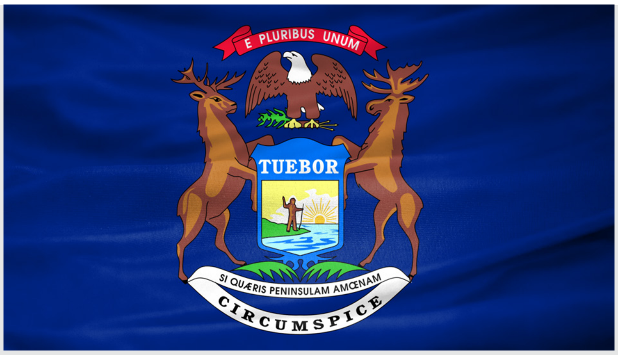
POLITICAL ECONOMY RESEARCH INSTITUTE
PERI
University of Massachusetts Amherst

THE PROSPECTS FOR EXPANDING CLEAN ENERGY INVESTMENTS AND JOB OPPORTUNITIES UNDER THE *MI HEALTHY CLIMATE PLAN*

An Economic Framework for Achieving Michigan's Greenhouse Gas Emissions Reduction Targets



By Robert Pollin, Jeannette Wicks-Lim, Shouvik Chakraborty, and Chirag Lala
Department of Economics and Political Economy Research Institute (PERI)
University of Massachusetts-Amherst

MAY 2026

Prepared for Michigan Department of Environment, Great Lakes, and Energy (EGLE)

Disclaimers and Acknowledgments

This project was commissioned by the Michigan Department of Environment, Great Lakes, and Energy (EGLE). The views and opinions of authors expressed herein do not necessarily state or reflect those of the Michigan Department of Environment, Great Lakes, and Energy. The study was funded wholly or in part by the United States Environmental Protection Agency (EPA) under assistance agreement 00E03462 to the Michigan Department of Environment, Great Lakes, and Energy. The contents of this document do not necessarily reflect the views and policies of the EPA, nor does the EPA endorse trade names or recommend the use of commercial products mentioned in this document, as well as any images, video, text, or other content created by generative artificial intelligence tools, nor does any such content necessarily reflect the views and policies of the EPA.

We greatly appreciate the financial support of the EPA. We also appreciate that the EGLE and EPA respected our terms of engagement. Those terms included full autonomy in drafting the study and reaching the conclusions presented here. We benefited from the contributions to our study by Alessandra Carreon, Chief Climate Officer, EGLE; Sayon Ghosh, Climate Research Officer, EGLE; and Jordan Power, Senior Climate Action Officer, EGLE. We are especially grateful to Julia Field, Deputy Chief Climate Officer, EGLE. Julia has provided valuable information, insights, and support at all stages in the development of this project. At PERI, Hanae Bouazza, Henrique De Abreu Grazziotin, and Enes Isik contributed excellent research assistance while proceeding with their own doctoral dissertation work. Kim Weinstein produced this wonderfully readable document out of our multiple cyber-piles of text and tables. PERI's Administrative Director Nicole Dunham provides a bedrock of support for all our research work.

Table of Contents

Highlights of Study

1. Introduction

- The *MI Healthy Climate Plan* includes greenhouse gas (GHG) emissions reduction targets
    - 52% GHG emissions reduction by 2030 relative to 2005 level
    - Carbon neutrality by 2050
- Study focuses on carbon dioxide (CO_2) emissions in Michigan
    - CO_2 emissions account for approximately 90% of all Michigan GHG emissions
    - 52% CO_2 emissions reduction requires:
        - Emissions cut from 200 million tons of CO_2 emissions as of 2005 to 96 million tons by 2030
        - Emissions cut from 96 million tons in 2030 to carbon neutrality by 2050
- We develop two scenarios for achieving Michigan's emissions reduction goals
    - **Scenario 1**, following directly from the *MI Healthy Climate Plan*
        - ***Phase 1, 2026 – 2030***: CO_2 emissions fall to 96 million tons
        - ***Phase 2, 2031 – 2050:*** CO_2 emissions fall to zero
    - **Scenario 2**, which expands Phase 1 from 5 to 10 years
        - ***Phase 1, 2026 – 2035:*** CO_2 emissions fall to 96 million tons
        - ***Phase 2, 2036 – 2050:*** CO_2 emissions fall to zero

2. Energy Consumption and Clean Energy Prospects for Michigan

- Investments in energy efficiency and clean renewable energy sources are the primary areas for clean energy transition in Michigan
    - Efficiency investments include building retrofits, industrial efficiency, grid upgrades, public transportation, and expanding electric/hybrid vehicles
    - Renewable energy investments are predominantly in solar—including utility, commercial, and residential scale—and onshore wind
        - Battery storage investments at 10 – 20% of all renewable investments
        - Smaller renewable investments in geothermal and low-emissions bioenergy
- Average investment cost estimates for clean energy investments
    - $15 billion per Q-BTU (quadrillion British Thermal Units) of energy efficiency savings
    - $180 - $200 billion per Q-BTU for expanding renewable supply capacity

3. Clean Energy Investment and Job Creation Scenarios for Achieving Michigan's Emissions Reduction Goals

- This section presents estimates for the required investment levels in energy efficiency and renewable energy to achieve Michigan's emissions reduction goals and the level of job creation generated by these investments.
- The required investment levels and job creation estimates for Scenarios 1 and 2 and for both phases with each scenario are:
    - **Scenario 1**
        - ***Phase 1, 2026 - 2030***
            - *Investment level: $30.8 billion/year = 4.2% of Michigan GDP*
            - *Job creation: 185,000 jobs = 3.6% of Michigan 2024 workforce*
        - ***Phase 2: 2031 – 2050***
            - *Investment level: $12.3 billion/year = 1.4% of Michigan GDP*
            - *Job creation: 61,000 – 75,000 jobs (depending on labor productivity growth rate) = 1.2% – 1.5% of Michigan 2024 workforce*
    - **Scenario 2**
        - ***Phase 1, 2026 – 2035***
            - *Investment level: $14.2 billion/year = 1.9% of Michigan GDP*
            - *Job creation: 87,000 jobs = 1.7% of Michigan 2024 workforce*
        - ***Phase 2, 2036 – 2050***
            - *Investment level: $17.1 billion/year = 1.9% of Michigan GDP*
            - *Job creation: 89,000 – 103,000 jobs (depending on labor productivity growth rate) = 1.7% –2.0% of Michigan 2024 workforce*
- The job creation figures will be maintained at these estimated levels as long as investment spending continues at the figures noted above.

4. Job Quality Measures and Worker Characteristics in Michigan's Clean Energy Labor Force

- This section reports on the quality of jobs that will be generated by Michigan's clean energy investments and the characteristics of the workers currently employed in these jobs. The results include:
    - Aggregated figures for clean energy jobs in comparison with quality measures and worker characteristics for Michigan's overall workforce
    - Disaggregated figures on job quality and worker characteristics for 10 individual energy efficiency and renewable energy sectors
- Comparative aggregate figures include:
    - Average hourly wages
        - Clean energy sectors: $39.07
        - Overall Michigan: $36.70

- Educational credentials
    - Shares with high school degrees as highest level:
        - *Clean energy sectors: 35.7%*
        - *Overall Michigan: 26.8%*
    - Shares with BA degree or higher:
        - *Clean energy sectors: 26.4%*
        - *Overall Michigan: 37.4%*
- According to the comparisons on wages and educational credentials between clean energy workers and Michigan's overall labor force, the clean energy jobs provide relatively high pay for workers without college degrees. Thus, expanding clean energy job opportunities is consistent with the *MI Healthy Climate Plan's* aim to create "good-paying jobs for working families."
- Female share of workforce:
    - Clean energy sectors: 27.0%
    - Overall Michigan: 47.9%
- White (non-Latinx) share of workforce:
    - Clean energy sectors: 77.7%
    - Overall Michigan: 74.2%
- The share of non-whites and especially women in the clean energy workforce will need to expand to align with the workforce goals of the *MI Healthy Climate Plan*.

5. Labor Demand, Labor Supply and Potential Labor Shortages

- We estimate the extent of possible labor supply shortages in individual occupations through the expansion of clean energy investments
- Focus on Scenario 1/Phase 1, 2026 – 30, during which labor demand expansion is largest
- We distinguish between "modest" and "significant" potential labor shortages
    - "Modest" shortages are relative to Michigan only workforce
        - 15 occupations would face "modest" shortages
    - "Significant" shortages are relative to overall Midwestern workforce
        - 4 occupations would face "significant" shortages
- The primary occupations likely to face significant shortages are for workers installing electrical power and telecommunications lines, along with supervisors in these areas

6. Contraction of Michigan's Fossil Fuel Industries and Just Transition for Fossil Fuel Workers

- Approximately 21,000 people employed in Michigan's fossil fuel and auxiliary industries
    - Equal to 0.5% of Michigan's overall workforce
- With incremental phase-out and voluntary retirements over Scenario 1/Phase1, 2026-30:
    - Approximately 700 workers per year face job displacement
- Job displacements will likely be approximately half the 2026 – 30 figure during Scenario1/Phase 2 and throughout Scenario 2:
    - Approximately 350 workers per year would face displacement
- Features of an illustrative just transition program for all displaced workers:
    - Pension guarantees for workers retiring as fossil fuel phase out proceeds
    - Re-employment guarantees for workers facing displacement
    - Income, retraining and relocation support for displaced workers
- We review research on the impact in Michigan as auto industry transitions from building primarily internal combustion engine vehicles (ICEVs) to battery electric vehicles (BEVs).
    - Transition could potentially expand employment for Michigan auto workers
        - Depends on effectiveness of policies to locate BEV manufacturing within Michigan

1. Introduction

In 2022, the Michigan Department of Environment, Great Lakes and Energy (EGLE) published the *MI Healthy Climate Plan*. EGLE has since published follow-up annual reports to the *MI Healthy Climate Plan* in 2023, 2024 and 2025. A centerpiece of the *MI Healthy Climate Plan* is its commitment for Michigan to achieve economy-wide carbon neutrality by 2050. Specifically, the plan establishes both an interim goal of reducing greenhouse gas (GHG) emissions in the state by 52 percent as of 2030 relative to a 2005 baseline and to reach carbon neutrality by 2050.

In this study, we present a detailed framework for Michigan to achieve both its 2030 interim emissions reduction goal and to become carbon neutral by 2050. We focus our discussion on carbon dioxide (CO_2) emissions, which constitute roughly 90 percent of total GHG emissions in Michigan.[1] Overall CO_2 emissions in Michigan in 2005 amounted to approximately 200 million metric tons, with 190 million tons coming from combusting oil, coal, and natural gas to produce energy.[2] The remaining 10 million tons result from burning bioenergy sources. It therefore follows that for Michigan to achieve its interim target of a 52 percent emissions reduction relative to 2005 that overall CO_2 emissions in the state will need to be no more than 96 million tons as of 2030.[3]

The aim of this study is to present a framework for Michigan to achieve both its interim emissions reduction goal of 96 million tons by 2030 and to reach carbon neutrality by 2050. The project includes two basic features. The first is for Michigan to phase out consumption of oil, coal and natural gas as the state's dominant energy sources. At present, the combustion of fossil fuels, along with bioenergy, accounts for nearly 90 percent of the state's overall energy supply. The second is to replace this existing fossil fuel-dominant energy infrastructure with an alternative clean energy infrastructure.

Building the clean energy infrastructure will, in turn, include two major components. The first is investments to dramatically raise energy efficiency standards throughout Michigan's economy. That entails reducing the amount of energy that is required to power buildings, transportation vehicles, information technologies and industrial equipment, and to transmit electricity over the state's electrical grid infrastructure.

The second is to also dramatically increase the supply of energy in Michigan generated by clean renewable energy sources. Within the time frame we are considering, the primary renewable sources will be solar energy, produced at utility, commercial and residential scales, along with onshore wind energy. Geothermal and low-emissions bioenergy can also provide significant supplemental clean energy supplies within the overall clean energy-dominant infrastructure. Geothermal, in particular, could become an increasingly important energy source in the latter phases of this clean energy transition. Offshore wind installations could also be developed to a significant degree over the next 25 years in Michigan. But within the framework of this study, we have assumed all wind energy projects in the state will be located onshore.[4]

The statewide investments in energy efficiency and clean renewables will become a large-scale source of job creation throughout Michigan's economy. The *MI Healthy Climate Plan* fully recognizes this prospect, stating that "aggressive action on climate change presents a variety of significant opportunities to better the lives of all Michiganders, including offering immediate opportunities to reduce costs and create good-paying jobs for working families," (p. 4).

We have generated detailed estimates as to the number of jobs in Michigan that will result from these clean energy investments. We also review three sets of issues related to this employment expansion in the state. One set of issues concerns job quality. The job quality measures we consider are levels, at present, of hourly wages, provision of health insurance and retirement plans, and union coverage rates within Michigan's clean energy sectors. A second area covers the characteristics of the state's present clean energy workforce, including the educational levels as well as their gender and racial composition. The third issue considers the prospect that labor shortages could result in some of the clean energy sectors as a result of the large-scale expansion of activity in these sectors.

Of course, the phase-out of Michigan's fossil fuel industries will necessarily produce job losses for workers now employed in these sectors. We estimate the extent of these job losses. As an illustrative exercise, we also sketch out an example of a just transition program for the workers that will experience job losses. This illustrative just transition program aligns with the *MI Healthy Climate Plan's* stated aim to "commit to environmental justice and pursue a just transition," (p. 4).

We present two scenarios for Michigan to achieve its emissions reduction goals. The first follows exactly from the benchmarks set out in the *MI Healthy Climate Plan*, i.e. to reduce emissions by 52 percent relative to 2005 as of 2030 and to achieve carbon neutrality by 2050. But it is clear that for Michigan to reduce emissions by 52 percent as of 2030 will be highly challenging, given that, as of this writing, 2030 is less than five years away. We therefore also present the second scenario within which Michigan's 52 percent emissions reduction target is achieved within a somewhat longer time span of 10 years, as of 2035. Under this second scenario, Michigan will still proceed to reaching carbon neutrality between 2035 – 2050. In this second scenario, the state will then have 15 years to bring its emissions down from 96 million tons to zero, as opposed to having 20 years, from 2031 – 2050 in the first scenario.

We will refer to the original *MI Healthy Climate Plan* scenario as Scenario 1, in which CO_2 emissions in the state fall to 96 million tons as of 2030, and then progresses from 96 million tons to carbon neutrality between 2031 – 2050. In Scenario 2 then, emissions fall to 96 million tons as of 2035, while the state still achieves carbon neutrality by 2050. Thus, both Scenarios 1 and 2 include two phases. In Scenario 1, Phase 1 is the 5-year period 2026 – 2030 in which emissions fall to 96 million tons by 2030 and Phase 2 covers the 20-year period 2031 – 2050 during which emissions will fall from 96 million tons to zero. In Scenario 2, Phase 1 runs for a decade, from 2026 – 35, during which emissions fall to 96 million tons. In Phase 2 of Scenario 2, emissions then fall to zero over the 15-year period 2036 – 50.

The study consists of six sections, including this Introduction. It also includes six appendices that review a range of methodological issues, technical details and references. The material covered in these appendices describe the resources we draw on to derive the main results in this study.

In Section 2, we begin by reviewing the basic data on Michigan's energy infrastructure and sources of CO_2 emissions. We focus on investments in energy efficiency and clean renewable energy sources as the foundations for Michigan's clean energy transition. As we discuss, in using the term "clean" renewable sources, we exclude bioenergy from this category when it is produced through processes which generate CO_2 emissions at levels comparable to those from burning coal, as is predominantly the case at present. But we include bioenergy as a "clean" renewable source if it generates negligible emissions, as is possible through alternative production methods.[5]

We consider, in particular, five energy efficiency investment activities, including building retrofits, industrial efficiency, grid upgrades, public transportation and expanding electric/hybrid vehicles. We then also consider five areas for clean renewable investments: solar energy, including industrial, commercial and residential scale installments; onshore wind; geothermal; low-emissions bioenergy; and battery storage. These energy efficiency and renewable energy investment areas are all central features of the *MI Healthy Climate Plan*.[6] We review in Section 2 the costs of undertaking large-scale investments in both energy efficiency and clean renewables in these 10 investment categories. These cost estimates become crucial reference points for our calculations as to the overall costs of enabling Michigan to achieve both its interim and final emissions reduction targets.

