) Number of workers requiring re-employment *(= row 3 – row 5 – row 6)*	13,137

Source: The 80 percent retirement rate for workers over 65 derived from U.S. Bureau of Labor Statistics data: https://www.bls.gov/cps/cpsaat03.htm. According to these BLS data, 20 percent of 65+ year-olds remain in the workforce..

TABLE A4.2

Attrition by Retirement and Job Displacement for Fossil Fuel Workers in California

EPISODIC TRANSITION — Episode 3: 2030

	Fossil fuel workers
1) Total workforce as of 2030 *(2026 workforce of 93,299 – Episode 2 contraction of 19,183 jobs)*	74,116
2) Job losses over 10-year transition, 2021-2030	57,548
3) Job loss per episode *(= row 2/3)*	19,183
4) Number of workers reaching 65 during 2030 *(% of workers at least 65 years old in 2030 x row 1)*	3,261 *(4.4% of workers)*
5) Number of workers retiring voluntarily in 2030 *(= 80% x row 4)*	2,609 *(80% of 65+ workers)*
6) Number of near-retirement workers laid-off *(= row 3 x % of workers between 60-64 years old in 2030)*	2,762 *(14.4% of job losses)*
7) Number of workers requiring re-employment *(= row 3 – row 5 – row 6)*	13,812

Source: The 80 percent retirement rate for workers over 65 derived from U.S. Bureau of Labor Statistics data: https://www.bls.gov/cps/cpsaat03.htm. According to these BLS data, 20 percent of 65+ year-olds remain in the workforce..

Endnotes

1 Our basic measures of CO_2 emissions throughout this study are units of metric tons. However, to simplify, for the most part we refer hereafter to this unit as "tons" of CO_2 emissions.

2 https://www.bea.gov/index.php/news/glance. Comparable January – March 2021 figures for California specifically are not available as of this writing.

3 https://www.cbsnews.com/news/california-covid-restrictions-vaccine-increase/.

4 Unless noted otherwise, the figures on COVID trends in California are from: https://covidactnow.org/us/california-ca/?s=1602544.

5 Formally, the figures reported in Table 1.3 are derived by multiplying the industry-specific employment loss shown in Table 1.2 by the percent of overall employment—in California and the U.S. overall—as shown in the "industry job loss as % of total state employment loss" columns in Table 1.3.

6 https://calmatters.org/california-divide/2020/05/poor-los-angeles-are-infected-and-dying-at-twice-the-rate/.

7 https://www.usatoday.com/in-depth/graphics/2020/06/30/maps-covid-19-rich-and-poor-neighborhoods-show-big-disparities/3257615001/.

8 https://www.umass.edu/lrrc/sites/default/files/Western%20Mass%20Essential%20Worker%20Survey%20-%20May%202020.pdf.

9 https://www.bls.gov/news.release/flex2.t01.htm.

10 https://www.usatoday.com/story/news/health/2020/04/22/how-coronavirus-impacts-certain-races-income-brackets-neighborhoods/3004136001/.

11 Funds for Trump Covid relief bill: https://stateofreform.com/news/california/2020/12/with-trumps-signature-heres-the-covid-relief-funding-expected-to-flow-into-california/; funds from American Rescue Plan: https://stateofreform.com/featured/2021/03/how-much-does-california-receive-from-the-american-rescue-plan/.

12 https://www.gov.ca.gov/2021/02/17/governor-newsom-legislative-leaders-announce-immediate-action-agreement-for-relief-to-californians-experiencing-pandemic-hardship/.

13 https://www.latimes.com/california/story/2021-05-10/gavin-newsom-new-stimulus-checks-californians-rent-assistance?utm_id=28916&sfmc_id=2975001.

14 http://www.ebudget.ca.gov/2021-22/pdf/BudgetSummary/EconomicOutlook.pdf. See also the useful summary discussion by Dan Waters, "How long will California's economy languish?", 2/7/21, https://calmatters.org/commentary/2021/02/california-economy-recovery-unemployment-recall/.

15 https://www.latimes.com/california/story/2021-05-10/drought-emergency-now-extends-to-4-1-california-counties-newsom-says.

16 https://www.peri.umass.edu/component/k2/item/1447-covid-19-vaccinations-a-shot-in-the-arm-for-universal-healthcare.

17 https://www.peri.umass.edu/publication/item/1127-economic-analysis-of-medicare-for-all; https://www.peri.umass.edu/publication/item/996-economic-analysis-of-the-healthy-california-single-payer-health-care-proposal-sb-562.

18 https://calbudgetcenter.org/resources/californias-recent-job-gains-are-promising-but-policy-choices-now-will-determine-if-an-equitable-economy-is-ahead/#:~:text=Report-,California's%20Recent%20Job%20Gains%20Are%20Promising%2C%20but%20Policy%20Choices%20Now,an%20Equitable%20Economy%20Is%20Ahead&text=The%20economic%20crisis%20amplified%20long,paid%20low%20wages%20much%20harder.

