6. Employment Impacts through Decarbonization for the San Diego Region

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Key Takeaways

- Between 2021 – 2030, the regional decarbonization pathway would generate an average of nearly 27,000 jobs per year in the San Diego region.
- Even taking into account the contraction of fossil fuel jobs, we estimate that no workers in the region's fossil fuel-based industries will have to experience job displacement before 2030.
- San Diego county and local governments should begin now to develop a viable set of just transition policies for the workers in the community who will experience job displacement between 2031 – 2050.
- The costs of a just transition will be much lower if the transition is able to proceed steadily rather than through a series of episodes. Under a steady transition, the proportion of workers who will retire voluntarily in any given year will be predictable, the transition process avoids having to provide support for a much larger share of workers.
- Geothermal production of the five sites identified in Imperial County would generate 1,900 jobs per year over a 10-year period.

In this chapter, we estimate the employment impacts of advancing the clean energy decarbonization program developed for the San Diego region by Evolved Energy Research, summarized in Appendix A. The Evolved Energy Research (ERR) model includes seven different energy system transformation scenarios between 2020 – 2050. The purpose of all of these scenarios is to present pathways through which CO_2 emissions in the San Diego region can fall to zero by 2050. In this chapter, we focus on what EER terms their "central case." They explain that this is the case through which the San Diego region can achieve zero CO_2 emission in 2050 at the lowest net cost. We focus in this chapter on the employment impacts between 2021 –

2030 through advancing the ERR central case in San Diego County.[xxxvi] We focus here on the 2021-2030 time period in order to inform future analysis on workforce development strategies for San Diego, modeled after California's Jobs and Climate Action Plan for 2030.[xxxvii] We do also report overall average annual job creation figures for the full 2020 - 2050 time period encompassed by ERR.

We also estimate in this chapter the impacts on employment of phasing down fossil fuel-based economic activity in the county. Within the ERR central case model, the phasing down of fossil fuel-based activity will be modest between 2021 – 2030, the decade of activity on which we focus here. As described in Appendix A, the model ERR assumes that natural gas consumption in the county will remain at its current level through 2030, while the consumption of oil will have fallen by 20 percent as of 2030 relative to current consumption levels. There is, at present, already close-to-zero coal consumption in the San Diego region.

This chapter will first focus on the employment creation impacts between 2021 - 2030 of the San Diego region advancing its zero-emissions program. We then turn to consider the employment impacts of phasing down fossil fuels in the region over this same period. [xxxviii]

Our overall findings can be summarized briefly. We estimate that, between 2021 – 2030, the regional decarbonization pathway would generate an average of nearly 27,000 jobs per year in the San Diego region. This amounts to an expansion of employment in the county of about 1.6 percent. It means that, if all else were held equal in the San Diego region labor market over

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[xxxvi] In fact, the ERR model from which we are generating employment estimates encompasses a broader geographic area than the San Diego region alone. The ERR model is for Southern California, which they define as including 13 counties in addition to San Diego. In order for us to produce estimates of employment impacts *within San Diego county itself*, we therefore need to work with some assumptions in defining the proportionate level of activity in San Diego County relative to all 14 counties constituting Southern California in the EER model. We describe our estimating methodology on this issue in Appendix 6.1. Because we have developed a methodology of converting their model for Southern California into estimates for San Diego County specifically, we refer throughout the chapter to the ERR model for the San Diego region.

[xxxvii] The County has retained Inclusive Economics to develop a comprehensive and coordinated regional strategy to address the workforce needs resulting from labor-market changes related to the region's Decarbonization Framework. The report will be jointly authored by Dr. Carol Zabin and Betony Jones and modelled after California's Jobs and Climate Action plan that provide recommendations on how to support San Diego's workforce as the region transitions to a carbon-neutral economy.

[xxxviii] A related profile of clean energy and fossil fuel-based employment levels in San Diego County is presented in a November 2020 spreadsheet report, *Clean and Renewable Energy in San Diego-Chula Vista-Carlsbad, CA*, by the San Diego Regional Economic Development Corporation, https://docs.google.com/spreadsheets/d/1mVZ4UXWzYG2zHu2XfnTFhXq2-1rwBBkr/edit?goal=0_c2357fd0a3-b9c8e8882a-84300641#gid=1212436047

2021 – 2030, the regional decarbonization project would itself be capable of reducing the county's unemployment rate from, say, 7.5 percent to 5.9 percent. The newly-created jobs will encompass a wide range of occupations, at all levels of the San Diego labor market. At the same time, between 2021 – 2030, we estimate that no workers in the county's fossil fuel-based industries will have to experience job displacement.

6.1. Overview of Job Creation Estimates

According to our calculations, as an average over 2021– 2030, total expenditures within the central case include $9.9 billion per year to purchase a wide range of products that operate through consuming energy, what we will term "energy demand expenditures." These include electric vehicles, heating and cooling systems, and refrigeration equipment.[xxxix] It also includes $5.1 billion per year to expand the supply of both clean renewable energy sources, including solar, wind, geothermal, and hydropower, as well as other low- to zero CO_2-emitting technologies, including nuclear power, biomass, and carbon sequestration. The average overall average spending total for both energy demand expenditures and energy supply investments, therefore, comes to an average of $15.0 billion per year between 2021 – 2030. This is equal to about 3.2 percent of San Diego's overall economic activity at its midpoint between 2021 – 2030 assuming that the San Diego County economy grows at an average annual rate of 2.5 percent over this 10-year period.

Working from these budgetary figures, we then estimate the amounts of jobs that will be created as a result of the spending amounts that EER have allocated to all categories in the areas of both energy demand and supply. Our overall findings are that an average of about 13,300 jobs per year will be generated through $9.9 billion in average annual energy demand expenditures in the region between 2021 – 2030 and another 13,400 jobs per year will be generated through spending an average of $5.1 billion per year in low- to zero-emissions technologies in the San Diego region. Overall, we estimate that the zero carbon emissions program for San Diego will generate an average of about 26,700 jobs between 2021 – 2030 in the San Diego region. This is equal to about 1.6 percent of the region's average projected labor force size between 2021 – 2030. This higher level of employment in San Diego will be sustained throughout this first decade of the county's clean energy transformation program (assuming no other major changes in the region's economy were to occur).

After estimating the number of jobs that these energy demand and supply expenditures will generate, we then present indicators of the quality of these jobs. These quality indicators

[xxxix] Appendix 1 in Pollin et al. (2020)[1] provides a full listing of all of the EER spending categories.

include average compensation levels, health care coverage, and union membership. We also provide data on the types of workers who are employed at present in the job areas that will be created by the energy demand and supply expenditures, including evidence on both educational credentials of these workers as well as their racial and gender composition. We then report on the prevalent types of jobs that will be generated through both the energy demand and supply expenditures.

6.2. Methodological Issues in Estimating Employment Creation

Before proceeding to present our detailed job creation and job quality estimates, we first briefly describe the methodology we used to generate our results.[xl]

Our employment estimates are figures generated directly with data from national surveys of public and private economic enterprises within the U.S. and organized systematically within the official U.S. input-output (I-O) model. The "inputs" within this model are all the employees, materials, land, energy and other products that are utilized in public and private enterprises within the U.S. to create goods and services. The "outputs" are the goods and services themselves that result from these activities that are then made available to households, private businesses and governments as consumers within both domestic and global markets. Within the given structure of the U.S. economy broadly and the San Diego region economy specifically, these figures from the input-output model provide the most accurate evidence available as to what happens within private and public enterprises when they produce the economy's goods and services. In particular, these data enable researchers to observe how many workers were hired to produce a given set of products or services, and what kinds of materials were purchased in the process.

Here is one specific example of how our methodology works. When the San Diego economy expands its solar energy productive capacity by $1 billion, we are able to estimate how much of the $1 billion will be spent on hiring workers, how much will be spent on non-labor inputs, including materials, energy costs, and maintaining factory buildings, and how much will be left over for business profits. Moreover, when businesses spend on non-labor inputs, we estimate the employment effects through giving orders to suppliers, such as glass manufacturers or trucking companies.