Our study does not take explicit account of major potential increases in energy consumption—electricity demand in particular—that would result through building large-scale data centers in Michigan. At present, a joint project of OpenAI and Oracle, to build a 1.4 gigawatt data center in Saline Township is in the planning and review process.[7] Additional data center projects in Michigan are also under consideration. But these projects also face major obstacles in terms of local opposition, construction delays due to labor, power and equipment shortages, and the need to secure adequate financing. The growth in Michigan's overall energy demand resulting from any build out of data centers in the state therefore remains uncertain. For the purposes of this study, what is central is that investments in energy efficiency and renewable energy will still need to constitute the centerpiece of any expansion of the state's electricity-generating capacity, if the state is going to achieve its emissions reduction goals. As we will review in what follows, a high-efficiency/renewable dominant energy infrastructure is the least expensive as well as the most environmentally benign approach for meeting any given expansion of Michigan's overall energy demand. An expansion of Michigan's clean energy investments beyond what we have estimated in this study will also generate a corresponding growth in job opportunities throughout the state.

In Section 3, we derive both the investment requirements in energy efficiency and clean renewable energy for Michigan to achieve its emissions reduction targets and the extent of job creation that will result through these statewide clean energy investments. We provide estimates for Scenario 1 and Scenario 2. Our primary focus is Scenario 1, which builds from the specific emissions targets set out in the *MI Healthy Climate Plan*. Under Scenario 1, we estimate that Michigan will need to spend an average of $30.8 billion per year between 2026 – 2030 on energy efficiency and renewable energy investments to lower the state's emissions to 96 million tons by 2030. According to our estimates, this would be equal to about 4.2 percent of Michigan's average GDP over those five years. We then estimate that clean energy investments in the state at that level will generate about 185,000 jobs in total, equal to about 3.6 percent of Michigan's 2024 workforce. For the state to bring emissions down from 96 million tons to zero between 2031 – 2050 will require a significantly smaller annual level of investment, since the time span covered in this phase of the project will be 20 years, as opposed to the five years between 2026 – 2030. According to our framework, the average annual investment requirement between 2031 – 50 will be $12.3 billion, equal to about 1.4 percent of Michigan's estimated GDP over that 20-year period. Clean energy investments at this level will generate between about 61,000 to 75,000 jobs (depending on the labor productivity growth rate over these years), equal to between 1.2 – 1.5 percent of the state's 2024 workforce.

Under Scenario 2, the investment requirements and job creation levels will be more evenly spread out, since Michigan would achieve its 52 percent emissions reduction level—to 96 million tons—in 10 years, by 2035 rather than in 5 years, by 2030. We estimate that, under Scenario 2, the average annual clean energy investment required to lower emissions to 96 million tons by 2035 will be $14.2 billion, equal to about 1.9 percent of the state's average GDP over 2026 – 35. We estimate that the state will generate an average of about 87,000 jobs through this clean energy investment level, equal to about 1.7 percent of Michigan's 2024 workforce level. We then estimate that for Michigan to reach zero emissions between 2036 – 2050, clean energy investments in the state will need to average $17.1 billion, which would again amount to about 1.9 percent of the state's GDP over this 15-year period. We estimate that these clean energy investments will create between about 89,000 – 103,000 jobs in the state (depending on the labor productivity growth rate), equal to between about 1.7 – 2.0 percent of Michigan's 2024 workforce.

In Section 4, we report on both the job quality features of the clean energy sector jobs in Michigan at present as well as the characteristics of the workers employed in these clean energy jobs. The job quality measures that we examine are hourly wages, the extent of employer-provided health insurance and retirement plan coverage, and unionization rates in these jobs. With respect to worker characteristics, we report figures on educational credentials as well as the gender and racial composition of the workforce. We show results both as weighted averages for all 10 clean energy sectors and within the 10 individual clean energy sectors. To provide comparisons, we also show these same job quality figures and worker characteristics for Michigan's overall workforce.

The most important results that emerge here are that, first, as an average, clean energy jobs are higher-quality than those for the overall Michigan workforce. In terms of pay levels, clean energy workers receive an average of $39.07 an hour, which is about 7 percent higher than the $36.70 figure for the overall state workforce. At the same time, on average, the educational requirements for clean energy jobs are significantly lower than for the overall Michigan workforce. As one key metric, roughly 36 percent of the state's clean energy employees have a high school degree as their highest educational level, while for the overall Michigan workforce, that figure is about 27 percent. Correspondingly, about 26 percent of clean energy workers have BA degrees or higher, while, for the overall Michigan workforce, that figure is 37 percent. These results—that clean energy jobs are, broadly speaking, relatively high-quality jobs for people without college degrees—are consistent with the stated aims of the *MI Healthy Climate Plan*, which includes creating "good-paying jobs for working families," (p. 4).

At the same time, Michigan's clean energy workforce includes a disproportionately large share of male employees, at 73 percent of all clean energy workers, with women holding only 27 percent of clean energy jobs. In sharp contrast, with Michigan's overall workforce, women comprise about 48 percent of all employees. Michigan's clean energy workforce is also heavily skewed to Whites, who comprise about 78 percent of all workers in all the state's clean energy sectors. But this figure is much more closely aligned with the figure for the Michigan economy overall, in which 74 percent of workers in the state are White.

There are differences between the individual energy efficiency and renewable energy sectors in terms of both job quality and worker characteristics measures. But, for the most part, the patterns for the individual clean energy sectors are consistent with the aggregate results. That is, pay levels tend to be higher and educational requirements are lower relative to the statewide averages. Male workers are also much more heavily represented in most of the individual clean energy sectors.

In Section 5, we estimate the extent to which there are likely to be large enough pools of workers who are qualified and available to move into the jobs that will be generated through Michigan's clean energy investment program. In addressing this question, we are especially focused on identifying employment areas in which labor supply shortages could emerge as investments in Michigan in energy efficiency and clean renewable energy reach their full targeted levels.

We focus our analysis here within the 2026 – 2030 Scenario 1/Phase 1 time period. This is because the increase in jobs resulting from clean energy investments during 2026 – 2030, at 3.6 percent of Michigan's 2024 labor force, will be more than twice as large as during the 2026 – 35 Scenario 2/Phase 1 period, which we estimate the labor demand increase at 1.5 percent of the state's 2024 labor force. The difference in the respective levels of labor demand between the two scenarios results, again, because Michigan would be attempting to cut CO_2 emissions by 52 percent relative to 2005 within 5 years in Scenario 1 versus over 10 years in Scenario 2. Moreover, during Phase 2, as Michigan advances towards its net zero emissions target either between 2031 – 50 under Scenario 1 or between 2036 – 50 under Scenario 2, we estimate the expansion in labor demand as ranging between 1.2 and 1.7 percent of the state's 2024 labor force (assuming labor productivity increases at 1 percent per year). As such, whatever labor shortages that may emerge over 2026 – 30, during Scenario 1/Phase 1, are not likely to recur either during Phase 2 of Scenario 1, between 2031 – 50, or over Scenario 2 at all, during either 2026 – 35 or 2036 – 50.

The central finding of this section is that there are 19 occupations in which we estimate labor shortages could result as clean energy investments in Michigan expand with the aim of achieving its 2030 emissions reduction goal. We further divide these 19 occupations according to whether, by our definition, these labor shortages would be "modest" or "significant." By our definition, the occupations with "modest" shortages would be those in which there would likely be shortages relative to the available pool of workers in Michigan alone for a given occupation. Fifteen occupations fall into this "modest" shortage category by our estimates.

The four remaining occupations in which we estimate that "significant" shortages could result are those in which, by our estimates, shortages would likely emerge even after broadening the potential available pool of workers to include those throughout all Midwestern states. Following this approach, we find that the primary employment areas that are likely to face significant shortages are for workers installing and repairing power and telecommunications lines, along with the supervisors of these front-line installers. Telecommunication line installers and repairers are needed for building out solar and onshore wind capacity. They install and repair the telecommunications cables and networking equipment to provide utility structures with, for example, the ethernet needed to control and monitor energy-producing equipment. Otherwise, we do not estimate labor shortages occurring over the 2026 – 2030 Scenario 1/Phase 1 period. It then follows that there should be no labor shortage problems emerging over any other time period as Michigan advances toward its 2050 emissions reduction target.

In Section 6, our focus is the impact that Michigan's emissions reduction project will have on workers in industries in the state that are currently dependent on statewide consumers purchasing fossil fuels. We assume throughout the study that production activity and employment in the natural gas, oil and coal sectors will decline at rates equal to the respective rates at which consumption declines. We then develop an illustrative just transition program through which fossil fuel industry dependent workers can move out of their existing jobs to alternative employment opportunities without experiencing significant changes in their incomes and overall living standards.

We estimate that, as of 2024, there are about 21,000 people employed in Michigan's fossil fuel and ancillary industries. These workers account for only 0.5 percent of all employment in the state. At the same time, on average, these are relatively high-paying jobs that also provide better benefits as well as higher wages than those for the state's clean energy sector workers and for the overall Michigan workforce.

Because the state will be phasing out fossil fuel consumption over a 25-year period, it follows that fossil fuel workers will face layoffs at an incremental rate over this full period. That is, we do not anticipate that there will be, for example, one or two large-scale layoff episodes in which all, or most, of the current 21,000 fossil fuel-based workers will lose their jobs at once. Moreover, a significant share of the current fossil fuel-based workforce will voluntarily retire over this full 25-year period. After accounting for these two factors—an incremental phase-out rate and voluntary retirements—we estimate that during 2026 – 30, i.e. the Scenario 1/Phase 1 period, about 700 fossil fuel-based workers per year will face displacement and require reemployment. The figure for displaced workers would then be roughly half this total—i.e. around 350 workers per year—under Scenario 2, in which the state's CO_2 emissions would be cut by 52 percent over 10 years, 2026 – 35, rather than the 5-year period, 2026 – 30. Considering just Scenario 1/Phase 1, 2026 – 30, our finding from Section 3 is that clean energy investments during this 5-year period will generate about 185,000 jobs throughout the Michigan economy. It should therefore not be difficult to provide new employment opportunities for these 700 displaced fossil fuel workers per year as a central feature of the *MI Healthy Climate Plan's* commitment to just transition policies.

The illustrative just transition program that we sketch in this section includes three major components: 1) guaranteeing the pensions for the workers in affected industries who will retire as the fossil-fuel phase down proceeds; 2) guaranteeing re-employment for workers facing displacement; and 3) providing income, retraining, and relocation support for workers facing displacement. We describe each feature of this program in some detail in this section, which then enables us to provide estimates of the costs of effectively operating each measure within the overall program.

We also consider in this section what will be the likely impact within Michigan's economy as the automobile industry transitions from building primarily internal combustion engine vehicles (ICEVs) to battery electric vehicles (BEVs). Clearly, this is a critical issue to examine following from the *MI Healthy Climate Plan* framework. As of 2025, total auto manufacturing employment in Michigan was about 49,000 jobs, i.e. more than double the employment level for all fossil fuel sector jobs in the state.

In fact, the challenges that will result for Michigan's auto industry workforce through this transition has been examined in detail in several recent research projects. Our discussion in Section 6 is confined to presenting a brief review of the main findings of these recent studies. These recent studies describe pathways through which the transition from ICEV to BEV auto manufacturing could potentially expand employment levels and improve conditions for auto workers within Michigan. But whether this happens will depend on the effectiveness of policies to locate BEV manufacturing operations, battery production in particular, at current ICEV manufacturing locations or, at least, within Michigan more generally.

Taking a still broader perspective, the extent of employment creation in Michigan resulting from its clean energy investment program will generate more than enough jobs to compensate for the job losses that the state could experience during the phase down of both its fossil fuel and ICEV manufacturing sectors. Whether the newly-created clean energy sector jobs are reasonable substitutes for the displaced fossil fuel and auto manufacturing workers will depend on the features of the just transition programs that are implemented within the overall *MI Healthy Climate Plan*.

2. Energy Consumption and Clean Energy Prospects for Michigan

Energy Consumption in Michigan

In this section, we review the sources of energy supply and demand in Michigan, 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 emissions reduction goals for 2030/2035 and 2050.

Table 2.1 shows Michigan'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

TABLE 2.1
Michigan State Energy Consumption by Sector and Energy Source, 2022
Figures are T-BTUs

	Buildings						
	Residential	Commercial	All buildings	Industrial	Transportation	TOTAL	% of TOTAL
1. Total	**795.0**	**615.7**	**1,410.7**	**691.0**	**709.0**	**2,810.7**	**100.0%**
2. Percent of total	**28.3%**	**21.9%**	**50.2%**	**24.6%**	**25.2%**	---	---
3. Natural Gas	465.3	314.3	779.6	278.2	30.5	1,088.3	38.7%
4. Petroleum	44.2	31.6	75.8	99.7	646.9	822.4	29.3%
5. Coal	131.0	138.8	269.8	153.7	0.0	423.5	15.1%
6. Nuclear	94.6	100.2	194.9	76.9	0.0	271.8	9.7%
7. Bioenergy	41.1	15.3	56.4	71.6	31.6	159.6	5.7%
8. Wind	10.9	11.5	22.4	8.8	0.0	31.2	1.1%
9. Geothermal	4.3	0.9	5.2	0.0	0.0	5.2	0.2%
10. Hydro	1.6	1.7	3.4	1.3	0.0	4.7	0.1%
11. Solar	2.0	1.4	3.4	0.8	0.0	4.2	0.1%

Notes: These figures are for "primary" energy consumption. That is, these figures do not account for energy losses produced through electricity generation. Figures in table do not include 98.3 T-BTUs in net electricity exports to other U.S. states and Canada. Inclusive of these net electricity exports, Michigan's total primary energy consumption in 2022 is 2,712.4 T-BTUs. The 98.3 T-BTUs in Michigan's net electricity exports are distributed proportionally in this table to each of the individual energy sources.
Source: U.S. Energy Information Administration (2025e).

about 1 BTU of energy. We will present figures on energy production and consumption, as appropriate, in terms of both trillion and quadrillion BTUs, using 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 Michigan in 2022 was 2,810.7 trillion BTUs, or, with rounding, 2.8 Q-BTUs.[8] This means that, roughly, 1 Q-BTU would be able to provide for Michigan, at its 2022 consumption level, all the energy consumed for all purposes for roughly four months.

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 Michigan's economy. As we see, about 50 percent is used in buildings, with the remaining 50 percent divided nearly evenly between industrial and transportation uses.

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, natural gas is the most heavily utilized energy source in Michigan, providing almost 40 percent of all the state's energy supply (1,088 T-BTUs of 2,811 T-BTUs total consumption). About 72 percent of natural gas is used for residential and commercial buildings in Michigan (779.6 T-BTUs), with about 26 percent consumed for industrial purposes. Transportation accounts for a negligible 3 percent of overall natural gas consumption in the state. Petroleum is the next most heavily consumed energy source in Michigan, at about 30 percent of the state's overall energy consumption. Nearly 80 percent of petroleum consumption in Michigan is for transportation, with 12 percent used in industrial operations and the remaining 9 percent for buildings.

The remaining 30 percent of Michigan's total energy consumption is provided mostly by coal, at 15 percent of total supply, and nuclear, at 10 percent of total supply.

With respect to renewables, high-emissions bioenergy is by far the largest source at present in Michigan, at 5.7 percent of total supply. The other renewable sources—i.e. the zero emissions sources, including wind, solar, geothermal and hydro—account at present for a negligible 1.5 percent of Michigan's total energy supply as of 2022. Given this current low level of clean renewable energy supply in Michigan, it is clear that the transition to a clean energy-dominant infrastructure in Michigan will be a substantial challenge.[9]

Electricity Supply and Demand

To further clarify the profile of energy consumption in Michigan, we show data in Tables 2.2 and 2.3 on the supply and demand for electricity in the state. Of course, electricity is unique in that it is an intermediate energy source, relying on several primary sources—including natural gas, coal, nuclear, bioenergy, and, to a small extent at present, wind, solar, hydro and geothermal energy—for its generation. It is also unique in that, as Table 2.2 shows, over two-thirds of all energy consumed is lost in the conversion process from the primary energy sources to electricity supply, while the other one-third is channeled into energy that is consumed. One evident way to raise

TABLE 2.2

Michigan State Total Electricity Consumption and Energy Losses in Electricity Generation, 2022

Total energy consumed in generating electricity	1,073.5 T-BTUs *(38.2% of state energy consumption)*
Electricity consumption as share of overall energy consumption	343.4 T-BTUs (*12.2% of state energy consumption)*
Energy losses as share of energy consumed in generating electricity	730.1 T-BTUs (*26.0% of state energy consumption)*

Source: U.S. Energy Information Administration (2025e).

energy efficiency, in Michigan and elsewhere, would therefore entail reducing the percentage of energy losses through electricity use.[10]

Overall, as Table 2.2 shows, electricity production requires 1,073.5 T-BTUs of Michigan's total primary energy consumption, amounting to 38.2 percent of all primary energy consumption in the state. But as an energy source to final consumers in the state's building, transportation and industrial sectors, electricity provides only 343.4 T-BTUs, or 12 percent of the total energy consumed in the state.