19 https://www.ipcc.ch/sr15/chapter/spm/.

20 A 2020 study by Michael Goss et al finds that autumn wildfires, in particular, in California have coincided with "extreme fire weather conditions during periods of strong offshore winds coincident with unusually dry vegetation enabled by anomalously warm conditions and late onset of autumn precipitation," https://iopscience.iop.org/article/10.1088/1748-9326/ab83a7.

21 https://www.ncdc.noaa.gov/billions/events/CA/1980-2020.

22 https://academic.oup.com/bioscience/article/51/9/723/288247.

23 https://www.latimes.com/environment/story/2020-12-23/billions-spent-fighting-california-wildfires-little-on-prevention.

24 https://www.sacbee.com/news/local/environment/article245776245.html.

25 www.sciencedirect.com/science/article/pii/S0048969717320223.

26 https://www.nature.com/articles/s41893-020-00646-7.

27 For the connection between droughts and climate change, see https://agupubs.onlinelibrary.wiley.com/doi/full/10.1002/2015GL064924; see also https://www.pnas.org/content/112/13/3931.

28 https://oehha.ca.gov/media/downloads/climatechange/report/2018caindicatorsreportmay2018.pdf.

29 https://agupubs.onlinelibrary.wiley.com/doi/abs/10.1002/2014GL062433.

30 For assessments of the costs incurred by 2011-2017 droughts, see http://www.cirsinc.org/rural-california-report/entry/the-economic-impacts-of-the-climate-crisis-1; https://watershed.ucdavis.edu/files/biblio/Final_Drought%20Report_08182015_Full_Report_WithAppendices.pdf; https://watershed.ucdavis.edu/files/DroughtReport_20160812.pdf; www.cpo.noaa.gov/News/News-Article/ ArtMID/6226/ArticleID/1619/MAPP-NIDIS-Launch-%E2%80%9CStory-Map%E2%80%9D-Telling-the-Story-of-the-Historic-California-Drought; and https://www.ncdc.noaa.gov/billions/events/CA/1980-2020.

31 For the connection between California heatwaves and climate change, see https://link.springer.com/article/10.1007/s00038-009-0060-8; https://ehp.niehs.nih.gov/doi/10.1289/ehp.11594; https://journals.ametsoc.org/view/journals/apme/53/1/jamc-d-13-0130.1.xml .

32 https://pubs.er.usgs.gov/publication/70034156; https://www.healthaffairs.org/doi/10.1377/hlthaff.2011.0229.

33 https://www.ncdc.noaa.gov/sotc/national/201706.

34 https://www.ncdc.noaa.gov/sotc/national/202008.

35 https://papers.ssrn.com/sol3/papers.cfm?abstract_id=1931333.

36 https://acp.copernicus.org/articles/18/4817/2018/.

37 Senate Bill 32, in conjunction with AB-197, passed in 2016, and was meant to expand upon AB-32 passed in 2006.

38 https://www.vox.com/energy-and-environment/2018/9/11/17844896/california-jerry-brown-carbon-neutral-2045-climate-change.

39 GHGs include: CO2, CH4, N2O, SF6, HFCs, PFCs, NF3, and other fluorinated GHGs are covered. Measured by Co2 equivalent.

40 https://en.wikipedia.org/wiki/Corporate_average_fuel_economy#2011_agreement_for_Model_Years_2017%E2%80%932025. The Trump administration did aim to overturn the California fuel efficiency standards. The Biden administration will certainly support them, and will likely be open to the California standards becoming more stringent after 2025. See also: https://theconversation.com/why-california-gets-to-write-its-own-auto-emissions-standards-5-questions-answered-94379.

41 https://www.edmunds.com/car-news/california-mandates-electric-cars-for-2035.html.

42 https://leginfo.legislature.ca.gov/faces/billNavClient.xhtml?bill_id=201720180SB100.

43 http://cpuc.ca.gov/energyefficiency/; See also: October 2015, SB 350, the Clean Energy and Pollution Reduction Act https://leginfo.legislature.ca.gov/faces/billNavClient.xhtml?bill_id=201520160SB350.

44 Publicly-owned electric utilities with more than 750,000 customers which also provide water are exempt from offering net metering. Los Angeles Department of Water and Power (LADWP) is the only utility that falls in this category.

45 For a regularly updated database of California's state policies and initiatives in California see: https://programs.dsireusa.org/system/program/ca. For funding opportunities offered by the California Energy Commission, see https://www.energy.ca.gov/funding-opportunities.

46 For more information on California's various federal, state and local electric vehicle (EV) incentives see: https://cleanvehiclerebate.org/eng/ev/incentives.

47 For more information on PACE financing programs in CA see: https://www.treasurer.ca.gov/caeatfa/pace/index.asp.

48 https://www.library.ca.gov/Content/pdf/GovernmentPublications/executive-order-proclamation/40-N-79-20.pdf. https://www.capradio.org/articles/2020/09/23/all-new-california-cars-trucks-must-be-zero-emission-by-2035-newsom-announces-in-executive-order/.