[xl] We provide a fuller discussion of our methodology in Pollin et al. (2020)[1] Appendix 2.

Direct, Indirect and Induced Job Creation

Spending money in any area of any economy will create jobs since people are needed to produce any good or service that the economy supplies. This is true regardless of whether the spending is done by private businesses, households, or government entities. At the same time, for a given amount of spending within the economy, for example, $1 billion, there are differences in the relative levels of job creation through spending that $1 billion in alternative ways. Again, this is true regardless of whether the spending is done by households, private businesses, or public sector enterprises.

There are three sources of job creation associated with any expansion of spending—direct, indirect, and induced effects. For purposes of illustration, consider these categories in terms of investments in manufacturing electric cars or building wind turbines:

1. *Direct effects*—the jobs created, for example, by installing solar panels or purchasing electric vehicles;

2. *Indirect effects*—the jobs associated with industries that supply intermediate goods for the solar panels or electric vehicles, such as silicon, steel, and transportation;

3. *Induced effects*—the expansion of employment that results when people who are paid in the glass, steel, or transportation industries spend the money they have earned on other products in the economy. These are the multiplier effects within a standard macroeconomic model.

In this study, we report on all three employment channels—direct, indirect, and induced job creation. But we emphasize that estimating induced effects—i.e. multiplier effects—within I-O models is much less reliable than the direct and indirect effects. In addition, induced effects derived from alternative areas of spending within a national economy are likely to be comparable to one another.

Within the categories of direct plus indirect job creation, how is it that spending a given amount of money in one set of activities in the economy could generate more employment than other activities? As a matter of simple arithmetic, there are only three possibilities. These are:

1. *Labor Intensity.* When proportionally more money of a given overall amount of funds is spent on hiring people, as opposed to spending on machinery, buildings, energy, land, and other inputs, then spending this given amount of overall funds will create relatively more jobs.

2. *Compensation per worker.* If $1 billion in total is spent on employing workers in a given year on a project, and each employee earns $1 million per year working on that project, then only 1,000 jobs are created through spending this $1 billion. However, if, at another enterprise, the average pay is $50,000 per year, then the same $1 billion devoted to employing workers will generate 20,000 jobs.

3. *Local content.* When a given amount of money is spent in the San Diego in either the areas of energy supply or demand, a significant share of the funds will support activities that occur outside the county itself. Of course, job creation in San Diego itself will increase as the relative share of locally produced goods and services rises. Through the input/output model, we are able to observe the level of job creation at existing local content levels. Additionally, we can also estimate how much overall job creation will change through assuming either an increase or decrease in the local content share, resulting, for example, from active economic development policies in the county. In what follows, we report job creation levels resulting from current local content ratios.

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 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 any assessment of the impact on the job creation of any clean energy investment activity.

There are two straightforward ways in which one can express such distinctions. 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 program, we are using in our example, we could express its effects as creating 100 jobs per year over the course of the 2021 – 2030 time period.

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 that the impact of any new investment, whether on renewable 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 prevent us from scaling the impact of investments on job markets at a given point in time. For example, as noted above, we estimate that employment creation in the region from the full set of energy demand and supply expenditures will average about 26,700 jobs per year over 2021 – 2030. We are able to scale that employment increase in the region relative to the size of the region's labor force. We estimate that the region's labor force will average about 1.7 million between 2021 – 2030. Thus, the increase of 26,700 jobs to the region's overall force of about 1.7 million jobs will amount to a growth of employment of 1.6 percent. We present the full derivation of these overall results below.

Incorporating Labor Productivity Growth over the 10-Year Investment Cycle

The figures we use for the input-output tables are based on the technologies that are prevalent at present for undertaking these clean energy investments. Yet we are estimating job creation through clean energy investments that will occur over the 10-year cycle between 2021 - 2030. The relevant production technologies will certainly change over this decade, so that a different mixture of inputs may be used to produce a given output.

For example, new technologies are likely to emerge, making other technologies obsolete. Certain inputs could also become more scarce, and, as a result, firms may substitute other less expensive goods and services to save on costs. The production process overall could also become more efficient so that fewer inputs are needed to produce a given amount of output. Energy efficiency investments do themselves produce a change in production processes—i.e. a reduction in the use of energy inputs to generate a given level of output. In short, the input-output relationships in any given economy—including its employment effects of clean energy investments—are likely to look different in 2030 relative to the present.

Pollin et al. address this issue in detail (e.g. 2015, pp. 133 - 44).[2] For the purposes of the present discussion, we work with a simple assumption: that average labor productivity in all the expenditure areas included in the ERR model will rise by 1 percent per year through until 2030.

6.3 Job Creation Estimates

Tables 6.1-6.5 report 2021-2030 job creation estimates generated by the ERR central case scenario and downscaled to the San Diego to enable the region to reach net-zero emissions by 2050.[xli] We report two overall sets of figures for both the energy demand and energy supply expenditures—first, job creation per $1 million in expenditure, then, job creation given the average annual level of spending incorporated into the ERR model, i.e. $9.9 billion per year in energy demand expenditures and $5.1 billion in energy supply investments. First, we report figures for direct and indirect jobs, along with the totals for these main job categories. Then, we include the figures on induced jobs and show total job creation when induced jobs are added to figures for direct and indirect jobs.

In Tables 6.1 and 6.2, we present our estimates as to the job creation effects generated by the full range of energy demand expenditures in the ERR central case. We have grouped this full set of projects into 10 categories: vehicles, heating/ventilation/air conditioning (HVAC), manufacturing, other commercial and residential spending, construction, appliances, refrigeration, mining, agriculture and lighting.[xlii] As Table 6.1 shows, direct plus indirect job creation per $1 million in spending range from 0.7 for mining to 10.0 for agriculture.

In Table 6.2, we show the level of job creation through spending an average of $9.9 billion per year on the full set of these projects between 2021 and 2030. As we see, of the full $9.9 billion average annual spending figure, the largest areas of expenditures include (with rounding): $7.7 billion on clean energy vehicles, $897 million on high-efficiency HVAC systems and $762 million on refrigeration equipment. These three spending categories, therefore, account for roughly 95 percent of total demand expenditures, with spending on clean energy vehicles alone accounting for 78 percent of all demand-side expenditures.

[xli] See Appendix A, Table 1 of the RDF report for more information on the Central Case. See Appendix 6.A.1 of this chapter for more information on downscaling Southern California data to the San Diego region.

[xlii] The “other” commercial and residential category of energy demand expenditures is taken directly from the ERR model—or, more precisely, this category combines the “commercial other” and “residential other” categories within the ERR model.

Table 6.1. Job Creation through Energy Demand Expenditures in San Diego, by Subsectors and Technology. Job creation per $1 million in spending.

Investment Area	Direct Jobs	Indirect Jobs	Direct Jobs+ Indirect Jobs	Induced Jobs	Direct Jobs+ Indirect Jobs+ Induced Jobs
Vehicles	0.47	0.19	0.66	0.21	0.87
HVAC	1.57	0.82	2.39	0.89	3.28
Refrigeration	1.81	0.68	2.49	0.98	3.47
Appliances	0.79	0.43	1.22	0.43	1.65
Construction	2.43	1.38	3.81	1.35	5.16
Lighting	1.74	0.93	2.67	0.98	3.65
Manufacturing	0.91	0.72	1.63	0.63	2.26
Other commercial and residential	1.6	0.8	2.4	0.9	3.3
Agriculture	8.78	1.27	10.05	2.74	12.79
Mining	0.39	0.33	0.72	0.34	1.06

Note: These figures are based on current rates of job creation, weighted by total investment amounts over 2021-2030. Source: IMPLAN 3.1

Table 6.2. Average Number of Jobs Created in the San Diego Region Annually through Energy Demand Expenditures from 2021-2030, by Subsectors and Technology. Figures assume 1 percent average annual productivity growth.