Table 2.3 provides more detail on the sources of electricity supply. As we see, as of 2022, coal remained the primary source of electricity generation in Michigan, accounting for over 35 percent of total supply. Natural gas and nuclear energy are the other two major electricity generation sources, providing 32 percent and 26 percent respectively of the state's total electricity supply. Here again we see that the share of electricity being generated by clean renewable sources is small. Wind power is providing nearly 3 percent of total electricity supply. Solar and hydro are each at less than one-half of one percent of total electricity generation in Michigan.

TABLE 2.3

Michigan Electricity Generation by Energy Source, 2022

Total Electricity Consumption: 343.4 T-BTUs

	T-BTUs total	Shares of total (%)
Coal	121.1	35.3 %
Natural Gas	108.7	31.7%
Nuclear	87.4	25.5%
Wind	10.0	2.9%
Bioenergy	7.1	2.1%
Petroleum	6.7	2.0%
Hydro	1.5	0.4%
Solar	0.9	0.3%

Source: U.S. Energy Information Administration (2025e).

Determinants of Michigan's CO_2 Emissions Levels

Table 2.4 shows how, as of 2022, Michigan generated approximately 168 million tons of CO_2 from burning a total of 2.5 Q-BTUs of fossil fuel energy and bioenergy.[11] In terms of the distribution of energy sources, natural gas is the leader at 1.1 Q-BTUs (44 percent), oil is next at 822 T-BTUs (33 percent), coal is at 424 T-BTUs (17 percent) and high-emissions bioenergy is at 161 T-BTUS (6 percent).

Of course, this distribution changes in terms of emissions levels from these alternative energy sources. Thus, emissions from burning natural gas are the lowest from these sources, at 52 million tons per Q-BTU of energy. Burning oil generates 69 million tons per Q-BTU and coal is the dirtiest fossil fuel source, at 94 million tons per Q-BTU. Emissions from burning bioenergy are roughly equivalent to those from coal, at 90 million tons per Q-BTU. As a result of these emissions per Q-BTU ratios, oil and natural gas combustion generated equal amounts of emissions in Michigan as of 2022, at 57 million tons each (37 percent each), with coal emissions lower at 40 million tons (26 percent). Emissions from bioenergy were smaller, but not negligible, at 14 million tons (9 percent).

It is clear from these figures that driving down overall CO_2 emissions in Michigan from 168 million tons in 2022 to 96 million tons by 2030—a 43 percent reduction relative to the 2022 figure as well as a 52 percent cut relative to the 2005 baseline of approximately 200 million tons—will require major reductions in the consumption of all fossil fuel sources as well as high-emissions bioenergy. The *MI Healthy Climate Plan* calls for the phase-out of all coal-generated electricity by 2030 (Michigan Department

TABLE 2.4
Sources of CO_2 Emissions for Michigan: *2022 Actuals and 2030 Projections*

	2022 Actuals			2030 Projections	
	1) 2022 Energy consumption *(in T-BTUs)*	**2) 2022 CO_2 emissions** *(in million metric tons)*	**3) CO_2 emissions per Q-BTU** *(in million metric tons) (= column 2/ (1/1000)*	**4) 2030 Energy consumption** *(in T-BTUs)*	**5) 2030 CO_2 emissions** *(in millions metric tons) (= column 3 x column 4/1000)*
1. Fossil Fuels					
2. Natural Gas	1,088	57	52	813	43
3. Petroleum	822	57	69	614	43
4. Coal	424	40	94	0	0
5. Fossil fuel totals	2,334	154	66	1,427	85
6. High-emissions bioenergy	161	14	90	120	11
7. Totals, including bioenergy	2,495	168	68	1,547	**96**

Source: U.S. Energy Information Administration (2025e).

of Environment, Great Lakes, and Energy, 2022, p. 28). We incorporate this feature in our calculations, shown in row 4 of Table 2.4. Following from this complete coal phase-out by 2030, we then reduce consumption of natural gas, oil, and bioenergy proportionally, as needed to bring overall CO_2 emissions down to 96 million tons by 2030. Thus, as Table 2.4 shows, emissions from oil and natural gas both fall to 43 million tons as of 2030 and bioenergy emissions fall to 11 million tons.

In terms of energy consumption levels, achieving this level of emissions reduction entails that the consumption levels for natural gas, oil, and bioenergy all fall by approximately 25 percent. Specifically, natural gas falls from 1.1 Q-BTUs to 813 T-BTUs; oil consumption falls from 822 to 614 T-BTUs; and bioenergy falls from 161 to 120 T-BTUs.

Once we allow for these energy supply reductions from all four emissions-generating sources, we then need to estimate the extent to which renewable energy supply will need to expand to meet Michigan's overall energy needs as of 2030. This entails analyzing the prospects for achieving gains in energy efficiency throughout the Michigan economy as well as the investment needs for expanding the state's renewable energy supply.

GDP, Energy Intensity, and Emissions Intensity as Emissions Drivers

In order to develop an effective strategy for achieving Michigan'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 Michigan, as well as other states, the U.S. overall, and elsewhere for comparative purposes, 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 Michigan, 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 2.5, we show these ratios for Michigan, as well as, the United States overall and India, and five other states. The states include three other midwestern states whose economies are roughly comparable to Michigan in terms of both per capita emissions and per capita GDP—i.e. Wisconsin, Ohio, and Pennsylvania. We also include two states, California and New York, that have significantly higher levels of per capita GDP but significantly lower levels of per capita emissions. We work with 2022 data in all cases.

TABLE 2.5

Determinants of Per Capita CO2 Emissions Levels in Michigan, the U.S., India, and Various Other U.S. States, 2022

Level of Development, Energy Intensity and Emissions Intensity

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

	Per capita CO_2 emissions *(in metric tons)*	**Per capita GDP** *(in 2024 U.S. dollars)*	**Energy intensity ratio** *(Q-BTUs/trillion dollars GDP)*	**Emissions intensity ratio** *(CO_2 emissions/Q-BTU)*
Michigan	**16.8**	**$65,998**	**4.1**	**62.2**
United States	16.1	$82,898	3.4	56.6
India	1.8	$2,485	9.3	76.6
Wisconsin	17.6	$72,644	4.1	57.6
Ohio	17.7	$74,938	4.0	59.3
Pennsylvania	17.5	$75,040	3.8	60.9
New York	9.1	$111,706	1.6	51.8
California	9.4	$98,239	1.8	53.8

Sources: U.S. Energy Information Administration (2025e) for emissions figures, U.S. Census Bureau (2024) for population figures, and Federal Reserve Economic Data for state-level GDP figures (BEA, 2025a, 2025b, 2025c, 2025d, 2025e, 2025f, 2025g, 2025h). Figures are inclusive of biomass emissions. India data from International Energy Agency (2025a), World Bank (2025a, 2025b, 2025c), and U.S. Energy Information Administration (2025a).

Some valuable observations emerge through considering these ratios for 2022. 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. One way 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 GDP in India is also extremely low, at about $2,500. India's energy intensity ratio is more than double that for Michigan and its emissions intensity ratio is 23 percent higher than Michigan's.

Per capita GDP in Michigan as of 2022 was about $66,000. Michigan could, hypothetically, reduce its per capita emissions figure by approximately half as of 2030 by also cutting per capita GDP in half, to around $33,000, while maintaining its existing energy infrastructure fully intact—i.e. maintaining stable energy and emissions intensity ratios. 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 transition project, again, is to achieve Michigan's emissions reduction goals of 96 million metric tons by 2030 (or 2035) and to be carbon neutral by 2050 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 Michigan's current level of per capita emissions. These are:

1. **Energy intensity:** Michigan's energy intensity ratio, at 4.1 Q-BTUs/trillion dollars of GDP, is comparable to those in Wisconsin, Ohio and Pennsylvania, but about 20 percent higher than the overall U.S. figure of 3.4. One major factor in the lower energy intensity ratio for the U.S. overall is the much lower figures for California and New York. California and New York operate with energy intensity ratios at 1.8 and 1.6 respectively, i.e. less than half the figure for Michigan. In other words, their economies are more than twice as efficient as Michigan in their overall usage of energy. These figures demonstrate that Michigan—as well as other high energy intensity U.S. states—can achieve major gains in efficiency, even without having to assume it can reach California/New York efficiency standards within 5 or even 10 years.
2. **Emissions intensity**: Michigan's emissions intensity ratio, at 62.2 million tons of CO_2/Q-BTU of energy, is about 10 percent higher than the figure for the U.S. overall, and is within close range also of Wisconsin, Ohio and Pennsylvania. Michigan's emissions intensity ratio is also about 20 percent higher than those for California and New York, at about 53.8 and 51.8 respectively. Thus, the gap between the emissions intensity ratio for Michigan (along with those for Wisconsin, Ohio and Pennsylvania) relative to the California and New York figures is much less than with the energy intensity ratios. This means that for Michigan to achieve its emissions reduction goals, it will have to expand its clean energy supply substantially beyond the levels achieved in the strongest performing U.S. states to date, such as California and New York.

In addition to these indicators of Michigan's performance relative to other U.S. states in terms of energy consumption and emissions as of 2022, it is also useful to observe changes in Michigan's performance over time. We present some relevant figures in Table 2.6. The key pattern to observe in Table 2.6 is that the state has achieved some gains over time in what is termed "absolute decoupling." That is, between 2003 – 2022, per capita GDP rose by 8.4 percent while per capita emissions fell by 16.8 percent. Similarly, per capita energy consumption fell by 14.9 percent. As the table also shows, this absolute decoupling pattern is entirely due to the reduction in the state's energy intensity ratio by 21.2 percent between 2003 – 2022. The state's emissions intensity ratio actually rose slightly, by 1.3 percent, between 2003 – 2022.

Michigan's absolute decoupling trajectory is certainly a favorable development. At the same time, for the state to reach its 2030/2035 and 2050 emissions reduction targets will require a much more aggressive, absolute, decoupling trajectory. This, in turn, will require a major investment program to achieve both further gains in energy efficiency as well as a dramatic expansion in the state's clean energy generating capacity. These are the issues to which we now turn.

TABLE 2.6
Changes in Michigan Economic and Energy Consumption Performances, 2003 – 2022

	Per capita GDP *(in 2024 dollars)*	Per capita CO_2 emissions *(in metric tons)*	Per capita energy consumption *(in T-BTUs)*	Energy intensity ratio *(Q-BTUs/trillion dollars GDP in 2024 dollars)*	Emissions intensity ratio *(CO_2 emissions/ Q-BTU)*
2003	$60,860	19.5	0.32	5.2	61.4
2022	$65,998	16.8	0.27	4.1	62.2
Percent change, 2003 – 2022	+8.4%	-16.8%	-14.9%	-21.2%	+1.3%

Sources: U.S. Energy Information Administration (2025e), Federal Reserve Economic Data (BEA, 2025c, 2025h), and Michigan Department of Management and Budget (2025).

Alternative Energy Sources for Building Michigan's Clean Energy Infrastructure

We consider here how large-scale investments in energy efficiency and clean renewable energy sources can serve as a centerpiece for enabling Michigan to achieve its emissions reduction targets—i.e. to reduce CO_2 emissions in Michigan, as of 2030/35, by 52 percent relative to 2005, and to transform the state into a net zero emissions economy by 2050. In particular, in the framework we develop, solar and onshore wind power are best positioned to become the primary energy sources in building Michigan's high efficiency/renewable energy-dominant infrastructure, with geothermal and low-emissions bioenergy as supplemental renewable sources.

There are additional options that Michigan could consider toward advancing the state's emissions reduction project. The most prominent such options are nuclear energy, carbon capture, geoengineering and bioenergy generated under existing processes. We conclude that, on balance, these do not present favorable options for large-scale build-outs for meeting Michigan's energy requirements for the foreseeable future. In the case of nuclear energy specifically, we do incorporate into our overall energy supply calculations the electricity generated by the two nuclear plants, Fermi and Cook, currently operating in the state. We also assume that the planned reopening of the Palisades nuclear plant will also contribute to the state's overall nuclear-based electricity supply. In Appendix 1, we discuss in more depth why we conclude that the overall prospects for nuclear, carbon capture, geoengineering, and conventional bioenergy are not favorable.

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; substituting high-efficiency hybrid or all-electric autos for conventional low-efficiency internal combustion engine vehicles; 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.

In the 2025 edition of its annual *World Energy Outlook,* the International Energy Agency highlights energy efficiency investments as a central component of its overall "Net Zero Emissions Scenario" by 2050.[12] The study reports efficiency gains capable of doubling the rate of annual energy efficiency improvement as including the following:

- Technical efficiency improvements in equipment and buildings;
- Switching from other fuels to electricity in end-uses where feasible, as electricity is much more efficient as an energy carrier than other fuels;
- Structural effects such as material efficiency and modal switching;
- Shifting to more efficient sources of energy where electrification is not feasible or where those sources are being used to generate electricity, for example where renewables are used in place of less efficient fuels to generate electricity.

Some of the specific efficiency measures described by the IEA study are as follows:

- "In the building sector, minimum energy performance standards for appliances and energy codes for new construction are combined with policies that boost retrofit rates."
- "In the transport sector, the switch from internal combustion engine (ICE) vehicles to EVs reduces energy consumption because of the higher efficiency of electric motors, regenerative braking and simpler drivetrains: an EV uses 70 – 80 percent less energy than a comparable ICE vehicle to travel the same distance. Modal shifts and vehicle downsizing can help to ensure more efficient use of batteries to meet transport needs."
- "In the industry sector, material efficiency measures such as light weighting products, extension of product lifetimes and enhanced recycling help to reduce the use of energy-intensive materials, while providing consumers with the same level of service. Increases in technical efficiency in industrial motors, drives and processes also contribute."

For the U.S. economy, the IEA estimates that, even under a relatively modest set of policy measures, energy efficiency will improve by an average of 2 percent per year between 2024 – 2050, while GDP proceeds at an average annual 1.9 percent growth rate. This estimated rate of energy efficiency gain is well within a realistic prospect for

Michigan specifically. As we saw in Table 2.6, Michigan's energy intensity ratio fell by 21 percent between 2003 – 2022. This is equal to a 1.2 percent average annual rate of energy intensity decline—that is, a 1.2 percent average rate of energy efficiency improvement over that 20-year period. These efficiency gains were achieved without Michigan having, as yet, either enacted aggressive policies to support efficiency investments; created a large-scale renewable energy infrastructure; or achieved major increases in the share of electric vehicles in the state's overall vehicle stock. Given that Michigan will be advancing all of these efficiency-improving measures, and similar initiatives, as features of the *MI Healthy Climate Plan*, it is reasonable to assume that the state can increase its overall rate of energy efficiency improvement to the 2 percent per year figure projected for the U.S. overall by the IEA.

Estimating Costs of Efficiency Gains

How much will it cost to achieve major gains in energy efficiency for Michigan? To estimate this, we draw on a series of studies that have observed the energy savings that electric utility companies have achieved through energy efficiency incentive programs for their customers. The Lawrence Livermore Berkeley National Laboratory has produced the most extensive ongoing research in this area. Its most recent 2024 study, *Consumer Benefits of Clean Energy: Energy Efficiency* (Frick et al., 2024) collected data on costs, energy savings, and peak demand savings for electricity efficiency programs from 64 investor-owned utilities and other program administrators in 21 states for 2021. From these data, they estimated an average saving-weighted cost of energy saved (CSE) at 2.1 cents per kilowatt hour (kWh). This figure is moderately lower than the average figure of 2.4 cents per kWh for 2018 from their comparable earlier study (Frick et al., 2021). A separate 2021 study, *The Cost of Saving Electricity for the Largest U.S. Utilities*, conducted by the American Council for an Energy-Efficient Economy (Cohn, 2021), also estimates the average cost of energy savings in 2018 at 2.4 cents per kWh.

For the purposes of this study, we will want to, if anything, overestimate rather than underestimate these efficiency cost figures. As such, we will work from the higher-end cost figures, of 2.4 cents per kWh, from both the Berkeley Lab and ACEEE studies. Moreover, we need to express these figures in 2024 dollars, consistent with adjustments throughout this study. These adjustments bring the average cost of efficiency gains, in 2024 dollars, to 3.1 cents per kWh of savings.

Converting these cents/kWh figures into billions of dollars per Q-BTU of energy, the average cost of efficiency gains comes to $10.6 billion per Q-BTU. Finally, again, so as not to underestimate the costs of our clean energy investment program, we inflate our average efficiency investment cost figure by roughly 40 percent, to $15 billion per Q-BTU. This is roughly equal to 4.3 cents per kWh of efficiency savings.

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 Michigan, especially 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 Michigan 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.[13] Moreover, we have effectively taken account of possible significant rebound effects, since, in terms of our cost estimates, these rebound effects will have the effect of raising the costs of achieving efficiency gains. The way we have accounted for such possible rebound effects is to have deliberately inflated our working estimate of the average cost of efficiency gains by 40 percent relative to the findings in the research literature, from the already higher end figure of 3.1 cents per kWh ($10.6 billion per Q-BTU) to 4.3 cents per kWh ($15 billion per Q-BTU).