49 https://www.gov.ca.gov/wp-content/uploads/2020/10/10.07.2020-EO-N-82-20-signed.pdf.

50 This is a nature-based 'carbon capture' technology, in contrast with the various artificial carbon capture technologies that are being developed. We briefly review these artificial carbon capture technologies further below.

51 See Pollin et al. (2014) for a review of the literature on high-emissions versus low-emissions bioenergy sources.

52 Various approaches to reduce energy losses in electricity generation are described in Prentiss (2015).

53 https://www.yaleclimateconnections.org/2016/07/pros-and-cons-the-promise-and-pitfalls-of-natural-gas/.

54 See, e.g. Alvarez et al. (2012); Romm (2014); Howarth (2015); and Peischl (2015). In addition to these measures of greenhouse gas emissions released, fracking operations produce further major negative environmental and public health impacts. See Pollin et al. (2020), pp. 19 – 20 for assessments of these impacts in Pennsylvania.

55 See, e.g.: https://www.nrc.gov/reading-rm/doc-collections/fact-sheets/3mile-isle.html; and https://www.thebalance.com/three-mile-island-nuclear-accident-facts-impact-today-3306337 For a dramatically more negative assessment of these health impacts, see http://www.greens.org/s-r/50/50-12.html.

56 https://globalhealth.usc.edu/2016/05/24/the-financial-costs-of-the-chernobyl-nuclear-power-plant-disaster-a-review-of-the-literature/.

57 Rachel Mealey, "TEPCO: Fukushima Nuclear Clean-Up, Compensation Costs Nearly Double Previous Estimate at $250 Billion," https://www.abc.net.au/news/2016-12-17/fukushima-nuclear-clean-up,-compensation-costs-nearly-double/8127268, December 16, 2016; "FAQs: Health Consequences of Fukushima Daiichi Nuclear Power.

58 See, for example, https://iopscience.iop.org/article/10.1088/1748-9326/aaac88/meta; https://science.sciencemag.org/content/359/6382/1328.full; https://iopscience.iop.org/article/10.1088/1748-9326/aaa512/meta.

59 https://www.documentcloud.org/documents/6889670-Scientist-Letter-to-Congress-8May20.html. Among the research findings cited in this letter is that by Sterman et al. (2018), who concludes that "Although bioenergy from wood can lower long-run CO_2 concentrations compared to fossil fuels, its first impact is an increase in CO_2, worsening global warming over the critical period through 2100 even if the wood offsets coal, the most carbon-intensive fossil fuel. Declaring that biofuels are carbon neutral as the EU and others have done, erroneously assumes forest regrowth quickly and fully offsets the emissions from biofuel production and combustion. The neutrality assumption is not valid because it ignores the transient, but decades to centuries long, increase in CO_2 caused by biofuels," (2018), p. 8, https://iopscience.iop.org/article/10.1088/1748-9326/aaa512/pdf.

60 Details on the economics of switchgrass as a bioenergy source are reviewed here: https://farm-energy.extension.org/the-economics-of-switchgrass-for-biofuel/.

61 See Pollin et al. (2014), pp. 113 – 117 for a more detailed review of the literature on high- versus- low-emissions bioenergy sources. For descriptions of California's bioenergy industry, including both high- and low-emissions sources, see: https://www.energy.gov/sites/prod/files/2015/10/f27/california_biofuels_benefits.pdf https://redwoodenergy.org/wp-content/uploads/2019/04/11-307.pdf.

62 https://www.pfpi.net/wp-content/uploads/2011/04/PFPI-biomass-carbon-accounting-overview_April.pdf.

63 https://www.fs.fed.us/pnw/rma/fia-topics/state-stats/California/index.php#:~:text=Forests%20cover%20about%20a%20third,and%20state%20and%20national%20parks.

64 https://earthobservatory.nasa.gov/images/1510/global-effects-of-mount-pinatubo.

65 These IEA projections are on pp. 686, 687, and 753 of its 2019 *World Energy Outlook*.

66 These more recent studies include Molina (2014), Ackerman et al. (2016) and Rosenow and Bayer (2016).

67 A detailed discussion of California's achievements in raising energy efficiency standards is the 2019 Natural Resources Defense Council study *California Stars: Lighting the Way to a Clean Energy Future*, https://www.nrdc.org/sites/default/files/california-stars-clean-energy-future-report.pdf.

68 See the discussion and references in Pollin et al. (2015), pp. 92 – 96.

69 Offshore wind remains more expensive, with IRENA estimating a global average figure at 11.5 cents per kilowatt hour as of 2019. However, costs for offshore wind are also falling, with the figure for Denmark being 8.7 cents as of 2019: https://www.irena.org/costs/Power-Generation-Costs/Wind-Power.

70 These cost figures are comparable with those reported for the U.S. economy exclusively through the U.S. Energy Information Agency (EIA). See the EIA's annual publication, "Levelized Costs and Levelized Avoided Cost of New Generation Resources," in the *Annual Energy Outlook*. The 2020 edition is here: https://www.eia.gov/outlooks/aeo/electricity_generation.php.