Investment Area	Average Annual Expenditure	Direct Jobs	Indirect Jobs	Direct Jobs + Indirect Jobs	Induced Jobs	Direct Jobs + Indirect Jobs + Induced Jobs
Vehicles	$7.7 billion	3,427	1,427	4,854	1,508	6,362
HVAC	$897.0 million	1,345	699	2,044	764	2,808
Refrigeration	$761.9 million	1,315	491	1,806	711	2,517
Appliances	$188.6 million	143	77	220	78	298
Construction	$113.4 million	263	149	412	146	558
Lighting	$106.6 million	177	95	272	100	372
Manufacturing	$45.7 million	40	32	72	27	99
Other commercial and residential	$38.9 million	59	30	89	33	122
Agriculture	$17.2 million	144	21	165	45	210
Mining	$2.4 million	1	1	2	1	3
TOTAL	$9.9 billion	6,914	3,022	9,936	3,413	13,349

Source: IMPLAN 3.1

The result of the demand expenditures at this level will be the creation of an average of about 6,914 direct jobs and 3,022 indirect jobs, for an average between 2021 and 2030 of 9,936 direct plus indirect jobs. Including induced jobs adds another 3,413 jobs per year to the total figure. This brings the total net job creation figure for the full set of energy demand expenditures, including induced jobs, to about 13,400 as an annual average figure between 2021 – 2030.

In Tables 6.3 and 6.4, we present our estimates as to the job creation effects generated by the full set of energy supply projects presented in the ERR model for San Diego County between 2021 - 2030. These include clean renewables, transmission and storage; fossil fuels; additional supply technologies, including nuclear, carbon sequestration and biomass; and grouping of difficult to categorize "other" investments.[xliii] By far, the largest share of investments assigned by the ERR model over 2021 – 2030 is in the fossil fuel category.
In Table 6.3, we see that the extent of direct plus indirect jobs ranges from 1.2 jobs per $1 million in spending for "other investments" to 3.5 jobs per million for both the fossil fuel and clean renewables investment categories. Adding induced jobs brings the range to between 1.9 jobs for other investments to 4.9 for fossil fuels and clean renewables.

Table 6.3. Job Creation through Energy Supply Expenditures in San Diego, by Subsectors and Technology. Job creation per $1 million in spending.

Investment Area	Direct Jobs	Indirect Jobs	Direct Jobs+ Indirect Jobs	Induced Jobs	Direct Jobs+ Indirect Jobs+ Induced Jobs
Fossil fuels	2.73	0.81	3.54	1.33	4.87
Clean renewables	2.47	1.00	3.47	1.41	4.88
Transmission and storage	0.61	0.90	1.51	0.91	2.42
Additional supply technologies	2.35	0.79	3.14	1.27	4.41
Other investments	0.77	0.38	1.15	0.70	1.85

Note: These figures are based on current rates of job creation, weighted by total investment amounts over 2021-2030. Source: IMPLAN 3.1

[xliii] Our energy supply expenditure "other" category includes electric boilers, hydrogen blend, industrial CO2 capital, other boilers, and steam production.

Based on these proportions, we see in Table 6.4 the levels of job creation in the San Diego region associated with $5.1 billion in average annual spending on these energy supply investments between 2021 - 2030. As noted above, the highest proportion of spending among the supply side investments is in the fossil fuel area, at $4.4 billion of the $5.1 billion total—i.e. amounting to about 86 percent of total spending. Spending on clean renewables totals to an average of $630 million per year, equal to another 12.3 percent of the total. Thus, the spending on fossil fuels and clean renewables together accounts for fully 98 percent of all spending on the supply side between 2021 – 2030 in the ERR model.

Within these budgetary allocations, we see first in Table 6.4 that total direct plus indirect job creation generated in the San Diego region by this specific expansion in energy supply expenditures will amount to an average of about 4,200 direct jobs and 4,400 indirect jobs per year between 2021 – 2030. This totals to about 8,600 direct and indirect jobs. We also estimate that, as an average between 2021 – 2030, an additional 4,700 induced jobs will be generated in San Diego by these investments. This brings the total of direct, indirect and induced jobs generated by net energy supply investments to about 13,400 jobs.

Table 6.4. Average Number of Jobs Created in the San Diego Region Annually through Energy Supply Expenditures from 2021-2030, by Subsectors and Technology. Figures assume 1 percent average annual productivity growth.

Investment Area	Average Annual Expenditure	Direct Jobs	Indirect Jobs	Direct Jobs+ Indirect Jobs	Induced Jobs	Direct Jobs+ Indirect Jobs+ Induced Jobs
Fossil fuels	$4.4 billion	2,538	3,777	6,315	3,805	10,120
Clean renewables	$629.5 million	1,488	601	2,089	848	2,937
Transmission and storage	$45.9 million	34	17	51	31	82
Additional supply technologies	$45.1 million	118	35	153	57	210
Other investments	$4.5 million	10	3	13	6	19
TOTAL	$5.1 billion	4,188	4,433	8,621	4,747	13,368

Source: IMPLAN 3.1

Tables 6.5A and 6.5B bring together our job creation estimates for both the energy supply investments and energy demand expenditures. In Table 6.5A, we first present the figures for 2021 – 2030, our time period of focus. Table 6.5B then presents the same set of aggregate employment figures for the full period of the ERR model, i.e. 2020 – 2050.

In Table 6.5A, we show the total job creation estimates through spending an average of $15.0 billion per year from 2021 --2030. We first report figures for direct plus indirect jobs only, then we also show the total when induced jobs are included.

Table 6.5. Estimated Average Annual Job creation in San Diego County through Combined Energy Supply and Energy Demand Expenditure Program

Table 6.5A. Figures for 2021-2030

	Number of Direct and Indirect Jobs	Number of Direct, Indirect, and Induced Jobs
1. $9.9 billion in average annual energy demand investments	9,936	13,349
2. $5.1 billion in average annual energy supply investments	8,621	13,368
3. $15.0 in average annual energy demand investments	18,557	26,717
4. Total job creation as a share of projected 2026 labor force *(projection is 1.68 million San Diego county labor force for 2026)*	1.1%	1.6%

Note: Figures assume 1 percent average annual labor productivity growth. Source: Figures derived from ERR energy model for Southern California.

Table 6.5B. Figures for 2020 - 2050

	Number of Direct and Indirect Jobs	Number of Direct, Indirect, and Induced Jobs
1. $4.4 billion in average annual energy supply investments	8,868	13,985
2. $11.4 billion in average annual energy demand expenditures	12,922	17,425
3. $15.8 billion in average annual combined expenditures	21,791	31,412
4. Total job creation as share of projected 2035 labor force *(Projection is 1.9 million San Diego County labor force for 2035)*	1.1%	1.7%

Note: Figures assume 1 percent average annual labor productivity growth. Source: Figures derived from ERR energy model for Southern California Energy demand figures are averages for 2018 – 2050.

We see in row 3 of Table 6.5A that total average direct and indirect job creation between 2021 – 2030—including jobs generated on both the supply and demand sides of the energy transformation—is, as discussed above, 18,557. Through adding induced jobs, the average annual job creation figures then rise to 26,717. As we see in row 4, this level of direct and indirect job creation would amount to about 1.1 percent of the likely San Diego region County labor force as of 2026. When we include induced jobs in the total, we reach 1.6 percent of the likely size of the county's 2026 labor force.

Not surprisingly, the patterns we report in Table 6.5B, covering the full period 2020 – 2050, parallel those shown in Table 6.5A. For the full 2020 – 2050 period, the average annual spending level rises to $15.8 billion, since spending levels increase in the later years of the ERR model. With average spending levels rising, the extent of job creation through the decarbonization project rises correspondingly. Thus, direct and indirect employment between 2020 – 2050 rises to an average of 21,791. When we include induced job creation, average annual employment increases rise to 31,214. These greater average employment levels remain at basically the same size relative to the overall San Diego County labor force—i.e. at 1.1 percent of the labor force for direct and indirect jobs only and at 1.7 percent when we include induced jobs. These stable shares of the overall San Diego labor force reflect the fact that the San Diego County labor force is growing over this full 2020 – 2050 period, along with the average level of spending within the region on its decarbonization project.