Prospects for Clean Renewable Energy

A critical factor for achieving the emissions reduction goals in the *MI Healthy Climate Plan* is the fact that, on average, the costs of generating electricity in the United States with clean renewable energy sources—wind and solar power in particular—are now below those for both fossil fuel-based energy and nuclear power and their relative costs are projected to continue falling. We see this in Table 2.7, which reports figures on U.S. average "levelized costs of electricity" (LCOE) from two separate sources—the International Energy Agency (IEA) and the U.S. Energy Information Administration (EIA). 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 also incorporates the costs of energy that is lost during the electricity-generation process.

The IEA reports actual average figures for 2024 and also provides projections for 2035 and 2050 under its Net Zero Emissions Scenario. The U.S. EIA estimates are for 2030 only. These EIA figures are notable in that their source is the current U.S. Energy Department under the Trump Administration.

Starting with the IEA's figures for 2024, we see that onshore wind costs are at 4.0 cents per kilowatt hour (kWh). This is less than half the 8.5 cents per kWh figure for natural gas and one-third the 11.0 cents figure for nuclear power. Solar is at 5.5 cents per kWh in 2024, i.e., one-third lower than that for natural gas and half that for nuclear. Further, the IEA projections are that onshore wind will fall modestly, to 3.5 cents per kWh as of 2035 and 2050, while solar falls sharply, to 3.0 cents in 2035 and 2.5 cents in 2050. The IEA also projects electricity generation from geothermal energy will fall sharply from 2024, at 33.0 cents per kWh, to 14 cents in 2035 and 7 cents in 2050. By contrast, according to the IEA's estimates, natural gas rises sharply in 2035, to 26.5

TABLE 2.7
Average Levelized Cost of Electricity (LCOE) in the U.S. from Alternative Energy Sources

Costs per Kilowatt Hour

Figures from International Energy Agency (IEA) and U.S. Energy Information Administration (EIA)

	International Energy Agency figures			U.S. Energy Information Administration figures
	2024	2035 est.	2050 est.	2030 est.
Clean renewable sources				
Onshore wind	4.0 cents	3.5 cents	3.5 cents	3.0 cents
Solar PV	5.5 cents	3.0 cents	2.5 cents	3.2 cents
Geothermal	33.0 cents	14.0 cents	7.0 cents	3.8 cents
Hydro	---	---	---	5.9 cents
Other sources				
Natural gas—combined cycle (turbine and steam)	8.5 cents	26.5 cents	---	6.5 cents
Nuclear	11.0 cents	11.5 cents	11.5 cents	8.2 cents
Biomass	---	---	---	8.1 cents

Sources: U.S. Energy Information Administration (2025b); International Energy Agency (2025b, p. 456).

cents in 2035. They do not report a 2050 estimate for natural gas. With nuclear, the IEA estimates that costs rise modestly in 2035 and 2050, to 11.5 cents per kWh.

The EIA's 2030 estimates are 3.0 cents per kWh for onshore wind and 3.2 cents for solar—that is, figures close to the IEA projections for 2035. In addition, the EIA estimates that geothermal will be a relatively low-cost source in 2030, at 3.8 cents per kWh. They project hydro at 5.9 cents. The EIA's 2030 estimates for natural gas and nuclear are lower than those for the IEA. But their figures, with natural gas at 6.5 cents per kWh and nuclear at 8.2 cents, are roughly twice as high as those for onshore wind and solar. The EIA's estimate for biomass, at 8.1 cents per kWh, is also more than twice those for solar and wind.

In addition to these respective LCOE figures, the overall costs for building a clean renewable-dominant energy infrastructure, in Michigan and elsewhere, must take account of the fact that both solar and wind power are intermittent energy sources—i.e. they only generate energy, respectively, when the sun is shining or the wind is blowing. Building out Michigan's clean energy-dominant infrastructure will therefore entail large-scale investments in battery storage capacity as well as major upgrades in the energy grid transmission system. However, these issues will not be pressing within the 2030 and 2035 emissions reduction scenarios. This is because petroleum, natural gas, high-emissions bioenergy and nuclear power will still be supplying roughly 75 percent of Michigan's total energy supply for achieving the state's 52 percent emissions reduction target as of either 2030 or 2035. Thus, the economy's primary baseload energy sources will continue to be fossil fuels, nuclear energy and bioenergy through the 2030/2035 scenarios, while Michigan's energy infrastructure also continues to achieve major gains in efficiency.

At the same time, Michigan's 2023 clean energy law does mandate building out the state's storage capacity to 2,500 MW by 2030.[14] As we describe in more detail below, the investment framework we develop for Scenario 1/Phase 1—entailing a 52 percent emissions reduction by 2030—includes about $3 billion per year in storage capacity investments between 2026 – 2030. At existing high-end battery storage costs of about $1.2 million per MW, Michigan would therefore be able to reach its 2,500 MW storage capacity target as of 2030 within roughly 1 year.[15] Even the more moderate Scenario 2/Phase 1, in which Michigan's 52 percent emissions reduction would be achieved as between 2026 – 2035 rather than 2026 – 2030, the clean energy investment budget would still include about $1.3 billion per year for battery storage investments. That would mean that achieving Michigan's goal of 2,500 MW of storage capacity will be achieved within about 2.5 years—i.e. by mid-2028.

Beyond 2030/2035, it will become increasingly important for Michigan to create significant battery storage capacity, operating in conjunction with the expanded solar and wind energy-generating capacity. In our calculations that follow, we do therefore take account of the increasing investment requirements in battery storage capacity necessary to operate a zero-emissions energy infrastructure by 2050. But even with factoring in these additional battery storage costs of solar and wind power, it will still be the case that Michigan's clean energy-dominant infrastructure will be able to deliver energy at lower costs than an alternative fossil fuel-dominant infrastructure. This is the case, moreover, without accounting for the environmental costs of burning oil, coal, natural gas, and high-emissions bioenergy.

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 67 – 73 percent for solar and onshore wind. They are somewhat lower, at 55 percent for geothermal power, and lower still, at 46 percent for low-emissions bioenergy. But even with bioenergy, capital costs are still the largest cost component.[16]

To estimate the investment costs of expanding the clean renewable generating capacity in Michigan over 2026 – 2050, we proceed as follows:

1. We focus on building renewable capacity in Michigan primarily through solar and wind power, with geothermal and low-emissions bioenergy providing a supplemental renewable supply. As of 2022, hydroelectric power supplied only about 0.1 percent of Michigan's total energy supply (see Table 2.1). We assume that there will be no additional hydropower investment or production in the state between 2026 – 2050.

2. We assume that Michigan's overall renewable supply will consist of 60 percent solar, 30 percent wind, and 5 percent each for geothermal and low-emissions bioenergy. We assume that wind power in the state will be fully provided by onshore installations. There may be viable opportunities to also build offshore wind installations in Michigan but we do not take account of these prospects in our present discussion.[17]
3. Within the solar category, we assume that the overall supply will be provided in equal shares by utility, commercial, and residential scale installations. The costs per unit of electricity generation are significantly lower for utility-scale solar relative to commercial and residential-scale projects. But utility-scale solar entails significant land-use requirements. Thus, we assume an equal-shares mix between utility, commercial and residential-scale installations in order to both reach the overall level of energy supply needed from solar at relatively low costs, while also minimizing land-use impacts. Of course, Michigan could also achieve the same level of energy supply from solar through alternative proportions between utility, commercial and residential solar installations. The combination that the state chooses will depend on the extent to which it prioritizes minimizing either energy costs or land-use impacts.
4. The IEA provides capital cost data for utility-scale solar, onshore wind, and geothermal energy for the U.S. economy. Their data includes the actual figures for 2024 as well as estimates for 2035 and 2050. We use the figures provided by the IEA under their Net Zero Emissions by 2050 Scenario. The IEA does not report cost figures for low-emissions bioenergy. For this estimate, we use the EIA's LCOE figures for biomass energy, and derive lump sum investment cost estimates based on their LCOE capital cost data.
5. Our estimates of the additional capital cost requirements for commercial and residential-scale solar are derived from the U.S. Department of Energy publication, *Solar Photovoltaic System Cost Benchmarks* (U.S. Department of Energy, 2024). This study reports the ratio of commercial/utility-scale solar costs at 1.4 and the residential/utility-scale costs at 2.7.
6. We derived our estimate for battery storage costs that will accompany investments in renewable energy capacity as follows:
    a. The 2024 U.S. Department of Energy study *Solar Photovoltaic System Cost Benchmarks* estimates that incorporating battery storage capacity into the costs of solar electricity raises the total costs by a weighted average of 80 percent, after accounting for cost increase differences between utility, commercial and residential scale solar installations.
    b. A 2022 study by the National Renewable Energy Lab (NREL), *Storage Futures Study: Grid Operational Impacts of Widespread Storage Deployment* (Jorgenson et al., 2022), estimates that when renewable energy sources provide nearly 100 percent of electricity supply in the U.S. the battery storage requirements will amount to about 25 percent of the electricity supply capacity.[18]

c. Based on these separate estimates, we incorporate a 20 percent increase in our figure for overall renewable energy capital costs. This figure is based on both the 80 percent cost increase per kWh of stored solar power and the estimate that the storage capacity requirement will be about 25 percent of overall electricity supply in a near-fully renewable energy system.[19]

Table 2.8 shows our estimate of the capital costs for a weighted average of clean renewable investments, given the proportionate investment shares as: 20 percent each for utility, commercial and residential-scale solar; 30 percent for onshore wind; and 5 percent each for geothermal and low-emissions bioenergy. We report these capital costs per Q-BTU of electricity-generating capacity, based on the IEA figures under its Net Zero Emissions by 2050 scenario.[20] Our overall capital cost estimate then also includes a 20 percent mark up over the capital costs to account for the required supply of battery storage capacity to operate along with the renewable equipment.

As we see, our overall weighted average capital cost figure is $175 billion per Q-BTU of electricity-generating capacity. So as not to underestimate these costs, we round this figure up to $180 billion.[21]

TABLE 2.8
Estimated Weighted Average Capital Costs for Michigan Clean Energy Investments, 2026 –2050

	1) Capital installation costs per Q-BTUs	2) Shares of overall installation	3) Capital installation costs with weighted shares, per Q-BTU (= columns 1 x 2)
Solar PV			
Utility scale	$95 billion	20%	$19 billion
Commercial scale	$134 billion	20%	$27 billion
Residential scale	$260 billion	20%	$52 billion
Wind—onshore	$111 billion	30%	$33 billion
Geothermal	$150 billion	5%	$7.5 billion
Low-emissions bioenergy	$150 billion	5%	$7.5 billion
TOTALS WITHOUT BATTERY STORAGE	---	---	$146 billion
Battery storage	20% mark-up over installation costs	---	$29 billion
TOTALS	**---**	**100%**	**$175 billion** ***rounded up to $180 billion***

Sources: See references in text and Appendix 2.

This $180 billion per Q-BTU estimate is based on a weighted average of the IEA's reported capital cost figures for solar, wind, and geothermal as of 2024, 2030, and 2050 respectively. The IEA estimates that these capital costs will decline over the full 2024 – 2050 period, by significant amounts for solar and geothermal, and modestly for wind.[22] Given these estimated rates of decline in capital costs, we can apply our full period average cost figure of $180 billion per Q-BTU for our scenarios in which Michigan proceeds from its 52 percent emissions reduction goal as of either 2030 or 2035 to achieve zero emissions by 2050. The $180 billion per Q-BTU average cost estimate is also valid for our scenario in which Michigan reaches its 52 percent emissions reduction target between 2026 – 2035. However, for the scenario in which Michigan reaches its 52 percent emissions reduction target within 5 years only, between 2026 – 2030, we need to allow that average renewable capital costs will be higher, since the capital cost reductions estimated by the IEA will not have had a significant impact between 2026 – 2030. Thus, for the 2026 – 2030 scenario for reaching Michigan's 52 percent emissions reduction target, we estimate that average renewable capital costs will be 10 percent higher than for the full period, at $200 billion per Q-BTU.[23]

Summary of Energy Efficiency and Renewable Energy Investment Costs

In what follows, we proceed with estimating the costs of *MI Healthy Climate Plan* based on the estimates, shown in Table 2.9 below, of the overall capital costs of both raising energy efficiency standards and building new clean renewable energy capacity.

TABLE 2.9

Estimated Average Energy Efficiency and Renewable Energy Capital Costs by Scenarios and Phases

Figures are billions of dollars per Q-BTU of either energy savings or new energy supply

	Scenario 1		Scenario 2	
	Phase 1: 2026 – 2030	Phase 2: 2031 – 2050	Phase 1: 2026 – 2035	Phase 2: 2036 – 2050
Energy efficiency	$15 billion	$15 billion	$15 billion	$15 billion
Renewable energy	$200 billion	$180 billion	$180 billion	$180 billion

3. Clean Energy Investment and Job Creation Scenarios for Achieving Michigan's Emissions Reduction Goals

In this section, we develop clean energy investment and job creation scenarios for Michigan to achieve both of its emissions reduction targets—its intermediate target of a 52 percent emissions reduction by 2030 relative to the 2005 baseline, and to become a net zero emissions economy by 2050. We also present a modified version of this Michigan proposal, in which the state achieves its 52 percent emissions reduction target as of 2035 rather than 2030. To reach the state's intermediate emissions reduction target means that CO_2 emissions in Michigan will need to be no more than 96 million tons, given that emissions in 2005 were approximately 200 million tons.

As we discussed in the Introduction, it will be highly challenging for Michigan to achieve the 52 percent emissions reduction target by 2030—that is, less than 5 years away, as of this writing. But it will nevertheless be a valuable exercise to consider the requirements for reaching this 2030 emissions reduction goal along with the requirements for reaching the modified 2035 target. We will refer to the scenario for reaching the 52 percent emissions reduction target by 2030 as Scenario 1 and the modified approach of reaching the 52 percent emissions reduction target by 2035 as Scenario 2.

With both scenarios, we do also present the investment requirements and job creation figures for reaching the state's zero emissions target by 2050. We will refer to these time periods for Michigan to achieve net zero emissions as Phase 2, with the time period for reaching the 52 percent emissions reduction target as Phase 1. Thus, with Scenario 1, Phase 1 covers 5 years, 2026 – 2030 and Phase 2 covers 20 years, 2031 – 2050. With Scenario 2, Phase 1 covers 10 years, 2026 – 35 and Phase 2 covers 15 years, 2036 – 2050.

Scenario 1/Phase 1: Emissions Reductions 2026 – 30

We review here the requirements for Michigan to bring CO_2 emissions in the state's economy down to 96 million tons as of 2030. This would represent the 52 percent emissions reduction level relative to the state's 2005 emissions level. It would also be a 43 percent emissions reduction level relative to the state's 2022 emissions figure of 168 million tons.

To explore this prospect systematically within the context of a growing Michigan economy, we must, unavoidably, work with some assumptions as to the state's real economic growth trajectory between 2026 – 2030. Thus, we assume that the Michigan economy will grow in real (i.e. inflation-adjusted) terms between now and 2030 at an average rate of 1.5 percent per year. This GDP growth figure is significantly faster than Michigan's actual growth rate over the 20-year period 2003 – 2022, which was 0.4 percent per year. However, the U.S. economy overall grew at an average rate of 2.0 percent per year between 2003 – 2022. It is reasonable to expect that Michigan's growth trajectory moving forward from 2026 will converge towards this previous U.S. overall average figure, even if still somewhat more slowly than the U.S. 2003 – 2022 growth experience. Moreover, the prospect for a more accelerated growth path for Michigan will certainly be supported by an ambitious clean energy investment program such as that which we are presenting here, based on the *MI Healthy Climate Plan*. Thus, for the purposes of this study, it is appropriate to assume that Michigan's economy will grow at a 1.5 percent average annual rate between 2026 – 2030 and indeed, through until 2050.

In Table 3.1, we first report on Michigan's real GDP as of 2022 (expressed in 2024 dollars) and the projected level in 2030, assuming the economy's average real growth rate is maintained at 1.5 percent through 2030. We see that, under this growth assumption, Michigan's real GDP will be approximately $749.4 billion in 2030, growing from the 2022 figure of $665.3 billion. Assuming again a 1.5 percent average annual growth rate, the 2026 GDP will be $706.1 billion. The midpoint over the 2026 – 2030 decade will be effectively June 30, 2028. Michigan's real GDP will be at $727.8 billion at that midpoint.