71 Such detailed figures are also available at https://www.irena.org/publications/2020/Jun/Renewable-Power-Costs-in-2019.

72 These figures are from the EIA, "Levelized Costs," https://www.eia.gov/outlooks/aeo/electricity_generation.php.

73 The full methodology for generating these costs is presented in Pollin et al. (2014) pp. 136-37.

74 A detailed discussion of California's achievements in raising energy efficiency standards is the 2019 Natural Resources Defense Council study *California Stars: Lighting the Way to a Clean Energy Future*, https://www.nrdc.org/sites/default/files/california-stars-clean-energy-future-report.pdf.

75 As a point of clarification, California's overall average annual GDP growth rate from 1999 – 2018 was 2.8 percent. The state's average annual per capita growth rate was lower, at 1.9 percent, as cited above. The reason the per capita income growth rate is slower than the GDP growth rate is that the state's population was also growing over this period, at a 0.9 percent average annual growth rate. Thus, California's GDP growth rate over 1999 – 2018 equals the combined growth rates of its population and per capita income.

76 For the sake of simplicity in this scenario only, we assume that nuclear energy supply also grows at the steady-state rate of 2.5 percent average annual growth through until 2030. We recognize that, in fact, the two Diablo Canyon reactors are scheduled to be shut down before 2030, in 2024 and 2025 respectively. .

77 American Council for an Energy-Efficient Economy (ACEEE). *The 2020 State Energy Efficiency Scorecard.* https://www.aceee.org/sites/default/files/pdfs/u2011.pdf p. 38; Solar Energy Industries Association (SEIA). 2020. *State Solar Spotlight: California*. https://www.seia.org/sites/default/files/2020-09/California.pdf; American Wind Energy Association (AWEA). 2020. *Wind Energy In California*. https://www.awea.org/Awea/media/Resources/StateFactSheets/California.pdf. Yearly increase from: https://www.osidenews.com/2020/04/20/annual-report-shows-wind-power-is-driving-economic-growth-in-california-creating-new-jobs-and-supporting-farmers/.

78 http://www.ebudget.ca.gov/2020-21/pdf/Enacted/BudgetSummary/SummaryCharts.pdf.

79 See Pollin, Wicks-Lim and Chakraborty (2020).

80 It is also the case that, in California's smaller-scale "distributed" solar energy sector—including in the area of residential solar installations—union representation and general labor conditions are well below those in the state's utility-scale sector. See Zabin (2020), pp, 221 – 223 for details.

81 *Carol Zabin ed. (2020) Putting California on the High Road: A Jobs and Action Plan for 2030*, https://laborcenter.berkeley.edu/wp-content/uploads/2020/09/Putting-California-on-the-High-Road.pdf, pp. 5 – 8.

82 https://www.hcd.ca.gov/building-standards/calgreen/index.shtml.

83 https://www.labormarketinfo.edd.ca.gov/occguides/Detail.aspx?Soccode=472111&Geography=0601000000.

84 EDD/LMID Occupational Employment Statistics Survey, 2020 Wages do not reflect self-employment. https://www.labormarketinfo.edd.ca.gov/data/wages.html.

85 http://www.calapprenticeship.org/programs/electrician_apprenticeship.php.

86 https://laborcenter.berkeley.edu/wp-content/uploads/2020/09/Putting-California-on-the-High-Road.pdf.

87 Local Hires example - The National Electrical Contractors Association (NECA) and the International Brotherhood of Electrical Workers (IBEW) Local 569 opened an apprenticeship training facility in 2009 in Imperial County, where project labor agreements included local hiring requirements, enabling skilled craftspeople living near the project site to be prioritized in the hiring process. As the utility-scale renewable project pipeline grew in the county as a result of the RPS, jobs were created for a local pool of entry-level workers who were subsequently trained at the IBEW/NECA Imperial Electrical Training Center https://laborcenter.berkeley.edu/wp-content/uploads/2020/09/Putting-California-on-the-High-Road.pdf p.215.

88 https://www.calctp.org/.

89 https://laborcenter.berkeley.edu/wp-content/uploads/2020/09/Putting-California-on-the-High-Road.pdf p.131 ; https://evitp.org/ .

90 https://www.labormarketinfo.edd.ca.gov/occguides/Detail.aspx?Soccode=472031&Geography=0601000000.

91 EDD/LMID Occupational Employment Statistics Survey, 2020 https://www.labormarketinfo.edd.ca.gov/data/wages.html.

92 https://www.hcd.ca.gov/building-standards/calgreen/index.shtml.

93 https://www.green.ca.gov/buildings/resources/leed/.

94 https://www.hcd.ca.gov/building-standards/calgreen/index.shtml.

95 https://www.labormarketinfo.edd.ca.gov/occguides/Detail.aspx?Soccode=472152&Geography=0601000000.