6.4. Job Quality Indicators in Energy Demand and Supply Employment

In Table 6.6 – 6.9, we provide some basic measures of job quality for the direct jobs in the core areas that will be generated through both the energy demand expenditures and energy supply investments within the ERR central case for the San Diego region. These basic indicators include: 1) average total compensation (including wages plus benefits) for wage-earning employees; 2) the percentage of workers receiving health insurance coverage through their employer; and 3) the percentage that are union members. We first present these figures for the energy demand categories in Tables 6.6 and 6.7, then for the energy supply investments in Tables 6.8 and 6.9

Energy Demand Expenditures and Job Quality

We focus here on figures for the three major energy demand expenditure areas—i.e. vehicles, HVAC, and refrigeration. These three spending categories comprise roughly 95 percent of all spending on energy demand between 2021 – 2030.

Starting with compensation figures, we see in Table 6.6 that the averages for the energy demand expenditures range between roughly $62,000 per year for workers in the vehicles' category to nearly $78,000 in the refrigeration category.

Table 6.6. Indicators of Job Quality in Energy Demand Investment Areas: Direct Jobs Only.

Investment Area	Average total compensation*	Health insurance coverage, percentage**	Union membership, coverage***
Vehicles	$62,000	58.2%	14.2%
HVAC	$72,000	53.8%	12.4%
Refrigeration	$77,600	55.2%	14.5%
Appliances	$70,800	51.1%	14.0%
Construction	$73,200	51.9%	13.0%
Lighting	$73,800	50.9%	14.2%
Manufacturing	$71,800	64.9%	7.3%
Other commercial and residential	$73,800	53.4%	13.2%
Agriculture	$59,500	44.7%	4.6%
Mining	$61,700	76.3%	NA

Source: CPS 2015-2019, ACS 2015-2019, IMPLAN 3.1.

Notes: *Compensation figures reflect only wage and salary workers, and excludes proprietors' compensation, in San Diego County. This is because wage and salary workers' employment in these activities serve as their primary jobs, whereas proprietors' employment in these activities are more likely to serve only as secondary jobs. **Health insurance coverage is based on workers within San Diego County plus the five surrounding counties that supply San Diego County with the highest numbers of commuting workers. These counties include: Imperial County, Los Angeles County, Orange County, Riverside County, and San Bernardino County. *** Union membership is based on workers in the southern region of California. "NA": the sample size is too small to generate a reliable union coverage estimate of workers in mining.

The share of workers receiving health insurance coverage is comparable for these major energy demand areas, ranging between 54 percent for HVAC to 58 percent for vehicles. Similarly, the level of union membership is also comparable, ranging between about 12 – 14 percent of the workforce in the area.

Educational Credentials and Race/Gender Composition

In Table 6.7, we present data on both the educational credentials and race/gender composition for workers employed in the full range of energy demand categories. We focus on the workers in the three core energy efficiency expenditure categories of vehicles, HVAC, and refrigeration, as well as the race and gender composition of these workers. We categorize all workers 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 a Bachelor's degree or higher.

Table 6.7. Educational Credentials and Race/Gender Composition of Workers in Energy Demand Investment Areas: Direct Jobs Only.

	Educational Credentials			Racial and Gender Composition	
Investment Area	% with high school degree or less	% with some college or Associate degree	% with Bachelor's degree or higher	% BIPOC workers	% Women workers
Vehicles	45.0%	32.7%	22.3%	70.0%	20.8%
HVAC	58.8%	26.9%	14.2%	70.0%	12.2%
Refrigeration	60.5%	27.7%	11.8%	70.4%	10.7%
Appliances	59.7%	26.7%	13.6%	69.9%	10.5%
Construction	61.3%	25.5%	13.1%	70.2%	10.9%
Lighting	59.8%	26.6%	13.6%	70.1%	10.4%
Manufacturing	51.0%	24.0%	25.1%	74.6%	32.6%
Other commercial and residential	59.3%	27.0%	13.8%	70.0%	11.6%
Agriculture	65.4%	22.0%	12.5%	75.4%	37.2%
Mining	55.8%	20.2%	24.0%	71.1%	17.1%

Sources: ACS 2015-2019, IMPLAN 3.1.

Note: All characteristics in this table are based on workers within San Diego County plus the five surrounding counties that supply San Diego County with the highest numbers of commuting workers. These counties include: Imperial County, Los Angeles County, Orange County, Riverside County, and San Bernardino County. For reference, across these counties, nonwhite workers make up 65.9% of the employed and women workers make up 45.9%

As Table 6.7 shows, the distribution of educational credentials is fairly consistent across the major energy demand spending categories. Thus, the range of workers with high school degrees or less varies from a low of 45 percent for workers employed in the vehicles category to 61 percent in refrigeration. Similarly, the share of workers with Bachelor's degrees or higher ranges from a low of 12 percent in refrigeration to 22 percent in the vehicles category.

It is clear from the figures in Table 6.7 that, at present, most jobs created by energy demand expenditures in San Diego County are primarily held by people of color (BIPOC), at about 70 percent of the total. With respect to gender composition, women are under-represented across all sectors. The share of female employment is between 11 – 21 percent in the major energy demand areas of vehicles, HVAC, and refrigeration, even while women make up 46 percent of the San Diego area workforce. [xliv]

Energy Supply Investments and Job Quality

Tables 6.8 and 6.9 present the job quality and demographic figures for all of the supply investment categories in the ERR model. We focus on the two core areas of expenditures on the supply side of their model, i.e. fossil fuels and clean renewables.

As we see first in Table 6.8, compensation for workers in San Diego's fossil fuel industry is high, with pay averaging nearly $190,000. This figure is clearly well above any of the employment categories on the demand side of the ERR model, where the range for the three main categories is between $62,000 and $78,000. Average compensation in clean renewables, at roughly $100,000, is well below that for workers in the fossil fuel industry, but still significantly higher than the averages for the energy demand categories.

In terms of the provision of employer-sponsored health care, the coverage rate is 83 percent for fossil fuel workers and 60 percent for those in clean renewables. The unionization rates are relatively high in these two largest energy supply areas, at 18 percent in the fossil fuel sector and 11 percent in clean renewables. These figures are close to those for the main areas of energy demand.

[xliv] In addition to the share of female employment in the San Diego County workforce, we estimate the share of the area's workforce that is non-White (including Latinx) is 66 percent.

Table 6.8. Indicators of Job Quality in Energy Supply Investment Areas: Direct Jobs Only.

Investment Area	Average total compensation*	Health insurance coverage, percentage**	Union membership, coverage***
Fossil fuels	$181,800	82.9%	18.1%
Clean renewables	$97,600	59.5%	11.0%
Transmission and storage	$69,700	69.4%	15.6%
Additional supply technologies	$75,100	51.3%	14.9%
Other investments	$75,900	55.8%	12.9%

Source: CPS 2015-2019, ACS 2015-2019, IMPLAN 3.1.
Notes: *Compensation figures reflect only wage and salary workers, and exclude proprietors' compensation, in San Diego County. This is because wage and salary workers' employment in these activities serves as their primary jobs, whereas proprietors' employment in these activities is more likely to serve only as secondary jobs. **The health insurance coverage estimate is based on workers within San Diego County plus the five surrounding counties that supply San Diego County with the highest numbers of commuting workers. These counties include: Imperial County, Los Angeles County, Orange County, Riverside County, and San Bernardino County. *** The union density measure is based on 14 counties that make up the southern region of California. These include: Fresno, Imperial, Inyo, Kern, Kings, Los Angeles, Mono, Orange, Riverside, San Bernardino, San Diego, Santa Barbara, Tulare and, Ventura.