Within this framework, we can then develop an energy and CO_2 emissions profile for Michigan for 2030. We consider two distinct projections, which we present in Table 3.2. For the first 2030 projection, we assume that the state's energy infrastructure as of 2022 remains basically intact through 2030. Specifically, in column 1 of Table 3.2, we show the actual breakdown of energy consumption and emissions as of 2022. In column 2, we then present estimated figures, assuming Michigan's economy grows at an average annual rate of 1.5 percent through 2030 and the state's energy infrastructure remains basically intact. We term this the "Business as Usual" (BAU) energy infrastructure trajectory for Michigan. In this projection, with the exception of nuclear energy, the state's existing energy demand and sources of supply grow at exactly the state's overall 1.5 percent annual GDP growth rate. With nuclear energy, we assume, as discussed in Section 2, that once the Palisades plant reopens in 2026, the state's nuclear energy supply will increase from 272 to 319 T-BTUs, then remain at this same level through both 2030 and 2050.

TABLE 3.1
Michigan State GDP Levels: 2022 Actual and Projections for 2026 – 2030
Figures are in 2024 dollars

2022 GDP	$665.3 billion
Projected average growth rate 2026–2030	1.5%
Projected 2026 GDP	$706.1 billion
Projected 2030 GDP	$749.4 billion
Projected midpoint GDP between 2026–2030	$727.8 billion

Source: U.S. Bureau of Economic Analysis (2025c, 2025h).

TABLE 3.2
Michigan State Energy Consumption and Emissions
2022 Actuals and 2030 BAU and Alternative Projections

	1) 2022 actuals	**2) 2030 BAU** *(assumed all categories grow at 1.5% annual rate)*	**3) 2030 through Clean Energy Investment Program**
1) Real GDP *(in 2024 billion dollars)*	665.3	749.4	749.4
2) Energy consumption *(T-BTUs)*	2712	3055	2548
3) Energy intensity ratio *(Q-BTUs / $1 trillion of GDP)*	4	4	3.4
4) Electricity exports to other U.S. states and Canada	98	110	92
Energy mix for in-state supply			
5) Non-renewables and bioenergy (T-BTUs)	*2495*	*2811*	*1547*
6) Natural gas	1088	1226	813
7) Petroleum	822	926	614
8) Coal	424	478	0
9) High-emissions bioenergy	161	181	120
10) Nuclear	272	319	319
11) Clean renewables (T-BTUs = row 2 – (row 4 + row 5 + row 10))	*43*	*36*	*774*
12) Solar	4	5	461
13) Wind	30	34	231
14) Low-emissions bioenergy	0	0	38
15) Geothermal	5	6	38
16) Hydro	5	5	5
Emissions			
17) Total CO_2 emissions *(million metric tons)*	168	189	96
18) Emissions Intensity Ratio *(CO_2 emissions per in-state-consumed Q-BTUs = row 17 / row 2/1000)*	62	62	38

Source: U.S. Energy Information Administration (2025c, p. 260, Table CT3, 2025e). See technical notes: U.S. Energy Information Administration (2025d).

In column 3, we then present figures through which Michigan reduces emissions to 96 million tons as of 2030 while maintaining an average annual GDP growth rate of 1.5 percent.

In the BAU projection, we assume that Michigan's electricity exports increase at the same 1.5 percent average annual growth rate as the overall state economy. This implies the Michigan's energy exports rise from its 2022 figure of 98 T-BTUs to 110 T-BTUs.

Within this overall set of assumptions, we then see in row 3, columns 1 and 2, that Michigan's energy intensity ratio remains constant between 2022 and 2030, at 4.0 Q-BTUs per $1 trillion of GDP. The state's emissions intensity ratio also remains unchanged, at 62 CO_2 emissions per in-state consumed Q-BTUs, as shown in row 18, columns 1 and 2. Given the BAU assumption of a stable energy infrastructure between 2022 and 2030 while the economy grows at 1.5 percent per year, we then see the impact on statewide CO_2 emissions in row 17 of Table 3.2. That is, total CO_2 emissions increase from 168 to 189 million tons, an increase of 12.5 percent.

In column 3 of Table 3.2, 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 96 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 Michigan economy. Specifically, we assume that, by 2030, Michigan is capable of reducing its energy intensity ratio from the 2022 level of 4.0 to 3.4 Q-BTUs per $1 trillion of GDP. This would be a 15.0 percent gain in overall energy efficiency in the state, achieved over 2026 – 2030, or a 3.2 percent annual gain in energy efficiency. At this energy intensity level, Michigan's energy infrastructure as of 2030 would still be only at an energy intensity level equal to the average figure for the U.S. overall as of 2022.

Working from this energy intensity level, we then consider the energy mix that will be necessary to allow for 2,548 T-BTUs of total energy consumption in Michigan while still maintaining emissions at no more than 96 million tons. As we saw in Table 2.4, in order to bring overall CO_2 emissions in Michigan down to 96 million tons by 2030, one viable path would be for coal consumption to be phased out entirely, and for natural gas, oil and high-emissions bioenergy consumption to all fall by 25 percent. As we see in column 3 of Table 3.2, this implies that natural gas is at 813 T-BTUs as of 2030, oil is at 614 T-BTUs and high-emissions bioenergy is at 120 T-BTUs. We also assume in this scenario that, as noted earlier, nuclear energy in Michigan rises from its 2022 output level of 272 T-BTUs to 319 T-BTUs. This increased nuclear output assumes that the recommissioning of the Palisades nuclear plant will be finalized at least by 2030.

Overall then, with fossil fuel and high-emissions bioenergy at 1,547 T-BTUs, nuclear power at 319 T-BTUs, and Michigan's energy exports at 92 T-BTUs, it follows that 774 T-BTUs of energy will need to be provided by clean renewable sources, in order for Michigan's overall energy consumption to reach 2,548 T-BTUs in 2030. As of 2022, all clean renewable sources—solar, wind, low-emissions bioenergy, geothermal, and hydro—combined to supply 43 T-BTUs of energy to Michigan. Effectively then, 731 T-BTUs of new supply needs to be provided by some combination of solar, wind, geothermal, low-emissions bioenergy, and hydro in order for Michigan's total energy supply to reach 2,548 T-BTUs in 2030. This is with emissions falling to 96 million tons by 2030—i.e. falling, again, by 52 percent in 2030 relative to the 2005 baseline of 200 million tons, and by 43 percent relative to the 2022 figure of 168 million tons.

As discussed above, between 2026 – 2030, we assume that the average capital expenditures needed to expand clean renewable energy supply by 1 Q-BTU, along with adequate battery storage capacity for this level of renewable supply will be $200 billion. This then means that, to expand the clean renewable supply/battery storage in Michigan by 731 T-BTUs, will require $146.2 billion in new capital expenditures. Working, again, with the assumption that this is a 5-year investment program, this implies that the average level of expenditures per year to increase the supply of clean renewable energy by 731 T-BTUs in 2030 will be $29.2 billion per year.

In Table 3.3, panels A-C, we summarize the main features of this Scenario 1/Phase 1 clean energy investment program for bringing CO_2 emissions in the state down to 96 million tons. These include the following:

- ***Efficiency.*** $1.5 billion per year in energy efficiency investments between 2026 – 2030, amounting to about 0.2 percent of Michigan's projected midpoint GDP between 2026 – 2030. These efficiency investments will generate 507 T-BTUs of energy savings relative to the BAU growth path for Michigan through 2030. This, again, is a 15 percent improvement in energy efficiency throughout Michigan's economy relative to the BAU figure for 2030.
- ***Clean renewables.*** $29.2 billion per year for investments in solar, wind, low-emissions bioenergy, and geothermal power with no expansion in hydro power supply. This will amount to about 4.0 percent of Michigan's projected midpoint GDP between 2026 – 2030. It will generate an increase of 731 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 $30.8 billion per year, or 4.2 percent of Michigan's projected midpoint GDP between 2026 – 2030. Overall, this program will generate 1,238 T-BTUs in either energy savings relative to the BAU scenario or expanding the clean renewable energy supply. The end result of this program will be that overall CO_2 emissions in Michigan in 2030 will be 96 million tons, 52 percent less than its level for 2005. Michigan will have achieved this 52 percent emissions reduction while the state's economy also will have grown at an average rate of 1.5 percent per year through 2030.
- ***Jobs generated by efficiency and clean renewable investments***. As we present in detail below, we estimate that this $30.8 billion per year in new clean energy investments between 2026 – 2030 will generate approximately 185,000 jobs throughout Michigan's economy. This level of employment expansion within Michigan's economy will then be sustained as long as the clean energy investment level is maintained within the state at $30.8 billion per year.

TABLE 3.3
Michigan Clean Energy Investment Program for 2026 – 2030

A) Energy Efficiency Investments

1. 2030 Energy intensity ratio	3.4 Q-BTUs per $1 trillion GDP *(15% improvement over 3.98 Q-BTU per $1 trillion GDP BAU figure)*
2. Total energy consumption	2,548 T-BTUs *(15% improvement over 3,055 Q-BTU BAU figure)*
3. Energy savings relative to BAU	507 T-BTUs *(3055-2548 T-BTUs)*
4. Average investment costs per Q-BTU in efficiency gains	$15 billion per Q-BTU
5. Costs of energy savings	$7.6 billion *(=15*0.507)*
6. Average annual costs over 2026 – 2030	$1.5 billion *(=7.6/5)*
7. Average annual costs of efficiency gains as % of midpoint GDP	0.2%

B) Clean Renewable Energy Investments

1. Total renewable supply necessary	774 T-BTUs
2. Expansion of renewable supply relative to 2022 level	731 T-BTUs
3. Average investment costs per Q-BTU for expanding renewable supply	$200 billion per Q-BTU
4. Costs of expanding renewable supply	$146.2 billion
5. Average annual costs over 2026 – 2030	$29.2 billion
6. Average annual costs of renewable supply expansion as % of midpoint GDP	4.0%

C) Overall Clean Energy Investments: Efficiency + Clean Renewables

1. Total clean energy investments	$153.8 billion
2. Average annual investments	$30.8 billion
3. Average annual investments as share of midpoint GDP	4.2%
4. Total energy savings or clean renewable capacity expansion	1,238 T-BTUs

Sources: See Table 2.8, Table 3.2, Appendix 2, and references on p. 21.

Job Creation through 2026 – 2030 Clean Energy Investments

In Tables 3.4 and 3.5 we present our estimates as to the job creation effects of investing in energy efficiency in Michigan. Tables 3.6 and 3.7 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 2026 – 2030, i.e. $1.5 billion in energy efficiency and $29.2 billion in clean renewable energy.[24]

Direct, Indirect and Induced Job Creation

Before reviewing the actual data on job creation in Tables 3.4 – 3.7, we need to briefly describe the three channels through which jobs will be generated through clean energy investments. In fact, these three sources of job creation will be associated with any expansion of spending in any area of the economy, including clean energy investments. They are: direct, indirect, and induced employment effects. For purposes of illustration, consider these categories in terms of investments in 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 3.4 – 3.7, 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.

Job Creation through Energy Efficiency Investments

In Table 3.4, 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 3.4 shows, direct plus indirect job creation per $1 million in spending ranges between 3.8 jobs for expanding the electric/hybrid vehicle auto fleet to 10.4 jobs for public transportation expansion and upgrades.

TABLE 3.4
Job Creation in Michigan 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	5.6	1.6	7.1	2.2	9.4
Industrial efficiency with CHP	3.8	1.3	5.2	1.9	7.1
Grid upgrades	5.1	1.2	6.3	2.1	8.4
Public transportation	8.7	1.7	10.4	2.2	12.6
Expanding electric/ hybrid vehicles	2.4	1.3	3.8	1.5	5.2

Source: See Appendix 3.

In Table 3.5, we show the level of job creation through spending an average of $1.5 billion per year on these efficiency projects in Michigan between 2026 – 2030. We have assumed that the overall level of funding is channeled into the various energy efficiency areas in equal shares of $300 million each per year. Working with this assumption, the overall result of $1.5 billion per year in efficiency investments in Michigan will be the creation of 7,689 direct jobs and 2,130 indirect jobs, for a total of 9,819 direct plus indirect jobs created through this energy efficiency investment program. Including induced jobs adds another 2,972 jobs to the total figure. This brings the total job creation figure for efficiency investments, including induced jobs, to 12,791 jobs.

TABLE 3.5
Annual Job Creation in Michigan through Energy Efficiency Investments, 2026 – 2030
Job creation through average annual spending of $1.5 billion in efficiency investments

	Spending amounts *(shares)*	Direct jobs	Indirect jobs	Direct + indirect jobs	Induced jobs	Direct, indirect + induced jobs
Building retrofits	$300 million (20%)	1,670	468	2,138	674	2,812
Industrial efficiency with CHP	$300 million (20%)	1,150	405	1,555	570	2,125
Grid upgrades	$300 million (20%)	1,541	345	1,886	630	2,516
Public transportation	$300 million (20%)	2,602	509	3,112	660	3,772
Expanding electric/ hybrid vehicles	$300 million (20%)	725	402	1,127	438	1,565
TOTALS	**$1.5 billion**	**7,689**	**2,130**	**9,819**	**2,972**	**12,791**

Source: See Appendix 3. Totals may not add exactly to sum of individual categories due to rounding.

Job Creation through Clean Renewable Energy Investments

In Table 3.6, we show the job creation figures for our five clean renewable energy categories—solar energy, including the three solar categories of utility, commercial, and residential; onshore wind; geothermal; low-emissions bioenergy; and battery storage. We have combined the three solar installation categories here, since the direct and indirect job creation estimates per level of expenditure for each of them are identical, even while, as we have described above, the respective installation costs themselves vary significantly.

As we see, the extent of direct plus indirect jobs ranges from 4.1 direct plus indirect jobs per $1 million in expenditure for on-shore wind projects to 5.8 direct and indirect jobs for investing $1 million in geothermal projects. Adding induced jobs brings the range to 5.7 jobs for wind, 5.8 for solar, 5.9 for battery storage, 6.9 for low-emissions bioenergy, and 8.0 jobs for geothermal.

Based on these job creation ratios, we see in Table 3.7 the levels of job creation in Michigan generated by spending an average of $29.2 billion per year between 2026 – 2030 in these areas of clean renewable energy. As we see in Table 3.7, we have divided total spending levels as follows:

- Investments in energy sources: 60 percent solar, 30 percent wind, and 5 percent each for geothermal and clean bioenergy.
    - Of the 60 percent spending on solar, the budgetary breakdown is 25 percent for utility scale solar, and 17.5 percent each for commercial and residential scale.
- Investments in battery storage: 10 percent mark-up over total energy investment spending.

TABLE 3.6
Job Creation in Michigan 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 (utility, commercial, residential scales)	3.1	1.1	4.2	1.6	5.8
Onshore wind	3.1	1.0	4.1	1.6	5.7
Geothermal	4.1	1.7	5.8	2.2	8.0
Low-emissions bioenergy	3.6	1.6	5.2	1.7	6.9
Batteries	2.9	1.3	4.2	1.7	5.9

Source: See Appendix 3.

TABLE 3.7

Annual Job Creation in Michigan through Clean Renewable Energy Investments, 2026 – 2030

Job creation through average annual spending of $29.2 billion in clean renewable investments

	Spending amounts *(shares of renewable spending)*	Direct jobs	Indirect jobs	Direct + indirect jobs	Induced jobs	Direct, indirect + induced jobs
Renewable sources (90% of overall investments)						
Solar	$15.7 billion (60%)	48,958	17,373	66,330	24,363	90,692
Utility scale	$6.7 billion (25%)	20,852	7,399	28,252	10,763	39,014
Commercial scale	$4.5 billion (17.5%)	14,053	4,987	19,039	6,800	25,839
Residential scale	$4.5 billion (17.5%)	14,053	4,987	19,039	6,800	25,839
Onshore wind	$8.2 billion (30%)	25,385	8,189	33,574	13,102	46,677
Geothermal	$1.2 billion (5%)	4,796	1,989	6,785	2,574	9,359
Low-emissions bioenergy	$1.2 billion (5%)	4,211	1,872	6,083	1,989	8,072
Batteries (10% of overall investments)	**$2.9 billion**	**8,481**	**3,802**	**12,283**	**4,972**	**17,255**
TOTAL	**$29.2 billion**	**91,832**	**33,223**	**125,056**	**46,998**	**172,054**

Sources: See Appendix 3. Totals may not add exactly to sum of individual categories due to rounding.

Following from these budgetary assumptions, we see in Table 3.7 that total direct plus indirect job creation generated in Michigan by this large-scale expansion in the state's clean renewable energy supply will be 125,056 jobs. If we include induced jobs, then the total rises to 172,054 jobs.

Table 3.8 brings together our job estimates for both energy efficiency and clean renewable energy through spending about $30.8 billion per year on this project in Michigan between 2026 – 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 3.8 that total annual average direct and indirect job creation for 2026 – 2030 is 134,874 jobs and 184,845 jobs when we add induced jobs to the total. As we see in row 14, this level of job creation amounts to between 2.6 and 3.6 percent of the total workforce in Michigan as of 2024, the range depending on whether we include induced jobs in the total.