96 EDD/LMID Occupational Employment Statistics Survey, 2020 https://www.labormarketinfo.edd.ca.gov/data/wages.html.

97 https://cabuildingtrades.org/local-unions-category/united-association-of-plumbers-fitters-ua/UA.

98 http://www.ua.org/education.

99 https://www.green.ca.gov/buildings/resources/leed/.

100 https://www.labormarketinfo.edd.ca.gov/OccGuides/Detail.aspx?Soccode=472061&Geography=0601000000.

101 www.bls.gov%2Fnews.release%2Fpdf%2Fosh.pdf&usg=AOvVaw2tIi_h3zN2QQYRDhLjWcCZ.

102 https://cabuildingtrades.org/local-unions-category/laborers-liuna/.

103 https://www.bls.gov/green/construction/#occupations.

104 http://www.calapprenticeship.org/programs/laborer_apprenticeship.php.

105 https://laborcenter.berkeley.edu/wp-content/uploads/2020/09/Putting-California-on-the-High-Road.pdf.

106 Women In Non-Traditional Employment Roles (WINTER) based in Long Beach, is a pre-apprenticeship program for women which builds foundational skills for a career in construction. www.winterwomen.org/.

107 https://www.flintridge.org/what/apprenticeship.htm.

108 https://www.labormarketinfo.edd.ca.gov/occguides/Detail.aspx?Soccode=172051&Geography=0601000000.

109 EDD/LMID Occupational Employment Statistics Survey, 2020 https://www.labormarketinfo.edd.ca.gov/data/wages.html.

110 http://pecg.org/.

111 https://www.hcd.ca.gov/building-standards/calgreen/index.shtml.

112 https://www.labormarketinfo.edd.ca.gov/occguides/Detail.aspx?Soccode=194021&Geography=0601000000.

113 EDD/LMID Occupational Employment Statistics Survey, 2020 https://www.labormarketinfo.edd.ca.gov/data/wages.html.

114 https://www.labormarketinfo.edd.ca.gov/occguides/Detail.aspx?Soccode=173023&Geography=0601000000.

115 Source: EDD/LMID Occupational Employment Statistics Survey, 2020 Wages do not reflect self-employment.

116 https://www.ifpte.org/.

117 http://www.ibew.org/.

118 https://www.goiam.org/.

119 https://www.speea.org/.

120 https://www.bls.gov/oes/current/oes533052.htm.

121 https://www.atu.org/union/directory?state=california; https://www.twucsc.org/; https://www.teamsterslocal896.org/.

122 https://www.dmv.ca.gov/portal/driver-licenses-identification-cards/commercial-driver-licenses-cdl/commercial-driver-license-classes-certifications/.

123 https://www3.epa.gov/ttnchie1/ap42/ch12/final/c12s19.pdf.

124 https://www.labormarketinfo.edd.ca.gov/occguides/Detail.aspx?Soccode=514121&Geography=0601000000.

125 Source: EDD/LMID Occupational Employment Statistics Survey, 2020 Wages do not reflect self-employment.

126 https://www.aws.org/certification/professionalcertifications.

127 https://www.sierraclub.org/sites/www.sierraclub.org/files/THRIVE_%20A%20Bold%20Plan%20for%20Economic%20Renewal.pdf.

128 https://static1.squarespace.com/static/5f53b5996b708446acb296c5/t/5f596f847cd042259067e795/1599696773913/THRIVE+resolution+CLEAN.pdf.

129 "Regenerative" and "organic" agriculture entail broadly similar practices. The difference between them is described in this article, "What is the Difference between Regenerative and Organic Agriculture?, https://www.noble.org/regenerative-agriculture/organic-vs-regenerative-agriculture/. For the purposes of our employment modeling, we treat regenerative and organic agriculture as involving the same production practices.

130 https://www.infrastructurereportcard.org/wp-content/uploads/2018/10/FullReport-CA_051019.pdf, p. 4.

131 We estimate the overall increase in manufacture/infrastructure spending to raise all workers to at least $15.00 by doing the following. Using micro-data from the Labor Department's Current Population Survey (2015-2019), we estimate that 22 percent of workers in direct, manufacture/infrastructure jobs would earn less than $15.00 per hour, or 53,395 direct jobs (242,704 direct jobs x 22 percent). These workers earn, on average, $11.70 and work 35 hours weekly. We then assume these workers work 50 weeks over the year. Therefore, raising these workers' wages by $3.30 per hour to $15.00 would sum to just over $308 million ($3.30/hr. x 35 hrs./wk. x 50 wks. x 53,395 direct jobs = $308.4 million). $308.4 million is equal to 0.8 percent of the annual manufacture/infrastructure investment figure of $39.2 billion. The analogous figures for agriculture/land restoration are: 58,245 workers earn, on average, $11.40 per hour and work 38 hours weekly. The cost of raising these workers' pay rate to $15.00 per hour would sum to nearly $400 million ($3.60/hr. x 38 hrs./wk. x 50 wks. x 58,245 direct jobs = $398.4 million). $398.4 million is equal to 1.8 percent of the annual agriculture/land restoration investment figure of $22.6 billion.