Educational Credentials and Race/Gender Composition

In Table 6.9, we present data on both the educational credentials as well as the race and gender composition of the workers employed in the supply-side areas of the ERR model. We again focus here only on the workers who are employed *directly* through these investments.

As Table 6.9 shows, in the fossil fuel sector, the educational attainment level of the industry's workforce is evenly divided between those without high school degrees or less, those with some college, and those with Bachelor's degrees or higher. In clean renewables, there is one major difference, in that nearly half of the workers have only high school degrees or less.

In terms of the share of workers who are black, indigenous and people of color (BIPOC), the percentages remain high in all of the supply expenditure categories, including the largest ones—i.e. with 64 percent of the fossil fuel workforce and 65 percent of the clean renewable workforce being BIPOC.

Women remain underrepresented in both of these main areas of supply-side expenditures, at 23 percent for fossil fuels and 19 percent in clean renewables.

Table 6.9. Educational Credentials and Race/Gender Composition of Workers in Energy Supply Investment Areas: Direct Jobs Only.

	Educational Credentials			**Racial and Gender Composition**	
Investment Area	% with high school degree or less	% with some college or Associate degree	% with Bachelor's degree or higher	% BIPOC workers	% Women workers
Fossil fuels	31.1%	35.6%	33.4%	62.7%	23.0%
Clean renewables	46.5%	23.4%	30.1%	64.8%	19.0%
Transmission and storage	40.6%	28.7%	30.7%	65.1%	20.4%
Additional supply technologies	58.8%	26.6%	14.6%	71.2%	21.5%
Other investments	51.9%	25.8%	22.3%	66.1%	16.3%

Sources: ACS 2015-2019, IMPLAN 3.1.

Note: All characteristics in this table are based on workers within San Diego County plus the five surrounding counties that supply San Diego County with the highest numbers of commuting workers. These counties include: Imperial County, Los Angeles County, Orange County, Riverside County, and San Bernardino County. For reference, across these counties, nonwhite workers make up 65.9% of the employed and women workers makeup 45.9%.

Prevalent Job Types with Energy Demand and Supply Employment

In addition to these average results across the various energy supply investment and energy demand expenditure areas, it is important to consider the range of the types of jobs that will be generated in each of the specified areas. To provide a picture of this range of jobs, in Tables 6.10A-6.10C and 6.11A – 6.11B, we present figures on more specific job categories in all of the investment and expenditure areas. It is difficult to summarize the detailed data on job categories presented in these tables, butut the overall point is clear. That is, investing to build a clean energy economy will produce new employment opportunities at all levels of the San Diego economy. New job opportunities will open for, among other occupations, carpenters, machinists, chemists, environmental scientists, secretaries, accountants, heating installers, truck drivers, pipe layers and construction laborers, as well as a full range of managerial occupations. At the same time, at least over the period 2021 – 2030, most fossil-fuel-based employment remains intact in the ERR model. This is evident from the energy supply figures we reported in Table 6.4, which shows that 10,120 of the 13,368 jobs generated by supply investments in the ERR model between 2021 – 2030—i.e. roughly 75 percent of the total—will be in the fossil fuel area.

Table 6.10. Prevalent Job Categories Generated through Energy Demand Expenditures

Table 6.10A. Vehicles: Prevalent Job Types: (Job categories with 5 percent or more employment)

Job Category	Percentage of Total Industry Employment	Representative Occupations
Transportation and material moving	38.2%	Order fillers; freight movers; bus drivers
Construction	13.7%	Electricians; carpenters; construction laborers
Production	13.6%	First-line supervisors; welding workers; electrical assemblers;
Management	9.3%	General managers; marketing managers; construction managers
Office and administrative support	7.0%	Dispatchers; bookkeeping clerks; administrative assistants

Sources: ACS 2015-2019, IMPLAN 3.1.

Table 6.10B. HVAC: Prevalent Job Types: (Job categories with 5 percent or more employment).

Job Category	Percentage of Total Industry Employment	Representative Occupations
Construction	53.0%	Electricians, first-line supervisors; painters
Management	13.2%	Chief executives; operations managers; sales managers
Production	9.5%	First-line supervisors; brazing workers; assemblers
Office and administrative support	6.3%	Shipping clerks; accounting clerks; general office clerks

Sources: ACS 2015-2019, IMPLAN 3.1.

Table 6.10C. Refrigeration: Prevalent Job Types: (Job categories with 5 percent or more employment).

Job Category	Percentage of Total Industry Employment	Representative Occupations
Construction	34.2%	First-line supervisors; painters; construction laborers
Production	21.4%	Inspectors; machinists; soldering workers
Installation and maintenance	15.5%	General maintenance workers; heating installers; heavy vehicle technicians
Management	8.9%	Marketing managers; operations managers; chief executives
Office and administrative support	6.6%	Inventory clerks; general office clerks; auditing clerks

Sources: ACS 2015-2019, IMPLAN 3.1.

Table 6.11. Prevalent Job Categories Generated through Energy Supply Expenditures.

Table 6.11A. Fossil Fuels: Prevalent Job Types: (Job categories with 5 percent or more employment).

Job Category	Percentage of Total Industry Employment	Representative Occupations
Office and administrative support	14.3%	Production clerks; executive secretaries; utility meter readers
Production	13.9%	Welding workers; inspectors; first-line supervisors
Management	11.5%	Financial managers; computer systems managers; general managers
Construction	10.5%	Construction equipment operators; electricians; pipelayers
Architecture and engineering	8.0%	Industrial engineers; mechanical engineers; petroleum engineers
Installation and maintenance	7.2%	Mobile equipment service technicians; truck mechanics; valve installers
Transportation and material moving	7.1%	Pumping station operators; freight movers; driver/sales workers
Extraction	6.4%	Earth drillers; explosive workers; derrick operators

Sources: ACS 2015-2019, IMPLAN 3.1.

Note: This table is based on workers within San Diego region, plus the five surrounding counties that supply San Diego County with the highest numbers of commuting workers. These counties include: Imperial County, Los Angeles County, Orange County, Riverside County, and San Bernardino County.

Table 6.11B. Clean Renewables: Prevalent Job Types: (Job categories with 5 percent or more employment).

Job Category	Percentage of Total Industry Employment	Representative Occupations
Construction	46.6%	Electricians, first-line supervisors; painters
Management	14.2%	Operations managers; sales managers; construction managers
Life, physical and social science	8.0%	Chemical scientists; material scientists; biological scientists
Office and administrative support	6.2%	Customer service representatives; auditing clerks; general office clerks

Sources: ACS 2015-2019, IMPLAN 3.1.

Note: This table is based on workers within San Diego region, plus the five surrounding counties that supply San Diego County with the highest numbers of commuting workers. These counties include: Imperial County, Los Angeles County, Orange County, Riverside County, and San Bernardino County.

Nevertheless, over this same period, San Diego's fossil fuel economy will undertake its first, if relatively modest, steps toward a near-total phase-out by 2050. As such, we now turn to the issues around fossil fuel job contraction over the 2021 – 2030 period.

6.5. Job Contraction for Workers in Fossil Fuel-Based Industries

The transition for the San Diego region into a zero-emissions economy by 2050 will of course entail the phasing out of burning oil, coal and natural gas to produce energy. In Table 6.12, we show the rates of contraction for oil, coal and natural gas within the ERR model. As the table shows, through 2030, the contraction rates for oil and gas in the ERR model are quite modest. Indeed, natural gas consumption in the ERR model does not decline at all through 2030, while the consumption of oil falls by only 20 percent. Coal is not consumed at all as an energy source as of 2030 in ERR, but the level of coal consumption in San Diego County, and throughout California more generally, is already close to zero at present.

Table 6.12. Assumptions on Contraction Rates for San Diego County Fossil Fuel Sectors: Contractions as of 2030 and 2050. Baseline Employment Figures from 2018.

	2030	2050
Oil	-20%	-95%
Natural Gas	No contraction	-75%
Coal	-100%	-100%

Note: Contraction rates for the San Diego region within ERR model.