TABLE 3.8

Annual Job Creation in Michigan through Combined Clean Energy Investments

Average annual figures for 2026 – 2030

Total Annual Clean Energy Investment Spending = $30.8 billion

Industry	Number of direct and indirect jobs created	Number of direct, indirect and induced jobs created
$1.5 billion in energy efficiency investments		
1) Building retrofits	2,138	2,812
2) Industrial efficiency with CHP	1,555	2,125
3) Grid upgrades	1,886	2,516
4) Public transportation	3,112	3,772
5) Expanding electric/ hybrid vehicles	1,127	1,565
6) Total energy efficiency job creation	*9,819*	*12,791*
$29.2 billion in clean renewables		
7) Solar	66,330	90,692
Utility scale	28,252	39,014
Commercial scale	19,039	25,839
Residential scale	19,039	25,839
8) Onshore wind	33,574	46,677
9) Geothermal	6,785	9,359
10) Low-emissions bioenergy	6,083	8,072
11) Batteries	12,283	17,255
12) Total job creation from clean renewables	*125,056*	*172,054*
13) Total job creation – efficiency and clean renewables	**134,874**	**184,845**
14) Total as a share of 2024 Michigan Labor Force *(Labor force at 5.1 million)*	**2.6%**	**3.6%**

Source: See Appendix 3. Totals may not add exactly to sum of individual categories due to rounding.

Scenario 1/Phase 2: Zero Emissions by 2050

If Michigan is able to bring overall CO_2 emissions in the state down to approximately 96 million tons by 2030—a 52 percent decline relative to the 2005 baseline of 200 million tons as well as a 43 percent reduction relative to the 168 million ton figure for 2022—it should also be able to establish a zero emissions statewide economy by 2050.

In fact, enabling Michigan to meet its 2050 emissions reduction target as set out by the *MI Healthy Climate Plan* will not require fossil fuel energy consumption in the state, and thereby CO_2 emissions, to fall precisely to zero. This is because Michigan's forested areas absorb approximately 15 million tons of CO_2 per year (see Appendix 1). Nevertheless, as a means of simplifying the analysis here, we assume that the goal will be for Michigan to reach zero emissions within the state by 2050. The global climate stabilization project would then be further strengthened as afforestation in the state contributes toward absorbing the accumulated stock of CO_2 in the atmosphere.

Michigan should be able to establish a zero-emissions energy infrastructure as of 2050 basically through continuing the clean energy investment project that would have proceeded during Scenario 1/Phase 1, from 2026 – 2030. Moreover, on an annual basis, the scale of the investments in energy efficiency and clean renewable energy between 2031 – 2050 that will be needed to reach zero emissions by 2050 will be significantly more modest than what we have described above for the project through 2030.

As we saw in Table 3.3, our estimate of the clean energy investment costs for bringing emissions down to 96 million tons between 2026 – 2030, within five years only, would be about 4.2 percent Michigan's GDP per year between these five years. Over 2031 – 50, as we will see, we estimate that the average annual clean energy investment costs necessary to bring emissions down to zero to be much smaller, at 1.4 percent of Michigan's average GDP. The impact of this much smaller investment project on job creation throughout the state will be similarly much smaller than during 2026 – 2030, though still strongly in the positive direction.

As with our analysis for 2026 – 2030, we necessarily work with a few credible assumptions regarding Michigan's economic trajectory over 2031 – 2050 in generating our estimates as to the costs of creating a clean energy infrastructure over this time period.

These include the following:

1. *Economic growth*. We assume that average economic growth in Michigan proceeds at the same rate as we have assumed for 2026 – 2030, i.e. at 1.5 percent per year.
2. *Energy efficiency*. Over 2026 – 2030, we assumed that Michigan will have achieved substantial gains in energy efficiency, specifically that the state's energy intensity ratio will have fallen from 4.0 to 3.4 Q-BTUs per $1 trillion of GDP—a 15 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 $15 billion per Q-BTU, the same cost figure for our 2026 – 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*. As discussed in Section 2, we assume that the weighted average cost of creating 1 Q-BTU of clean renewable energy capacity will fall from $200 billion over 2026 – 2030 to $180 billion between 2031- 2050. As discussed in Section 2, this lower figure is derived from the IEA's average capital cost estimates through 2050 under its Net Zero Emissions by 2050 scenario. In addition to the IEA's estimates, we also incorporate two other factors that impact our 2031– 2050 cost estimate. These are:
    - We have increased the shares of commercial and residential solar installations from 17.5 percent each over 2026 – 2030 to 20 percent each between 2031 – 2050. Commercial and residential solar installations are more expensive than utility-scale installation costs. But they provide the important benefit that, in contrast with utility-scale installations, their land-use impacts are negligible.
    - We increase investment spending on battery storage capacity from 10 percent of overall renewable/storage investments over 2026 – 2030 to 20 percent between 2031 – 2050. This increase in storage investments will be needed as renewables transition to becoming Michigan's predominant energy source. As that transition occurs over 2031 – 2050, it means that fossil fuels and nuclear energy will be less available to provide baseload power to compensate for periods when the intermittency of solar and wind power might otherwise create short-term supply shortages.
4. *Job creation*. To estimate job creation, we first work with the same employment/output ratios for the various energy efficiency and renewable energy investment areas that we reported in Tables 3.4 and 3.6. We then generate a second estimate of overall job creation by assuming that average labor productivity in Michigan's clean energy sectors will increase by 1 percent per year between 2031 – 2050. Due to these productivity gains, labor demand resulting from the given level of clean energy investments will fall by the same 1 percent per year relative to the figures generated by the various employment/output ratios.

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 Michigan could become a zero emissions economy by 2050. We present these results in Tables 3.9 – 3.12.

In Table 3.9, we show Michigan's GDP projection for 2050 based on a 1.5 percent average annual growth rate for 2031 – 2050. This growth path begins at the 2030 GDP baseline of $749 billion (in 2024 dollars). This figure is itself a projection, of course, which we derived through assuming that Michigan's GDP would grow at an average annual rate of 1.5 percent between 2026 – 2030, starting from the 2022 actual GDP

TABLE 3.9
Michigan Average Economic Growth Projections for 2031– 2050
Assumption is 1.5% average annual GDP growth rate

Projected 2030 GDP level	$749 billion
Projected 2031 GDP level	$760 billion
Projected 2050 GDP level	$1.0 trillion
Midpoint GDP level for investment spending estimates *(2031 GDP level + 2050 GDP level)/2)*	$885 billion

Source: See Table 3.1.

level of $665 billion. Based on these assumptions, as we see in Table 3.9, Michigan's GDP will be $1.0 trillion in 2050. We then calculate the midpoint GDP level between 2031 – 2050 under this scenario. As we see, this midpoint figure is $885 billion.

In Table 3.10, we then estimate the investment costs necessary to bring Michigan's energy intensity ratio down from the 2030 figure of 3.4 to 2.3 Q-BTUs of energy/$1 trillion of GDP. This would represent a 32 percent improvement in average energy efficiency throughout the Michigan economy, i.e. a roughly 1.9 percent improvement per year between 2031 – 2050. Table 3.10 shows that to arrive at a 2.3 energy intensity ratio by 2050 will require $17 billion in new energy efficiency investments between 2031 – 2050 under the 1.5 percent GDP growth assumption. Considered on an annual basis, these total costs amount to an average of $850 million per year.

In Table 3.11, we perform a comparable set of calculations for clean renewable energy investments between 2031 – 2050. We begin these calculations with the assump-

TABLE 3.10
Energy Efficiency Investment Needed to Achieve Michigan Energy Intensity Ratio of 2.3 by 2050

2050 GDP assumption	$1.0 trillion
Total 2050 energy consumption at 3.4 energy intensity ratio	3,411.4 T-BTUs
Total 2050 energy consumption at the 2.3 energy intensity ratio	2,281.0 T-BTUs
Reduced energy demand through 2031 - 2050 efficiency investments	1,130.4 T-BTUs
Cost of investment in energy efficiency	$17.0 billion
Costs per year over a 20-year investment cycle	$850 million

Notes: Energy Intensity Ratio = Q-BTUs of energy/ GDP in trillions of dollars. Assumption is 1.5% average GDP growth rate.

Source: See references on p. 21.

tion of an energy intensity ratio of 2.3 for 2050. This then entails that, in 2050, overall energy consumption in Michigan will be at 2,044 T-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 774 T-BTUs. This means that the net expansion of clean renewables by 2050 will need to be 1,270 T-BTUs. As we see in rows 4 – 7 of Table 3.11, achieving this higher level of productive capacity in clean renewables will require a level of investment averaging $11.4 billion per year.

In Table 3.12, we then summarize these results for achieving zero emissions in Michigan as of 2050. As we see, we estimate these overall costs to be $245.7 billion, which averages to $12.3 billion per year over 2031 – 2050. As a share of Michigan's projected midpoint GDP over 2031 – 2050, these annual cost figures would amount to 1.4 percent of GDP. As mentioned above, these figures are significantly below the cost level we have estimated for the initial 2026 – 2030 investment period that would be necessary to bring Michigan's CO_2 emissions down to 96 million tons by 2030. We estimated those costs to amount to about 4.2 percent of the state's average GDP between 2026 – 2030.

TABLE 3.11
Clean Renewable Energy Investments Needed to Reach Zero Emissions in Michigan by 2050

1) Total 2050 energy consumption at the 2.3 energy intensity ratio	2,281 T-BTUs
2) Total clean renewable supply required	2,044 T-BTUs
3) Clean renewable supply as of 2030	774 T-BTUs
4) Clean renewable energy expansion needed by 2050	1,270 T-BTUs
5) Cost per Q-BTU of expanding energy supply	$180 billion
6) Total cost of reaching 1.27 Q-BTU in renewable supply	$228.7 billion
7) Average annual costs of a 20-year investment cycle	$11.4 billion

Sources: See Table 2.8, Table 3.3, Table 3.10, and Appendix 2.

TABLE 3.12
Estimated Costs of Achieving Zero Emissions in Michigan by 2050

Total energy efficiency costs	$17 billion
Total renewable energy investment costs	$228.7 billion
Total clean energy investment costs	$245.7 billion
Average annual costs over 20-year investment cycle	$12.3 billion
Average annual costs as a percentage of mid-point GDP	1.4%

Sources: See Tables 3.9 – 3.11 and Appendix 2.

For the 2031 – 2050 investment phase under Scenario 1, as with the initial 2026 – 2030 phase, the investments in energy efficiency and renewable energy will be a major engine of job creation throughout Michigan's economy. We next turn to developing our estimate as to how this average investment level of $12.3 billion per year will generate about 75,000 jobs throughout the state. Moreover, this 75,000 job creation figure will be maintained over 2031 – 2050 as long as clean energy investment spending in the state is also maintained at an average of $12.3 billion per year.

Job Creation through 2031 – 2050 Clean Energy Investments

In Table 3.13, we show estimates of jobs that will be generated by an average annual clean energy investment level in Michigan of $12.3 billion, including $850 million per year in energy efficiency investments and $11.4 billion in clean renewable energy. The table shows the investment levels and shares of overall investment spending for each of the individual energy efficiency and renewable energy investments. The job creation figures are derived from the same employment/output ratios for each of the energy efficiency and renewable energy investment activities that we presented in Tables 3.4 and 3.6.

Based on these employment/output ratios, along with annual investment levels at $850 million in energy efficiency and $11.4 billion in renewable energy, we estimate that employment creation will amount to 54,486 jobs through the direct and indirect channels, equal to about 1.1 percent of Michigan's 2024 overall workforce. The total job creation rises to 74,643 jobs when we add the jobs generated by the induced channel, along with the direct and indirect channels. This total job creation level is equal to about 1.5 percent of Michigan's 2024 workforce.

Our job estimates reported in Table 3.13 assume that the employment/output ratios reported in Tables 3.4 and 3.6 remain constant over 2031 – 2050. It is more likely that improvements in labor productivity will result over this 20-year period. Thus, in Table 3.14, we provide revised job creation estimates based on the assumption that labor productivity improves by an average of 1 percent annually between 2031 – 2050. As we see, through this assumption of steady, if modest, annual labor productivity gains, our estimate of job creation falls from 54,486 to 44,564 through the direct and indirect channels and from 74,643 to 61,051 in total, including induced jobs. Under this assumption of improving labor productivity, total jobs generated through clean energy investments in Michigan between 2031 – 2050 would amount to about 1.2 percent of the state's 2024 labor force.

TABLE 3.13

Annual Job Creation in Michigan through Combined Clean Energy Investments

Average annual figures for 2031 – 2050

	Number of direct and indirect jobs created	Number of direct, indirect and induced jobs created
$850 million in energy efficiency investments All efficiency categories at $170 million; 20% of efficiency investments		
Building retrofits	1,209	1,590
Industrial efficiency with CHP	879	1,201
Grid upgrades	1,066	1,422
Public transportation	1,759	2,132
Expanding electric/ hybrid vehicles	637	885
Total energy efficiency job creation	*5,550*	*7,229*
$11.4 billion in clean renewables		
Solar *($5.5 billion; 60% of renewables)*	23,052	31,833
Utility scale ($1.8 billion; 20% of renewables)	7,684	10,611
Commercial scale ($1.8 billion; 20% of renewables)	7,684	10,611
Residential scale ($1.8 billion; 20% of renewables)	7,684	10,611
Onshore wind *($2.7 billion; 30% of renewables)*	11,251	15,641
Geothermal *($460 million; 5% of renewables)*	2,653	3,659
Low-emissions bioenergy *($460 million; 5% of renewables)*	2,378	3,156
Batteries *($2.3 billion; 20% of overall renewable investments)*	9,604	13,492
Total job creation from clean renewables	*48,937*	*67,414*
Total job creation – efficiency and clean renewables	**54,486**	**74,643**
Total job creation as a share of 2024 Michigan Labor Force *(Labor force at 5.1 million)*	**1.1%**	**1.5%**

Source: See Appendix 3.

TABLE 3.14
Job Creation through Michigan Clean Energy Investments, 2031 – 2050 under Alternative Labor Productivity Assumptions:

1. Constant labor productivity (=fixed employment/output ratios)
2. 1 percent annual labor productivity gains

	Job creation at constant labor productivity		Job creation with 1% annual labor productivity gains	
	Job creation level	Job creation as share of Michigan 2024 labor force	Job creation level	Job creation as share of Michigan 2024 labor force
Direct and indirect job creation	54,486	1.1%	44,564	0.9%
Total job creation, including induced jobs	74,643	1.5%	61,051	1.2%

Source: Table 3.13.

Scenario 2: Emissions Reductions and Job Creation, 2026 – 2035 and 2036 – 2050

In our Scenario 2, we introduce only one change in the overall framework relative to Scenario 1. That is, we assume that Michigan reaches its goal of lowering CO_2 emissions to 96 million tons—a 52 percent reduction relative to the state's 2005 emissions level—in 10 years, as of 2035, rather than in 5 years, as of 2030. Our estimates with Scenario 1 showed that achieving the 52 percent emissions reduction goal in 5 years, by 2030, would be highly challenging. It will require clean energy investments at $31 billion per year over the 2026 – 2030 period, equal to an average of 4.2 percent of Michigan's economy over these years. New job creation generated by this level of investment would amount to 3.6 percent of the state's workforce.

As we noted in the Introduction, Michigan has been a leader in clean energy investments since the passage of the state's clean energy investment law in 2023. According to a 2025 report by Climate Power (2025), clean energy investments in Michigan totaled to $27.8 billion between 2022 – 2025, which is the third largest figure among all U.S. states. But even this high investment level amounts to an average of $9.3 billion per year between 2022 – 2025. This is less than one-third of the roughly $31 billion per year that we estimate is necessary for the state to reach the 52 percent emissions reduction goal by 2030.

The Michigan economy does have the physical, human, and financial resources at hand to increase the state's annual clean energy investment level to about $31 billion a year between now and 2030—i.e. to devoting about 4.2 percent of the state's annual GDP over those 5 years to clean energy investments and mobilizing about 3.6 percent of the state's workforce through these investments. But it is clear that doing so would entail a major redirection of the state's economy within a short timeframe. As such, it is a useful exercise for us to consider a somewhat less challenging, but still ambitious, intermediate emissions reduction target of reaching the 52 percent emissions reduction target by 2035 rather than 2030.

Within this Scenario 2, we still work with the assumption that Michigan will become a zero emissions economy by 2050 as well as having reduced emissions to 96 million tons as of 2035. As such, the requirements for reducing emissions from 96 million tons to zero will be somewhat more ambitious than in Scenario 1, since going from 96 million tons of emissions to zero emissions will need to be achieved in 15 years, 2036 – 2050, rather than in the 20-year, 2031 – 2050, time frame under Scenario 1.