132 https://www.labormarketinfo.edd.ca.gov/occguides/Detail.aspx?Soccode=518031&Geography=0601000000.

133 EDD/LMID Occupational Employment Statistics Survey, 2020 https://www.labormarketinfo.edd.ca.gov/data/wages.html.

134 https://www.local39.org/; http://www.ibew.org/; https://www.oe3.org/.

135 https://www.waterboards.ca.gov/water_issues/programs/operator_certification/.

136 https://www.labormarketinfo.edd.ca.gov/occguides/Detail.aspx?Soccode=119013&Geography=0601000000.

137 EDD/LMID Occupational Employment Statistics Survey, 2020 https://www.labormarketinfo.edd.ca.gov/data/wages.html. The figure we report in Table 4.8 for "average total compensation" in Organic Farming of $55,800 includes the incomes of both farm owners and employees.

138 https://www.nal.usda.gov/afsic/edtr/institution-name/college-marin.

139 https://www.ccof.org/; https://www.cdfa.ca.gov/is/organicprogram/registration.html.

140 https://www.labormarketinfo.edd.ca.gov/occguides/Detail.aspx?Soccode=452092&Geography=0601000000.

141 EDD/LMID Occupational Employment Statistics Survey, 2020 http://www.labormarketinfo.edd.ca.gov/data/wages.html.

142 https://ufw.org/.

143 https://www.labormarketinfo.edd.ca.gov/occguides/Detail.aspx?Soccode=399032&Geography=0601000000.

144 EDD/LMID Occupational Employment Statistics Survey, 2020 https://www.labormarketinfo.edd.ca.gov/data/wages.html.

145 https://cbrpc.org/.

146 We work with the simplifying assumption that the proportions of primary energy sources for the state's imported electricity are the same as the proportions for electricity generated within California.

147 We emphasize that this assumption of a 50 percent decline in production and employment in California's fossil fuel industries is only a *rough approximation*—though we believe it is the most reasonable such approximation. There are reasons to assume that production and employment in the affected industries will decline by less than the full fall in consumption. It is possible that California's fossil fuel related businesses will find it profitable to maintain a disproportionately large workforce even while overall demand declines because doing so maintains their operations at the most effective level. By contrast, it could also follow with some firms that the decline in demand for their products will encourage them to lay off workers by a more than proportional extent—i.e. to reorganize production with a higher level of capital intensity. Some firms could also shut down altogether due to the steady decline in demand (Pollin and Callaci (2018) discuss this latter prospect more fully). Given this range of possibilities—some of which are counteracting—on balance, we conclude, again, that the most reasonable working assumption for our purposes is that the decline in production and employment in California's fossil fuel related industries will be commensurate with the decline in statewide fossil fuel consumption.

148 We do not report in this section the comparable figures for California's various bioenergy sectors, since the employment levels are quite small and the relevant data are not consistently reliable. We do have reliable figures on the state's biomass electricity sector. This sector provides 1.3 percent of California's total electricity supply. But it accounts for only 325 jobs, equal to only 0.5 percent of the state's fossil fuel employment level as of 2018, according to the 2020 IMPLAN database. There are not comparably reliable employment data in IMPLAN for the state's other bioenergy-related activities, even though these other bioenergy activities—fuel ethanol, biodiesel and co-products—provide California with about 40 percent of the amount of energy provided by biomass electricity (i.e. 121 T-BTUs for biomass electricity versus 52 T-BTUs for the other sectors). For the purposes of our policy analysis, we assume that the forms of just transition policy support provided for fossil fuel-based industry workers will also be available to workers facing displacement through the contraction of California's bioenergy industry activities.

149 https://laborcenter.berkeley.edu/wp-content/uploads/2020/09/Putting-California-on-the-High-Road.pdf.

150 We also assume that the high-emissions bioenergy sector will contract at the same rate as oil and natural gas. We focus on the oil and natural contractions here because they are of much greater significance in California.

151 According to data published by the U.S. Labor Department, 20 percent of 65+ year-olds remain in the workforce. See: https://www.bls.gov/cps/cpsaat03.htm.

152 The financial situation for the California Resources Corporation turned sharply negative in 2020, with the firm filing for Chapter 11 bankruptcy protection in July: This bankruptcy filing by the California Resources Corporation reflected the broader sharp decline in the U.S. oil and gas industry resulting from the COVID-19 recession. The overall prospects for the industry for 2021 seem much more favorable. See: https://www.desertsun.com/story/tech/science/energy/2020/10/13/judge-approves-california-resources-corp-plan-emerge-bankruptcy/3642935001/; and: https://www.ft.com/content/66fe5644-00dd-41db-8802-ea3278f29007.

153 https://obamawhitehouse.archives.gov/the-press-office/2015/03/27/fact-sheet-partnerships-opportunity-and-workforce-and-economic-revitaliz.

154 https://www.univstats.com/community-colleges/?state=CA.