As Table 6.12 shows, the major contractions in oil and gas consumption in San Diego County will occur between 2031 – 2050 within the ERR model. But this latter period is not the primary focus of our analysis in this chapter. We focus here on the contraction process in oil and gas through 2030 in the San Diego region, as it impacts on employment in the county.

Current Levels of Fossil Fuel-Based Employment

Table 6.13 shows the most recent figures on employment levels for all fossil fuel and ancillary industries in San Diego County. As we see, total fossil fuel-based employment in San Diego County as of 2018 is 9,239. This amounts to about 0.6 percent of total employment in the county as of 2018. Of this total level of employment, we also see that 6,434 of the total, amounting to nearly 70 percent of all the fossil fuel-based jobs in the county, are in natural gas distribution. Another 1,418 jobs, about 15 percent of the total, are in oil and gas extraction. About 5 percent of the total are in wholesale distribution of oil. In short, roughly 90 percent of all fossil fuel-based employment in San Diego County is in these three areas—first, and most importantly, natural gas distribution, then to a lesser extent, oil and gas extraction as well as the wholesale distribution of petroleum products.[xlv]

[xlv] We should note that the ancillary fossil fuel-based industries listed in Table 13 approximately match up with the industries in which *indirect employment* occurs resulting through fossil fuel sector production, as defined in the input-output tables, and as we have described above. In estimating the number of workers who might experience job displacement, it is more accurate to focus on the direct employment figures for these ancillary fossil fuel industries, as opposed to utilizing the indirect employment data from the input-output tables. With the data reported on in Table 13, we are able to incorporate important details on employment conditions in these ancillary industries by working with the available employment data on the specific industries, as opposed to relying on a single generic category of indirect employment for the oil/gas and coal industries. At the same time, for the purposes of drawing comparisons with the figures we have presented above on employment creation through clean energy investments, it is useful to keep in mind that the figures we are reporting here on ancillary employment relative to the oil/gas and coal industries are the equivalent of the indirect employment figures we report in the clean energy industries.

Table 6.13. Number of Workers in San Diego County Employed in Fossil Fuel-Based Industries, 2018

Industry	2018 Employment Levels	Industry share of total fossil fuel-based employment
Natural gas distribution	6,434	69.6%
Oil and gas extraction	1,418	15.4%
Wholesale -petroleum and petroleum products	491	5.3%
Support activities for oil/gas	228	2.5%
Oil and gas pipeline transportation	218	2.4%
Support activities for coal	177	1.9%
Drilling oil and gas wells	118	1.3%
Oil and gas field machinery and equipment manufacturing	45	0.5%
Fossil fuel electric power generation	41	0.4%
All other petroleum and coal products manufacturing	32	0.3%
Petroleum refining	29	0.3%
Oil and gas pipeline construction	8	0.1%
Mining machinery and equipment manufacturing	0	0.0%
Coal mining	0	0.0%
Fossil fuel industry total	9,239	100.0%
TOTAL FOSSIL FUEL EMPLOYMENT AS SHARE OF SAN DIEGO EMPLOYMENT ***(San Diego County 2018 employment = 1,464,125)***	0.63%	

Source: IMPLAN 3.0. U.S. Department of Labor.

Characteristics of Fossil Fuel and Ancillary Industry Jobs

Table 6.14 provides basic figures on the characteristics of the jobs in fossil fuel-based industries. As the table shows, on average, these are relatively high-quality jobs. The average overall compensation level is $212,900. Of course, this figure is 2 – 3 times higher than any of the energy demand sectors, as reported in Table 6.6. It is also more than twice as high as the average compensation level in renewable energy.

Table 6.14. Characteristics of Workers Employed in San Diego County's Fossil Fuel-Based Sectors.

	Fossil Fuel-Based industries
Average total compensation	$212,900
Health insurance coverage	86.8%
Union membership coverage*	21.9%
Educational credentials	
Share with high school degree or less	25.2%
Share with some college or Associate degree	36.3%
Share with Bachelor's degree or higher	38.5%
Racial and gender composition of workforce	
Pct. BIPOC workers	62.4%
Pct. female workers	26.1%

Source: ACS 2015-2019; CPS ORG 2015-2019.

Note: All the estimates aside from the compensation figures and union membership coverage—in this table are based on data from the ACS. Compensation figures are from IMPLAN and are for San Diego County. The estimates for the other characteristics are based on data from workers in San Diego County plus the five surrounding counties that supply San Diego County with the highest numbers of commuting workers. These counties include: Imperial County, Los Angeles County, Orange County, Riverside County, and San Bernardino County. The one exception is the union measure. The ACS does not ask about union membership. The union coverage measure is estimated from the ORG files of the CPS, which have smaller sample sizes than the ACS. To construct an adequate sample size, the union density measure is based on 14 counties that make up the southern region of California. These include: Fresno, Imperial, Inyo, Kern, Kings, Los Angeles, Mono, Orange, Riverside, San Bernardino, San Diego, Santa Barbara, Tulare and, Ventura.

The figure is even roughly $30,000 higher than the $182,000 average compensation figure we report in Table 6.8 for the supply-side investments in the fossil fuel sector itself. The reason that Table 6.8 and 6.14 figures are not identical, even though they both are showing compensation figures in the fossil fuel sector, is that the mix of specific spending areas within the supply investment categories is not the same as the current overall profile of employment in the county's fossil fuel sectors.

Workers in these industries are also relatively well off in terms of the benefits they receive from their jobs. Nearly 90 percent of them receive health insurance from their jobs. Union membership is at nearly 22 percent. This figure is more than 3 times higher than average for the entire U.S. private sector, at only 6.2 percent. Again, these figures are largely reflecting the favorable working conditions in the natural gas distribution industry in the region.

Table 6.14 also reports figures on educational credential levels for workers in each of the fossil fuel-based industries, as well the percentages of non-white and female workers. The jobs are distributed fairly evenly with respect to educational credentials, with 25 percent of workers having high school degrees or less, 36 percent having some college and 39 percent with Bachelor's degrees or higher. The percentage of non-white workers (BIPOC) in these areas of employment is also high, at 62 percent of the workforce. However, the share of female workers is low, at only 26 percent of the total.

We provide more specifics on the composition of the workforce in the fossil fuel-based industries in Table 6.15, in which we list all the job categories in which 5 percent or more of the workforce is employed. As we see, the highest percentage of jobs, at 18.6 percent, are in office and administrative support, including dispatchers, production clerks and meter readers. Various forms of management are the next largest category of employment in the fossil fuel-based industries in San Diego, at 12.4 percent. Next comes production workers, at 10.6 percent of all employment. The representative occupations in these jobs include welding workers, inspectors and first-line supervisors.

Generally speaking, as with the areas of employment in on both the demand and supply sides of the ERR expenditure program, we see that San Diego County's fossil fuel-based industries employ a wide range of workers. Some of them will have skills specific to the industry and will therefore face difficulties moving into new employment areas. But the majority of the workers will have jobs that should be transferable to new employment opportunities, in the clean energy economy or elsewhere.

Table 6.15. Prevalent Job Types in San Diego County's Fossil Fuel-Based Industries (Job categories with 5 percent or more employment).

Job Category	Percentage of Direct Jobs Lost	Representative Occupations
Office and administrative support	18.6%	Dispatchers; production clerks; meter readers
Management	12.4%	Financial managers; computer and information systems managers; chief executives
Production	10.6%	Welding workers; inspectors; first-line supervisors
Construction	9.9%	Construction equipment operators; electricians; construction laborers
Architecture and engineering	8.7%	Surveying technicians; mechanical engineers; petroleum engineers
Installation and maintenance	8.6%	Precision instrument and equipment repairers; truck mechanics; control and valve installers
Transportation	5.6%	Motor vehicle operators; pumping station operators; freight movers
Computer and mathematical science	5.3%	Computer programmers; computer systems analysts; software developers

Source: ACS 2015-2019. These estimates are based on data from workers in San Diego County plus the five surrounding counties that supply San Diego County with the highest numbers of commuting workers. These counties include: Imperial County, Los Angeles County, Orange County, Riverside County, and San Bernardino County.