Otherwise, we maintain in Scenario 2 all of the key assumptions from Scenario 1. These include:

1. The average annual GDP growth rate remains at 1.5 percent per year for the full period, 2026 – 2050;
2. The average costs to achieve energy savings through energy efficiency investments remains at $15 billion per Q-BTU;
3. The average costs to expand clean renewable energy capacity remains at $200 billion per Q-BTU over Phase 1, 2026 – 2035 and $180 billion per Q-BTU over Phase 2, 2036 – 2050.
4. The employment/output ratios for all energy efficiency and clean renewable investments remain as we presented in Tables 3.4 and 3.6.

Based on this same set of assumptions, we then estimate the overall costs of meeting both the 2035 intermediate emissions reduction target of 96 million tons and reaching zero emissions by 2050. We present the full set of results under Scenario 2 in Appendix 4. We report here, in Table 3.15, the main summary findings under Scenario 2.

As Table 3.15 shows, under Scenario 2, we estimate that over Phase 1, between 2026 – 35, clean energy investments will need to reach an average of $14.2 billion per year, amounting to 1.9 percent of the state's average GDP between 2026 – 35. The job creation for this investment level—including direct, indirect, and induced jobs—will reach 86,782, equal to 1.7 percent of Michigan's 2024 labor force.

During Phase 2 of Scenario 2, for Michigan to reach zero emissions between 2036 – 2050, clean energy investments will need to be maintained at an average of $17.1 billion per year. This is, again, equal to 1.9 percent of Michigan's average GDP, now over 2036 – 50. The level of employment creation from these investments will amount to 102,776 jobs. This is equal to 2.0 percent of Michigan's 2024 labor force.

These employment estimates assume a constant level of labor productivity throughout the full 2026 – 2050 investment period (i.e. the employment/output ratios reported in Tables 3.4 and 3.6 remain constant). If we assume instead a 1 percent rate of productivity growth per year between 2035 – 2050 (similar to the calculations we present in Table 3.14 for the 2031 – 2050 period), our average overall employment estimate for this 15-year period would decline to about 89,000 jobs. This reduced level of average job creation would amount to about 1.7 percent of Michigan's 2024 workforce.

TABLE 3.15
Clean Energy Investments and Job Creation under Scenario Two

- **Phase 1**: 52% emissions reduction by 2035 relative to 2005
- **Phase 2**: Zero emissions by 2050

	Phase 1: 2026 – 35: *52% emissions reduction relative to 2005*	**Phase 2: 2036 – 2050** *Zero emissions*
Clean energy investments, annual averages *(in 2024 dollars)*	$14.2 billion	$17.1 billion
Annual clean energy investments as share of Michigan GDP	1.9%	1.9%
Job creation: direct, indirect, and induced jobs	86,782	102,776
Total job creation as share of Michigan 2024 labor force	1.7%	2.0%

Source: See Appendix 4.

In Table 3.16, we present a direct comparison between these Scenario 2 results with those from Scenario 1, in terms of both the investment share of GDP and the job creation share of Michigan's overall workforce.

The critical figures are those for the respective Phase 1 periods, i.e. 2026 – 2030 under Scenario 1 and 2026 – 35 under Scenario 2 (assuming constant labor productivity throughout the full investment period). As we see, the clean energy investment share falls from 4.2 percent of GDP in Scenario 1 to 1.9 percent of GDP in Scenario 2. This sharp decline in the Phase 1 investment requirement results, of course, from Phase 1 being 10 years under Scenario 2 versus five years in Scenario 1. Correspondingly, the labor demand increase falls from 3.6 percent of Michigan's workforce under the 5-year Scenario 1 to 1.7 percent under the 10 years under Scenario 2.

The Scenario 2 average investment level of $14.2 billion over Phase 1, 2026 – 35, is still more than 50 percent larger than the state's $9.3 billion clean energy investment level between 2022 – 25. Nevertheless, it clearly will be less difficult for Michigan to raise its annual investment level by $4.9 billion, from $9.3 billion to $14.2 billion, than to increase it by nearly $22 billion under Scenario 1, to $31 billion per year between 2026 – 2030.

The differences between the two scenarios are reduced significantly in comparing the respective Phase 2 results, given that the time spans for Phase 2 are less compressed, i.e. 20 years, 2031 – 50, under Scenario 1 and 15 years, 2036 – 50, under Scenario 2. With both scenarios, the clean energy investment share of GDP and the job creation share of the labor force are all within the range of about 1.5 – 2 percent of Michigan's economy.

TABLE 3.16

Comparing Scenarios 1 and 2: Clean Energy Investments and Job Creation

- **Scenario 1**: Phase 1 = 2026 – 30; Phase 2 = 2031 – 2050
- **Scenario 2**: Phase 1 = 2026 – 2035; Phase 2 = 2036 – 2050

	Scenario 1	**Scenario 2**
Clean energy investments as pct. of midpoint Michigan GDP		
Phase 1	4.2%	1.9%
Phase 2	1.4%	1.9%
Total job creation as pct. of 2024 Michigan labor force *(figures assume constant labor productivity)*		
Phase 1	3.6%	1.7%
Phase 2	1.5%	2.0%

Source: See Tables 3.3, 3.8, 3.12, 3.14-3.15, and Appendices 3 and 4.

4. Job Quality Measures and Worker Characteristics in Michigan's Clean Energy Labor Force

We report in this section on the quality of the jobs that will be generated by Michigan's clean energy investment program as well as the characteristics of the workers currently employed in these jobs.

We first present these results in Table 4.1 through aggregating the figures for all five of our clean renewable investment areas and the five energy efficiency areas. We focus here on the direct jobs generated by all of these investment categories. We then compare these aggregated direct job figures in terms of job quality and worker characteristics with those for the overall Michigan workforce.

As we saw in Section 3, for the 2026 – 2030 period—i.e. Scenario 1/Phase 1—we estimate that the full $30.8 billion per year in overall clean energy investments over 2026 – 2030 generates 99,521 direct jobs per year. Of this total, 93 percent are in the clean renewable sectors, with the other 7 percent in the energy efficiency sectors. These proportions roughly coincide with the relative spending shares that we have allocated to the respective renewable and energy efficiency categories.

In Tables 4.2 – 4.4, we then show disaggregated figures for job quality and workers characteristics for each of the five renewable energy and five energy efficiency investment areas.

Aggregate Clean Energy Job Features

Job Quality. Within the current Michigan labor market, the job quality features in the 10 clean energy investment categories are consistently higher than those for the overall Michigan workforce. Thus, we see in Panel A of Table 4.1 that the average hourly wage for the clean energy jobs, at $39.07, is about 6 percent higher than the $36.70 figure for the overall Michigan workforce. The state's clean energy jobs at present also include higher ranges of health insurance coverage (55.1 percent versus 50.7 percent), retirement plans (43.9% versus 39.9 percent), and union coverage (16.0 percent versus 14.5 percent).

Educational Credentials. The overall higher job quality indicators for Michigan's clean energy sectors is especially notable given the educational credentials of Michigan's clean energy workforce relative to the overall workforce. As we see in Panel B of Table 4.1, the educational attainment levels for the clean energy workforce is significantly lower than that for the overall state workforce. In particular, with the clean energy workforce, about 36 percent of workers have high school degrees as their formal educational attainment level and 26 percent have BA degrees or higher.

TABLE 4.1
Job Quality Indicators and Worker Characteristics: Michigan Clean Energy Industries vs. Overall State Workforce

Clean Energy Employment Figures Include ***Direct Jobs Only***
99,521 direct jobs in 2030 scenario *(Scenario 1/Phase 1)*

A) Indicators of Job Quality

	Mean hourly wage	Health Insurance coverage, %	Retirement plans, %	Union coverage, %
Clean Energy Workforce	$39.07	55.1%	43.9%	16.0%
Total Michigan employed workforce	$36.70	50.7%	39.9%	14.5%

B) Educational Credentials

	Less than a high school degree	High school degree or equivalent	Some postsecondary education but no degree	Associates degree	BA degree or higher
Clean Energy Workforce	6.8%	35.7%	18.8%	12.3%	26.4%
Total Michigan employed workforce	6.1%	26.8%	17.9%	11.8%	37.4%

C) Gender and Racial Composition

	Gender composition	Racial composition						
			BIPOC, including Latinx					
	Women	White, non-Latinx	All BIPOC, including Latinx	Black, non-Latinx	Asian, non-Latinx	American Indian, Aleut/Eskimo, non-Latinx	Other non-Latinx	Latinx
Clean Energy Workforce	27.0%	77.7%	22.3%	8.5%	3.2%	0.3%	3.8%	6.5%
Total Michigan employed workforce	47.9%	74.2%	25.8%	11.6%	3.8%	0.3%	4.3%	5.9%

Source: See Appendix 5.

With the overall workforce, these proportions are basically reversed—27 percent of the overall workforce have high school degrees and 37 percent have BA degrees or higher.

Considering these results on job quality and educational credentials together, we can conclude that the clean energy investments in Michigan provide relatively high-quality jobs especially for workers who do not have high educational credentials.

Gender and Racial Composition. What emerges in Panel C of Table 4.1 is that the jobs generated by clean energy investments, relative to those in Michigan's overall economy, are held to a large disproportionate extent by White male workers. This disparity is primarily in comparing male versus female job holders. As we see, only 27 percent of the jobs in Michigan's clean energy sectors are held by women, as opposed to 48 percent in Michigan's overall workforce.

The disparities are more modest in comparing the relative workforce composition by race. About 78 percent of the clean energy workforce is White, while for the overall Michigan workforce, the share of White workers is 74 percent. Correspondingly, the share of Black workers is modestly lower in the clean energy workforce, at 8.5 percent, versus 11.6 percent for the overall Michigan workforce. The differences are similar as regards the relative shares of Asians and Latinx workers in the clean energy sectors versus the overall workforce.

Overall then, we see that, in the current Michigan economy, the state's clean energy sectors provide higher quality jobs and are much more open to workers without college degrees. At the same time, these benefits associated with clean energy jobs in Michigan are much more available to White men than to women or people of color.

Clearly, one important goal in advancing the *MI Healthy Climate Plan* will be to maintain, and continue strengthening, the clean energy sector's relatively high job quality standards and to continue offering these good job opportunities to people with less than college degrees. At the same time, policymakers should focus on increasing opportunities for women and people of color as the state's clean energy investment program undergoes a large-scale expansion.

Sector-by-Sector Figures on Job Quality and Worker Characteristics

We report now the job quality and worker characteristics broken out according to our five energy efficiency investment areas—i.e. public transit, building retrofits, grid upgrades, industrial efficiency, and electric/hybrid vehicle promotion—as well as our five clean renewable investment areas—solar, onshore wind, geothermal, low-emissions bioenergy, and battery storage.

Job Quality. As Table 4.2 shows, with all four of the job quality measures—hourly wages, health insurance coverage, retirement plan coverage, and unionization rates—there are significant, though not extremely large differences among the state's various clean energy sectors.

Thus, with hourly wages, the range among the five energy efficiency sectors is between $30.40 for public transit workers and $44.40 in the industrial efficiency sector. With the exception of the industrial efficiency sector, average wages are somewhat higher in the five renewable energy sectors, ranging between $34.50 in low-emissions bioenergy jobs and $41.95 in the battery storage sector.

TABLE 4.2
Indicators of Job Quality in Michigan Clean Energy Industries: **Direct Jobs Only**

	Mean hourly wage	Health insurance coverage, %	Retirement plans, %	Union coverage, %
Energy efficiency investments				
Public transit *(2,602 jobs in 2030; 2,082 jobs in 2035)*	$30.40	42.0%	40.7%	21.2%
Building retrofits *(1,670 jobs in 2030; 1,336 jobs in 2035)*	$32.55	44.5%	33.6%	16.3%
Grid upgrades *(1,541 jobs in 2030; 1,233 jobs in 2035)*	$36.70	57.5%	47.0%	18.5%
Industrial Efficiency with CHP *(1,150 jobs in 2030; 920 jobs in 2035)*	$44.40	57.3%	45.1%	10.0%
Electric and hybrid vehicles *(725 jobs in 2030; 580 jobs in 2035)*	$38.25	51.2%	40.5%	11.9%
Clean renewables investments				
Solar *(48,958 jobs in 2030; 21,781 jobs in 2035)*	$38.53	55.6%	43.9%	15.1%
Onshore wind *(25,385 jobs in 2030; 11,294 jobs in 2035)*	$41.05	58.0%	47.0%	19.9%
Geothermal *(4,796 jobs in 2030; 2,134 jobs in 2035)*	$39.65	57.0%	43.5%	14.3%
Low-emissions bioenergy *(4,211 jobs in 2030; 1,874 jobs in 2035)*	$34.50	47.5%	37.8%	14.8%
Battery storage *(8,481 jobs in 2030; 3,773 jobs in 2035)*	$41.95	51.4%	40.9%	9.6%
Total Michigan employed workforce	$36.70	50.7%	39.9%	14.5%

Sources: See Appendix 5.

With employer health insurance coverage, among the energy efficiency sectors, the lowest coverage rate is 42.0 percent for public transit workers while about 57 percent of workers in the grid upgrade and industrial efficiency sectors are provided health insurance by their employers. With the renewable energy sectors, again, the coverage rate is somewhat better, with the lowest coverage rate at 47.5 percent in bioenergy, and the highest rates, for geothermal and wind, at 57 – 58 percent, comparable to the highest rates in the efficiency sectors. Finally, in terms of union coverage, the range among the energy efficiency sectors is between 10.0 percent for workers employed in the industrial efficiency sector and 21.2 percent for public transit workers. With the renewable energy sectors, the range is between 9.6 percent union coverage for workers in battery storage and 19.9 percent for workers in the onshore wind sector.

Overall, these disaggregated figures enable us to observe at sector-specific levels how job quality standards in Michigan's clean energy sectors are higher than those for the state's overall workforce. These higher job quality standards are prevalent across most of Michigan's clean energy sectors. In particular, the state's solar and wind sectors, which will experience the largest shares of the state's new clean energy investments, are among the clean energy sectors that operate with relatively high job quality standards.

Educational Credentials. The important figure that we noted above with the aggregated data on educational credentials—that, overall, the workers in Michigan's clean energy sectors have lower average formal educational credentials but better average pay and benefits than the average for the overall Michigan workforce—also holds consistently among our 10 separate clean energy sectors, as Table 4.3 shows.

Thus, as we saw in Table 4.1, 27 percent of Michigan's overall workforce hold high school degrees as their highest formal educational level, while 37 percent of Michigan's clean energy workforce have high school degrees as their formal educational level. In terms of Michigan's individual clean energy sectors, industrial efficiency is the only one with a share of workers with high school degrees as low as that for Michigan's overall workforce. With the other 9 clean energy sectors, the shares of workers with high school degrees as their highest formal educational level range between 31 percent in the geothermal sector to 44 percent in public transportation.

The share of workers with BA degrees or higher in Michigan's clean energy sectors follows a similar pattern. Only 2 of the individual clean energy sectors, industrial efficiency and geothermal, have shares with BA degrees or higher that are comparable to the overall Michigan workforce, at 37 and 39 percent respectively. With the other 8 clean energy sectors, the shares with BA degrees or higher ranges between 18 percent in the electric vehicle sector to 28 percent in solar. It is especially notable that Michigan's wind energy sector, with 24 percent holding BA degrees or higher, along with solar, both operate with lower shares of workers holding college degrees than for Michigan's overall workforce, since solar and wind are, by a significant amount, the two primary areas for expanding clean energy investments.

TABLE 4.3
Educational Credentials of Michigan Clean Energy Industries: **Direct Jobs Only**

	Less than a high school degree	High school degree or equivalent	Some post-secondary education but no degree	Associates degree	BA degree or higher
Energy efficiency investments					
Public transit *(2,602 jobs in 2030; 2,082 jobs in 2035)*	5.3%	44.1%	17.4%	11.5%	21.7%
Building retrofits *(1,670 jobs in 2030; 1,336 jobs in 2035)*	9.8%	36.9%	18.0%	9.8%	25.5%
Grid Upgrades *(1,541 jobs in 2030; 1,233 jobs in 2035)*	6.4%	36.9%	20.1%	14.3%	22.2%
Industrial Efficiency with CHP *(1,150 jobs in 2030; 920 jobs in 2035)*	4.9%	27.1%	17.8%	11.4%	38.7%
Electric and hybrid vehicles *(725 jobs in 2030; 580 jobs in 2035)*	7.5%	41.7%	20.9%	11.9%	18.0%
Clean renewables investments					
Solar *(48,958 jobs in 2030; 21,781 jobs in 2035)*	6.7%	34.4%	18.9%	12.1%	27.9%
Onshore wind *(25,385 jobs in 2030; 11,294 jobs in 2035)*	6.2%	37.0%	18.5%	13.8%	24.4%
Geothermal *(4,796 jobs in 2030; 2,134 jobs in 2035)*	6.0%	30.9%	15.7%	10.3%	37.1%
Low-emissions bioenergy *(4,211 jobs in 2030; 1,874 jobs in 2035)*	11.6%	37.0%	19.1%	9.9%	22.5%
Battery storage *(8,481 jobs in 2030; 3,773 jobs in 2035)*	7.3%	38.6%	20.9%	11.8%	21.4%
Total Michigan workforce	6.1%	26.8%	17.9%	11.8%	37.4%

Sources: See Appendix 5.