155 According to the 2020 article in Moneyzine "Job Relocation Expenses," these expenses for an average family range between $25,000 and $75,000 (https://www.money-zine.com/career-development/finding-a-job/job-relocation-expenses/). The costs include: selling and buying a home, including closing costs; moving furniture and other personal belongings; and renting a temporary home or apartment while house-hunting for a more permanent residence. For our calculations, we assume the upper-end figure of $75,000.

156 We present the tables illustrating the 2026 and 2030 episodic contraction patterns in Appendix 3. The bottom-line figures of number of workers requiring re-employment in these second and third episodes are higher than in the first episode. This is because the number of workers who would be retiring voluntarily in the second and third episodes will be smaller than in the first episode.

157 https://www.conservation.ca.gov/calgem/Pages/Wellfinder.aspx; https://www.latimes.com/business/la-fi-oil-bakersfield-20150129-story.html .

158 https://www.latimes.com/business/la-fi-oil-bakersfield-20150129-story.html; https://undark.org/2018/12/03/air-pollution-california/.

159 https://www.kcrw.com/news/shows/kcrw-features/red-county-blue-county-kern-bakersfield-oil-industry-california-renewable-energy;.

160 https://kernedc.com/wp-content/uploads/2021/01/2021-Kern-County-Market-Overview-Member-Directory.pdf .

161 https://www.kcrw.com/news/shows/kcrw-features/red-county-blue-county-kern-bakersfield-oil-industry-california-renewable-energy.

162 https://west.stanford.edu/sites/g/files/sbiybj12076/f/publications/towns_in_transition_-_ada_statler-web.pdf.

163 https://fred.stlouisfed.org/series/ACOILWTICO/; https://www.dallasfed.org/research/economics/2020/0514 .

164 http://www.latimes.com/business/la-fi-kern-fiscal-emergency-20150127-story.html .`

165 https://www.vvdailypress.com/story/news/coronavirus/2020/07/16/california-resources-corp-leading-oil-and-gas-producer-files-for-chapter-11-bankruptcy/42043055/.

166 https://kernedc.com/wp-content/uploads/2021/01/2021-Kern-County-Market-Overview-Member-Directory.pdf p.42.

167 https://www.calwea.org/fast-facts.

168 https://www.bakersfield.com/news/solar-power-tax-incentive-comes-under-scrutiny-from-kern-supervisors-as-state-begins-transition-away/article_1da1630a-0816-11eb-a7ee-3f3361ca7ef5.html).

169 https://www.bakersfield.com/kern-business-journal/aera-glasspoint-to-build-state-s-largest-solar-project/article_91ea9b38-e29a-5ead-92ae-addd3dcc0a4d.html; https://www.ecowatch.com/most-solar-saturated-zip-codes-california-1954601457.html .

170 https://www.pv-tech.org/news/california_property_tax_exemptions_for_pv_systems_extended_to_2025 .

171 https://laborcenter.berkeley.edu/pdf/2017/economic-impacts-climate-programs-san-joaquin-valley.pdf.

172 https://energynews.us/2020/06/23/national/support-grows-for-taxpayer-funded-oil-well-cleanup-as-an-economic-stimulus/.

173 https://www.latimes.com/projects/california-oil-well-drilling-idle-cleanup/.

174 https://f61992b4-44f8-48d5-9b9d-aed50019f19b.filesusr.com/ugd/bd8505_4a2770fe90234929994b5935a6da9373.pdf.

175 https://www.latimes.com/california/story/2020-01-24/cleanup-of-california-oil-and-gas-wells-could-cost-500-million-new-report-says.

176 https://ccst.us/wp-content/uploads/CCST-Orphan-Wells-in-California-An-Initial-Assessment.pdf.

177 https://www.fractracker.org/2019/03/failing-abandoned-wells/.

178 https://scholarship.law.duke.edu/cgi/viewcontent.cgi?article=1026&context=dflsc.

179 https://d1c2gz5q23tkk0.cloudfront.net/assets/uploads/1893311/asset/the-benefits-and-risks-of-solar-powered-irrigation-an-overview.pdf?1551350307.

180 https://www.infrastructurereportcard.org/wp-content/uploads/2018/08/2018-Kern-County-Infrastructure-Report-Card-1.pdf.

181 J. Mijin Cha's chapter in Zabin ed. (2020), titled "Just Transition: Tools for Protecting Workers and Their Communities at Risk of Displacement Due to Climate Policy," provides additional useful examples and policy proposals that complement those we present here.

182 With respect to repurposing the infrastructure around the nuclear sites, Lowrie et al. write that "much of federal investment leaves behind little usable on-site infrastructure to provide long-term economic benefits to a region. For instance, there are odd-shaped buildings, unusable waste management systems, and roads and railroads with inefficient locations. It is hard to convert resources for arms production to civilian uses because the technologies are significantly different and the workers skills are unique," (1999, pp. 120 – 121).

183 In May 2016 Congress legislated to maintain funding for the site: http://www.portman.senate.gov/public/index.cfm/press-releases?ID=84DB38D2-5B4C-434F-BC68-B14E60DFA440.