Estimating Annual Job Losses through Fossil Fuel Contraction

For understanding the impact on employment of the phase-down of the fossil fuel-based industries in San Diego County (and elsewhere), the most relevant metric will be the rate at which workers are likely to be losing their jobs through the phase-down. Within the ERR model described in Chapter 1 and Appendix A, we have seen that, by 2030, the level of oil consumption will be 20 percent lower than at present, while natural gas consumption will remain stable. We have also reported in Table 6.8 that, through the supply-side investments in the ERR model, over 6,000 new jobs will be generated on average between 2021 – 2030 in the county's fossil fuel sectors. Nevertheless, the contraction of the county's consumption of oil by 20 percent will engender some job losses.

Moreover, the assumption in ERR of a stable level of natural gas consumption in the San Diego region is crucial since, as we have seen, roughly 70 percent of the 9,239 fossil fuel industry-based jobs in the county are in the natural gas distribution sector. Most of these jobs will remain at current levels through 2030. However, some employment losses will result in this sector before2030 because, while consumption of natural gas will remain stable through 2030, there will also be no need to expand the region's natural gas distribution infrastructure. Rather, the region's existing natural gas distribution channels should remain adequate through 2030, given the county's stable natural gas consumption level. As such, it is reasonable to assume that the construction industry jobs associated with San Diego's natural gas industry—jobs that would be tied to the expansion of the sector—will be phased out by 2030. We have incorporated this factor into our estimate below of the overall fossil fuel-based industry employment losses through 2030.

We, therefore, estimate the total number of jobs that will be phased out in San Diego's fossil fuel-based industries through 2030, based on the assumptions that: 1) oil consumption declines by 20 percent; 2) natural gas consumption remains constant; and 3) construction activity in the natural gas sector falls to zero. We also incorporate two other considerations in generating the job contraction estimates for the county's fossil fuel-based sectors. These are: 1) the attrition rate in the sector's labor force due to voluntary retirements; and 2) whether the rate of contraction will be steady or episodic.

Labor force attrition through voluntary retirements. About 80 percent of workers in the U.S. fossil fuel-based industries choose to retire voluntarily once they reach age 65. As San Diego's fossil fuel-based industries contract, the workers employed in the industry who are choosing to retire will, of course, not experience job losses, in contrast with those workers, of all ages, who are not choosing to retire. As such, to the extent that the rate of voluntary retirements in the industry counterbalances against the rate at which the industry is contracting, the extent of job losses and displacement experienced by workers in the industry will be correspondingly reduced. It, therefore, becomes an important component of our estimate of job losses in the sector to take account of the rate of voluntary retirements per year in the industry.

Steady versus Episodic Industry Contraction. The scope and cost of any set of policies to manage a just transition for impacted workers will depend heavily on whether the contraction is steady or episodic. Under a pattern of steady contraction, there will be uniform annual employment losses over both the 2020 – 2030 and 2031 – 2050 periods, with the steady rates determined by the overall level of industry contraction within the given time period. 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 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 predictable. This will enable the transition process to avoid having to provide support for a much larger share of workers. The share of workers requiring support would rise if several large businesses were to shut down abruptly and lay off their full workforce at once, including both younger as well as older workers Similarly, it will be easier to find new jobs for displaced workers if the pool of displaced workers at any given time is smaller.

For the purposes of our calculations, we proceed by assuming that the San Diego region will successfully implement a relatively smooth contraction of its fossil fuel industries. This indeed would be one important feature of a well-designed and effectively implemented just transition program. As a practical matter, a relatively smooth transition should be workable as long as policymakers remain focused on that goal.

Incorporating these considerations, in Table 6.16, we show figures on annual employment reductions in the county's fossil fuel-based industries over 2021 – 2030. We also then estimate the proportion of workers who will move into voluntary retirement at age 65 as of 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 industry-wide contraction.

Table 6.16. Attrition by Retirement and Job Displacement for Fossil Fuel Workers in San Diego County, 2021-2030.

	Fossil Fuel Workers
1) Total workforce as of 2018	9,239
2) Job losses over 10-year transition, 2021-2030	1,078*
3) Average annual job loss over 10-year production decline *(= row 2/10)*	108
4) Number of workers reaching 65 over 2021-2030 (=row 1 x % of workers 54 and over in 2019)	1,977 *(21.4 % of all workers)*
5) Number of workers per year reaching 65 during 10-year transition period (=row 4/10)	198
6) Number of workers per year retiring voluntarily	158 *(80% of 65+ workers**)*
7) Number of workers requiring re-employment (= row 3 – row 6)	0

Source: Table 6.1.

Note: *Job losses includes 605 construction jobs in the natural gas distribution industry that will phase out in phase 1 because the industry will contract by 75 percent during 2031-2050. **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.

We begin in Table 6.16 with the total fossil fuel-based industry workforce of 9,239 workers. Based on the respective contraction rates for the oil and construction activity in natural gas, we estimate that the total job contraction will amount to 1,078 workers over 2021 – 2030 Assuming a steady rate of contraction, this amounts to an average rate of job losses of 108 per year.

We then estimate that 1,977 workers employed in the industry will reach the age of 65 over 2021 – 2030, which averages to 198 workers per year. Of this total, we assume that 80 percent of these workers will retire voluntarily once they reach age 65. This amounts to 158 workers in San Diego County's fossil fuel-based industries retiring voluntarily per year.

Thus, according to our estimates, 108 jobs per year will be lost in the San Diego region due to the contraction of fossil fuel consumption, while 158 workers per year will voluntarily retire from the industry. In total, therefore, San Diego should not experience any job displacements through 2030 as a result of the region's commitment to move onto a zero-emissions trajectory through 2030. In other words, through 2030, no workers in the county that are currently employed in any of its fossil fuel-based industries will require reemployment.

Planning a Just Transition Program

In working from the ERR model for transitioning San Diego County into a zero-emissions economy by 2050, we have seen that the fossil fuel industry in the county will not experience job displacements through 2030. However, job displacements will certainly result between 2031 – 2050, as oil consumption in the county falls by 95 percent relative to the present level and natural gas consumption falls by 75 percent. As such, as one critical part of the project of advancing the transition to a zero-emissions economy by 2050, San Diego county and local governments should begin now to develop a viable set of just transition policies for the workers in the community who will experience job displacement between 2031 – 2050.

In previous work, we have outlined just transition programs that include five policy measures (e.g. Pollin et al. 2020).[1] These are:

1. ***Pension guarantees*** for all workers in fossil fuel-based industries, especially those workers who will be retiring voluntarily over the transition period.
2. ***Reemployment guarantees*** for all displaced workers.
3. ***Wage insurance*** for all displaced workers. One approach is to guarantee 3 years of total compensation at levels the workers had been receiving in their fossil fuel jobs.
4. ***Retraining support.*** This could include 2 years of retraining support for workers who required this in their new areas of employment.[xlvi]
5. ***Relocation support.*** This should be sufficient to cover full moving expenses for all workers who are forced to relocate.

It would be beneficial for the San Diego region's governments to begin now to consider the most effective ways through which to implement this or some comparable set of measures. To begin this process now will greatly increase the likelihood that the region will succeed in building a zero-emissions economy, while also preventing large numbers of community members from experiencing major economic losses as the transition program advances.

[xlvi] The County has retained Inclusive Economics to develop a comprehensive and coordinated regional strategy to address the workforce needs resulting from labor-market changes related to the region's Decarbonization Framework. The report will be jointly authored by Dr. Carol Zabin and Betony Jones and modelled after California's Jobs and Climate Action plan that provide recommendations on how to support San Diego's workforce as the region transitions to a carbon-neutral economy.