184 U.S. Department of Energy (2010), "U.S. Departments of Energy and Interior Announce Site for Solar Energy Demonstration Projects in the Nevada Desert," Press release, 7/8/10, http://energy.gov/ articles/ us-departments-energy-and-interior-announce-site-solar-energy-demonstration-projects-nevada.

185 The general descriptions in this paragraph is based on Galgoczi (2015) and Dohmen and Schmid (2011).

186 See, for example, Chow (2017).

187 Prentiss does, however, recognize that, beyond providing the average level of energy demanded at any given time is the challenge of meeting the specific energy demand needs, given that wind and solar power both are intermittent energy sources. Thus, she explains that technological advances will also be necessary to achieve an energy infrastructure that relies on renewable energy for 100 percent of supply. She writes that "The question of whether renewable energy could provide all of the actual instantaneous energy needs of the United States is an open question that depends on how fluctuating renewable energy sources can be harnessed to provide power on demand. A revolutionary advance in large-scale energy storage would greatly ease the transition to a 100 percent renewable- energy economy; however, a combination of increases in energy efficiency due to widespread adoption of existing technologies and 'smart grid' that pool energy supply and demand over large geographical areas may allow a renewable energy economy to flourish even without large-scale energy storage," (2015, p. 2). Prentiss reiterates that basic conclusion in a more recent 2019 article, "The Technical Path to Zero Carbon," in which she concludes that through a range of approaches, including battery storage and straightforward improvements in energy transmission systems, "science and technology are not preventing us from achieving a 100 percent U.S. renewable energy economy." A broadly similar assessment as to the potential for renewable energy to supply 100 percent of energy needs for India was developed by Prof. S.P. Sukhatme in his 2013 paper, "Can India's Future Needs of Electricity be Met by Renewable Energy Sources?"

188 https://www.nytimes.com/2020/12/28/business/economy/second-stimulus-package.html.

189 https://www.whitehouse.gov/briefing-room/legislation/2021/01/20/president-biden-announces-american-rescue-plan/.

190 Funds for Trump Covid relief bill: https://stateofreform.com/news/california/2020/12/with-trumps-signature-heres-the-covid-relief-funding-expected-to-flow-into-california/; funds from American Rescue Plan: https://stateofreform.com/featured/2021/03/how-much-does-california-receive-from-the-american-rescue-plan/.

191 https://www.whitehouse.gov/briefing-room/blog/2021/02/03/the-economics-of-the-american-rescue-plan/?fbclid=IwAR3bynaZYWNYreHUwzgm3zgT9kK4GoShKCqeoXHlLYBBXONna9RvuDBWzZE.

192 https://www.sierraclub.org/sites/www.sierraclub.org/files/THRIVE-jobs.pdf.

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194 http://www.ebudget.ca.gov/; https://signal-tribune.com/2017/01/14/browns-proposal-urges-corrective-action-in-light-of-uncertain-financial-future/.

195 https://www.latimes.com/california/story/2021-05-10/gavin-newsom-new-stimulus-checks-californians-rent-assistance.

196 https://www.fitchratings.com/research/us-public-finance/improved-revenue-outlook-supports-california-budget-21-01-2021.

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198 https://www.latimes.com/california/story/2021-05-10/gavin-newsom-new-stimulus-checks-californians-rent-assistance?utm_id=28916&sfmc_id=2975001.

199 http://www.ebudget.ca.gov/2021-Infrastructure-Plan.pdf.

200 https://california.municipalbonds.com/bonds/recent/.

201 https://www.brookings.edu/research/fed-response-to-covid19/.

202 In recent data sets, IMPLAN has started reporting electricity generation from some renewable sources — biomass, solar, geothermal, hydro, etc., which primarily captures the operation and maintenance of the industry.

203 We use the CPS data files provided by IPUMS-CPS: "Integrated Public Use Microdata Series, Current Population Survey: Version 7.0, Minneapolis, MN: IPUMS, 2020," published by Sarah Flood, Miriam King, Renae Rodgers, Steven Ruggles and J. Robert Warren. https://doi.org/10.18128/D030.V7.0.

204 For up-to-date rankings from the EIA, see https://www.eia.gov/state/rankings/?sid=CA.

205 For a company list, see https://www.shalexp.com/california/companies.

206 According to the BLS QCEW survey, the total number of wage and salary fossil fuel jobs in CA in 2019 was about 48,340. NAICS industry 21112 employed 3,135, industry 21113 employed 1,295, and industry 213112 employed 6,797. For NAICS industry-specific employment in CA, see https://data.bls.gov/cew/apps/table_maker/v4/table_maker.htm#type=11&year=2019&qtr=A&own=5&area=06000&supp=0.

207 For oil and gas production data for the top twenty companies and for California in total, see https://www.shalexp.com/california. We last checked this on January 18, 2021, at which time the data was for May 2020.

208 See: https://www.dol.gov/agencies/ebsa/about-ebsa/our-activities/public-disclosure/foia/form-5500-datasets.

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