SUPPLEMENTAL NOTE: Employment Impacts of Geothermal Energy Projects for Imperial County

Chapter 2 of this project on "Geospatial Analysis of Renewable Energy Production," describes a project to develop geothermal energy production sites in Imperial County. The authors write:

> Five geothermal sites are identified in Imperial County with generation of 10,680 GWh of electricity (seen as green points in Figure 2.8). This analysis assumes these plants become fully operational by 2030 and supply the remaining capacity to San Diego after satisfying Imperial's electricity demand (p. 6-7).

In this note, we estimate the employment impacts of developing this geothermal energy project. Because the project will be developed in Imperial County rather than San Diego County, we estimate in this case the employment effects throughout Southern California.

Our estimate is that this project will generate about 1,900 jobs per year throughout Southern California over the course of the 10-year period to complete the work.

We derive this result as follows:

1. Chapter 2 states that the aim of the project will be to generate 10,680 GWh of electricity capacity.
2. This level of electricity generation is equal to 0.04 quadrillion BTUs ("Q-BTUs" or "quads" of energy).
3. In its February 2021 report on levelized costs of energy generation, the U.S. Energy Information Agency estimates the lump sum capital expenditures to develop one Q-BTU of geothermal generating capacity is $78 billion.[xlvii]
4. This, to develop 0.04 Q-BTUs of geothermal electricity generating capacity will cost about $3.1 billion (i.e. $78 billion x 0.04 = $3.1 billion).
5. From these figures, we document in Table 6.17 our estimate of job creation throughout Southern California through from building this level of geothermal capacity in Imperial County. As Table 6.17 shows, we estimate that this project will produce as an average over 2021 – 2030 810 direct jobs, 465 indirect jobs and 589 induced jobs. This amounts to 1,275 direct and indirect jobs and 1,864 jobs in total.

[xlvii] EIA study is here: https://www.eia.gov/outlooks/aeo/pdf/electricity_generation.pdf. See Pollin et al. (2021)[3], p. 27 for conversion of EIA capital costs in overall levelized cost framework into lump sum capital expenditures.

Table 6.17. Job Creation in Southern California through Geothermal Energy Projects in Imperial County.

	1. Job Creation per $1 million	2. Job creation through $3.1 billion in spending	3. Job creation per year over 10-year period, 2021 – 2030 *(= column 2/10)*
Direct Jobs	2.6	8,100	810
Indirect Jobs	1.5	4,650	465
Induced Jobs	1.9	5,890	589
Total Jobs	6.0	18,640	1,864

Sources: IMPLAN 3.0.; citations in text.

Appendix 6.A.1: Estimating San Diego County-Specific Employment

The ERR model is for Southern California includes 13 counties in addition to San Diego County. These 13 additional counties are: Ventura; Fresno; Mono; San Bernardino; Riverside; Santa Barbara; Kings; Los Angeles; Orange; Kern; Tulare; Imperial; and Inyo. In order to generate estimates of employment impacts *within San Diego County itself*, we therefore need to work with some assumptions in defining the proportionate level of activity in San Diego County relative to all 14 counties constituting Southern California in the EER model.

As of 2019, San Diego County's total economic output is $417.9 billion. This amounts to about 14.6 percent of the total level of activity throughout Southern California, which is $2.87 trillion. In reviewing the evidence from the EER model as well as the detailed input-output data for the activities in this model, we conclude that a reasonable assumption for estimating employment creation in San Diego County is a straightforward one. That is, *we estimate that the level of employment creation in San Diego County will amount to 15 percent of the employment creation in Southern California overall through the EER model.* In other words, employment creation in San Diego County generated by the activities in the EER model will be proportional to the ratio of total output in San Diego County relative to Southern California, i.e. as with San Diego County's output at roughly 15 percent of that for Southern California.

One could certainly develop more detailed assumptions that would relate to various specific features of the EER model. But incorporating a more highly specified set of assumptions is not likely to generate more accurate employment estimates. Here are the main considerations through which we reached this conclusion:

Demand-Side and Supply-Side Activities in ERR Model

The EER model consists of two sets of activities: demand-side purchases and supply-side investments. We consider these two sets of activities separately.

Demand-side purchases. The demand-side purchases include everything that consumers in Southern California purchase that will provide energy services at reduced rates of energy consumption. These would include purchases of electric vehicles, electric heat pumps and other HVAC equipment, appliances, and refrigeration equipment. EER modeling estimates that these costs will be between $55.0 and $74.0 billion per year in the Southern California zone, with an annual average of $66.9 billion.

With these demand-side purchases, it is reasonable to assume that San Diego County's increased purchases will not be constrained by any shortages that would be specific to the county itself. Shortages of specific products could well emerge as the level of clean energy expenditures in the region grows rapidly. But there is no reason to assume that any such shortages are likely to emerge specifically in San Diego County, as opposed to the broader Southern California region. Thus, we assume that roughly 15% of Southern California's demand-side purchases take place in San Diego: $9.9 billion dollars per year, on average.

Supply-side investments. The supply-side investments include everything that contributes to supplying a zero-emissions economy—e.g. architectural, engineering and related services, communication and energy wire manufacturing, turbine manufacturing, residential construction, scientific research and development, as well as ongoing investments in the county's fossil fuel-based industries. EER modeling estimates that these costs will be between $33.1 and $35.0 billion per year in the Southern California zone, with an annual average of $34.1 billion.

Relative to the demand-side investments, it is less straightforward with the supply-side investments to assume that the San Diego share of total Southern California activity will remain proportionate to the Southern California figure. The major consideration that could produce disproportionately slower growth with any given investment activity within the county would be if this investment activity produces significant supply constraints to growth within the county as clean energy activities scale up throughout the region. For example, the installation of solar panels in San Diego County might be disproportionately low because of land-use issues. A disproportionately large share of solar installations might then take place in, say, Riverside County. The solar-generated electricity could then be imported from Riverside to San Diego County. Thus, we assume that roughly 15% of Southern California's supply-side investments take place in San Diego: $5.1 billion dollars per year, on average.

In fact, in examining the current profile of supply-side investments in San Diego County within the ERR model, it does not appear that there should be significant supply constraints specific to San Diego County as clean energy investments expand in the region. At present, there are only 7 supply-side activities in the EER model in which San Diego County's current share is over 25 percent of all Southern California activity—i.e. significantly greater than San Diego's current share of overall Southern California output, at 15 percent. These activities are: natural gas distribution; sugar cane mills and refining; turbine and turbine generator set units manufacturing; capacitator and other inductor manufacturing; other communication and energy wire manufacturing; all other miscellaneous electrical equipment and component manufacturing; and scientific research and development services. Of these 7 activities, there is only one in which this activity accounts for more than 2 percent of all of San Diego's economic activity. That is scientific research and development services, which currently account for nearly 9 percent of all of San Diego County's total output.

It is not likely that San Diego County would face supply constraints in expanding its scientific research and development services. This activity will not generate significant land-use demands. It will also not produce any significant negative environmental impacts. As such, it is reasonable to conclude that San Diego County is well-positioned to absorb a substantial absolute increase in scientific research activity within the county. Indeed, it is almost certain that the county will welcome a major expansion of activity in this sector.

Overall, again, it therefore seems reasonable to work with a straightforward assumption that San Diego County's share of supply-side activities in the EER model will be maintained, as with the demand-side activities, at its current share of aggregate Southern California output. We therefore assume that the share of both the demand- and supply-side activities within the ERR model for Southern California will generate employment in San Diego County that is equal to 15 percent of employment creation in Southern California.

An important caveat to this is that the regional level costs—both demand and supply-side—reported by the EER model are subject to significant uncertainty. These models are meant to estimate costs over broad geographic areas, and do not produce detailed outlines of the geographic distribution of these costs in sub-regions. The distribution of costs depend on many factors—including fuel availability, sequestration costs, and economic and population trends—which are very difficult to estimate over time at a very high spatial resolution. For this reason, we have treated EER model cost estimates for zones (like Southern California) as broad approximations.

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