Gender and Racial Composition. The gender and racial composition of Michigan's 10 individual clean energy sectors reflect the pattern with the aggregated figures that we described above. Thus, as we see in Tables 4.4A and 4.4B, the share of women employed in each of Michigan's 10 clean energy sectors is substantially lower than for Michigan's overall workforce. While nearly half of Michigan's overall workforce are women, with the state's 10 clean energy sectors, the female share ranges between a low of 21 percent in building retrofits storage to 37 percent with public transportation and industrial efficiency. For solar and wind, the largest clean energy sectors, the female employment shares are 28 and 23 percent respectively.

In terms of the racial composition of Michigan's clean energy workforce, the patterns among the 10 clean energy sectors are all similar to Michigan's overall workforce. That is, there are no clean energy sectors in Michigan in which the racial composition of the workforce differs significantly from what we reported with the aggregate figures. One notable pattern that becomes apparent in these disaggregated figures, however, is that people of color, particularly Black people, are over-represented in the lowest-paying public transit jobs.

TABLE 4.4A

Gender and Racial Composition of Michigan Clean Energy Industries: **Direct Jobs Only**

	Gender composition	Racial composition						
			BIPOC, including Latinx					
	Women	White, non-Latinx	All BIPOC, including Latinx	Black, non-Latinx	Asian, non-Latinx	American Indian, Aleut/Eskimo, non-Latinx	Other non-Latinx	Latinx
A. Energy efficiency jobs								
Public transit *(2,602 jobs in 2030; 2,082 jobs in 2035)*	36.5%	70.2%	29.8%	16.9%	1.6%	0.6%	2.9%	7.9%
Building retrofits *(1,670 jobs in 2030; 1,336 jobs in 2035)*	21.2%	79.6%	20.4%	6.3%	1.6%	0.7%	3.7%	8.1%
Grid Upgrades *(1,541 jobs in 2030; 1,233 jobs in 2035)*	25.2%	78.7%	21.3%	8.3%	2.5%	0.3%	3.8%	6.5%
Industrial Efficiency with CHP *(1,150 jobs in 2030; 920 jobs in 2035)*	37.2%	76.2%	23.8%	9.6%	4.1%	0.3%	4.2%	5.6%
Electric and hybrid vehicles *(725 jobs in 2030; 580 jobs in 2035)*	31.0%	76.9%	23.1%	11.2%	2.1%	0.2%	3.6%	5.9%
Total Michigan workforce	47.9%	74.2%	25.8%	11.6%	3.8%	0.3%	4.3%	5.9%

TABLE 4.4B
Gender and Racial Composition **of Michigan Clean Energy Industries: Direct Jobs Only**

	Gender composition	Racial composition						
	Women	White, non-Latinx	BIPOC, including Latinx					
			All BIPOC, including Latinx	Black, non-Latinx	Asian, non-Latinx	American Indian, Aleut/Eskimo, non-Latinx	Other non-Latinx	Latinx
B. Clean renewables jobs								
Solar *(48,958 jobs in 2030; 21,781 jobs in 2035)*	27.5%	77.2%	22.8%	8.5%	3.7%	0.3%	3.9%	6.4%
Onshore wind *(25,385 jobs in 2030; 11,294 jobs in 2035)*	22.8%	79.7%	20.3%	7.5%	2.7%	0.3%	3.5%	6.2%
Geothermal *(4,796 jobs in 2030; 2,134 jobs in 2035)*	26.7%	78.2%	21.8%	7.1%	3.8%	0.6%	3.8%	6.4%
Low-emissions bioenergy *(4,211 jobs in 2030; 1,874 jobs in 2035)*	30.1%	75.5%	24.5%	8.8%	2.5%	0.5%	4.0%	8.7%
Battery storage *(8,481 jobs in 2030; 3,773 jobs in 2035)*	31.9%	77.5%	22.5%	9.9%	2.8%	0.2%	3.8%	5.9%
Total Michigan workforce	47.9%	74.2%	25.8%	11.6%	3.8%	0.3%	4.3%	5.9%

Sources: See Appendix 5.

Prevalent Job Types with Clean Energy Investments

To provide a more concrete picture of the jobs that will be created in Michigan through investments in energy efficiency and clean renewable energy, in Tables 4.5 – 4.6, we report on the prevalent job types generated by investments in solar and onshore wind energy, the two major clean energy investment areas. In Table 4.7, we also show prevalent job types for public transportation investments in Michigan. With all three tables, we report on the employment categories which account for at least 5 percent of total job creation in the three respective sectors.

As we see in Tables 4.5 and 4.6, with both solar and wind energy investments, a large share of the jobs generated will be in the categories of construction and installation/maintenance. With solar, the construction employment share is roughly 17 percent, while installation/maintenance amounts to another 13 percent. The two categories thus represent about 30 percent of overall employment. These shares are even higher with the onshore wind sector, with installation/maintenance at 23 percent and

TABLE 4.5
Residential, Commercial and Utility Solar: Prevalent Job Types in Michigan Industry
(Job categories with 5 percent or more employment)

Job category	Percentage of direct jobs	Representative occupations
Construction	16.7%	Construction laborers; first-line supervisors of construction trades workers; carpenters
Sales	13.9%	Retail salespersons; parts salespersons; first-line supervisors of retail sales workers
Installation and maintenance	12.9%	Automotive service technicians and mechanics; electrical power-line installers and repairers; first-line supervisors of mechanics, installers, and repairers
Manufacturing	11.8%	Electrical, electronic, and electromechanical assemblers, except coil winders, tapers, and finishers; miscellaneous assemblers and fabricators; inspectors, testers, sorters, samplers, and weighers
Management	9.8%	General and operations managers; construction managers; sales managers
Office and administrative support	8.6%	General office clerks; bookkeeping, accounting, and auditing clerks; customer service representatives
Transportation and material moving	7.0%	Light truck drivers; hand laborers and freight, stock, and material movers; heavy and tractor-trailer truck drivers
Business operation specialists	6.8%	Project management specialists; accountants and auditors; cost estimators
Architecture and engineering	6.2%	Industrial engineers, electrical and electronic engineering technologists and technicians, electrical engineers

Source: See Appendix 5.

construction at 19 percent, so that the two categories combined total to 42 percent of wind energy direct employment.

Manufacturing workers also represent a large share of employment with both solar and wind investments, at 12 percent with solar and 10 percent with wind, including such occupations as assemblers, fabricators and machinists.

In addition to these categories of construction and manufacturing employment, with both solar and wind, large shares of employment are in sales. This is because the economic activity fueled by clean energy investments increases the trade of goods and services, generating more jobs in occupations such as retail and parts salespersons. Combined with office support, management and business operation specialists, these four categories account for roughly 40 percent of employment in the solar sector and 31 percent in wind.

In short, through investments in both the solar and wind sectors, extensive job opportunities will be created for workers in construction and manufacturing, along with some standard categories of sales and business management activities.

TABLE 4.6
Onshore Wind: Prevalent Job Types in Michigan Industry
(Job categories with 5 percent or more employment)

Job category	Percentage of direct jobs	Representative occupations
Installation and maintenance	22.5%	Electrical power-line installers and repairers; automotive service technicians and mechanics; first-line supervisors of mechanics, installers, and repairers
Construction	18.9%	Construction laborers, first-line supervisors of construction trades workers; operating engineers and other construction equipment operators
Manufacturing	9.9%	Miscellaneous assemblers and fabricators; engine and other machine assemblers; machinists
Sales	9.4%	Retail salespersons; parts salespersons; first-line supervisors of retail sales workers
Management	8.4%	General and operations managers; construction managers; sales managers
Office and administrative support	7.8%	General office clerks; bookkeeping, accounting, and auditing clerks; secretaries and administrative assistants
Transportation and material moving	6.3%	Light truck drivers; hand laborers and freight, stock, and material movers; cleaners of vehicles and equipment
Business operation specialists	5.7%	Project management specialists; accountants and auditors; buyers and purchasing agents
Architecture and engineering	5.1%	Industrial engineers; mechanical engineers; electrical engineers

Source: See Appendix 5.

With the public transportation sector, as Table 4.7 shows, nearly half of all employees in Michigan are in occupations directly involved in providing transportation, such as bus or shuttle drivers or supervisors of these drivers. Another 15 percent are in construction, engaged in maintaining and expanding the state's public transportation infrastructure. Seven percent are in manufacturing jobs to produce the equipment needed for maintaining and expanding the state's transportation infrastructure. Other than these job categories, the only occupations employing more than 5 percent of Michigan's transportation sector workforce are those in management and office support.

Overall then, these figures on prevalent job categories in solar, wind and public transportation show with greater specificity where clean energy investments create a large share of job opportunities for workers in construction, manufacturing and transportation services. For the most part, these are employment areas that do not require workers to have BA degrees.

TABLE 4.7
Public Transportation: Prevalent Job Types in Michigan Industry

(Job categories with 5 percent or more employment)

Job category	Percentage of direct jobs	Representative occupations
Transportation and material moving	46.2%	Transit and intercity bus drivers; shuttle drivers; first-line supervisors of transportation and material moving workers
Construction	15.1%	Carpenters; construction laborers; first-line supervisors of construction trades workers
Office and administrative support	8.5%	Dispatchers; general office clerks; customer service representatives
Manufacturing	7.0%	Miscellaneous assemblers and fabricators; welders, cutters, solderers, and brazers; first-line supervisors of production and operating workers
Management	6.4%	Construction managers; general and operations managers; transportation, storage, and distribution managers

Source: See Appendix 5.

5. Labor Demand, Labor Supply and Potential Labor Shortages

In this section, we estimate the extent to which there are likely to be large enough pools of workers who are qualified and available to move into the jobs that will be generated through Michigan's clean energy investment program. In addressing this question, we are especially focused on identifying employment areas in which labor supply shortages could emerge as investments in Michigan in energy efficiency and clean renewable energy reach their full targeted levels.

Through identifying areas where such shortages are more likely to emerge, this section of the study can then help provide a framework to advance policies that can expand the available labor supply in the relevant occupations to meet the growing demand. The most important policy measures will be in the areas of apprenticeships, job training, job placement, and related programs. Depending on the specific occupation, these include certificate programs provided by community colleges, unions or industry-based organizations; occupation-related Associates degrees along with internships or other types of hands-on training programs run by community colleges; and 4-year college degree programs.[25]

We focus our analysis here within the 2026 – 2030 Scenario 1/Phase 1 time period. As we have seen, summarized in Table 3.8, the increase in jobs resulting from clean energy investments during 2026 – 2030, at 3.6 percent of Michigan's 2024 labor force, will be more than twice as large as during the 2026 – 35 Scenario 2/Phase 1 period, during which we estimate the labor demand increase at 1.5 percent of the state's 2024 labor force. The difference in the respective levels of labor demand between the two scenarios results, again, because Michigan would be attempting to cut CO_2 emissions by 52 percent relative to 2005 within 5 years in Scenario 1 versus 10 years in Scenario 2. Moreover, during Phase 2, as Michigan advances towards its net zero emissions target either between 2031 – 50 under Scenario 1 or between 2036 – 50 under Scenario 2, we estimate the expansion in labor demand as ranging between 1.7 and 2.0 percent of the state's 2024 labor force (assuming constant labor productivity levels). As such, whatever labor shortages that may emerge over 2026 – 30, during Scenario 1/Phase 1, are not likely to continue either during Phase 2 of Scenario 1, between 2031 – 50, or over Scenario 2 at all, during either 2026 – 35 or 2036 – 50.

Central Findings on Potential Labor Shortages over 2026 – 2030

The central finding of this section is that there are 19 occupations in which we estimate labor shortages could result as clean energy investments in Michigan expand with the aim of achieving its 2030 emissions reduction goal. We further divide these 19 occupations according to whether, by our definition, these labor shortages would be "modest" or "significant." By our definition, the occupations with "modest" shortages would be those in which there would likely be shortages relative to the available pool of workers in Michigan alone for a given occupation. Fifteen occupations fall into this "modest" shortage category by our estimates. The four remaining occupations in which we identify "significant" shortages resulting are those in which, by our estimates, shortages would likely emerge even after broadening the potential available pool of workers to include those throughout all Midwestern states.[26]

We show in what follows how we derive these main results. As for the results themselves, we find that the primary employment areas that are likely to face significant shortages are for *workers installing electrical power and telecommunications lines, along with the supervisors of these front-line installers.*

Focus on Shortages through Direct Job Creation Channel

In Table 5.1, we show the breakdown of total average annual job creation through the three respective channels—direct, indirect, and induced job creation. The figures in Table 5.1 combine the jobs generated by the full set of energy efficiency and clean energy investments presented in Section 3. As we see, of the roughly 185,000 total jobs generated through all three channels by all of the investment projects, about 100,000 (54 percent) are direct jobs, 35,000 (19 percent) are indirect jobs, and 50,000 (27 percent) are induced jobs.

For the purpose of estimating potential labor supply shortages, we concentrate on the 100,000 jobs generated through the direct jobs channel. As we noted above, concentrating on direct jobs enables us to focus on the labor issues, in this case labor supply issues, resulting specifically from the Michigan clean energy investment project, as opposed to assessing labor supply challenges more generally within the Michigan labor market. Of course, our estimate that labor demand will increase by about

TABLE 5.1
Categories of Overall Job Creation through 2026 – 2030 Clean Energy Investment Program

Overall 2026 – 2030 Clean Energy Investments = $30.8 billion/year

	Energy efficiency	Renewable energy	Total
Direct jobs	7,689	91,832	99,521
Indirect jobs	2,130	33,223	35,353
Induced jobs	2,972	46,998	49,970
Total job creation	12,791	172,054	184,845

Sources: See Tables 3.5 and 3.7.

85,000 jobs in Michigan through the indirect and induced job creation channels can also generate broader impacts within Michigan's labor market. However, the labor supply issues in Michigan generated by these indirect and induced jobs channels are beyond the scope of this study.

Occupations with Largest Labor Demand Increases from State-Level Clean Energy Investments

In Tables 5.2 and 5.3, we list the set of 30 individual occupations that, by our estimates, will experience the largest increases in labor demand generated by the clean energy investments in Michigan resulting from the state's project to achieve its 2030 emissions reduction target. Table 5.2 includes the occupations that will experience the largest labor demand increases measured in terms of *absolute number of new job openings* due to these clean energy investments. Table 5.3 then lists the occupations that will experience the largest *percentage increases* in labor demand generated by the clean energy investments.

As we see in Table 5.2, the five occupations with the largest *absolute increases* in labor demand will be for retail salespersons, construction laborers, auto service technicians, first-line construction supervisors and electric power-line installers and repairers. Overall, the total direct job creation within the 30 occupations listed in Table 5.2 amounts to 58,810. This is equal to 59 percent of the overall increase of 99,521 direct jobs generated by 2030 clean energy investment scenario (i.e. Scenario 1/Phase 1).

Table 5.3 lists the occupations that we estimate will experience the largest *percentage increase* in labor demand from Michigan's 2030 clean energy investment scenario. This table provides an important complement to the occupations that will experience the largest *absolute* demand increases. This is because the occupations with high percentage increases in labor demand could create labor market bottlenecks even if the total number of workers that need to be newly hired into these occupations is relatively small.

For example, we estimate that the largest percentage increase in labor demand due to the 2030 clean energy investment scenario will be for semiconductor processing technicians. We estimate that the increase in labor demand for these technicians will be a relatively small absolute number, at 440 workers in total. But this increase in labor demand nevertheless represents an expansion of 50 percent relative to the 2024 employment level for this occupation. Thus, it will be critical to recognize the needs for expanding labor supply in occupations in which the supply needs are high in percentage terms, even if relatively low in absolute numbers.

Considering now the occupations listed in both Tables 5.2 and 5.3, there is a total of 54 occupations in which the increase in the absolute level or the percentage increase in labor demand is among the largest 30 among all occupations. In Table 5.4, we list these 54 occupations. 6 of these occupations are included in both Tables 5.2 and 5.3, meaning that the labor demand increases in these occupations generated by the 2026 – 2030 clean energy investment (Scenario 1/Phase 1) will be high both

TABLE 5.2
Absolute Level Labor Demand Increases

30 Occupations with Largest Absolute Amount of Labor Demand Increases due to Scenario 1/Phase 1 Investment Activities

Occupation title	Number of annual direct Jobs	Annual direct jobs as % of 2024 employment*
Retail salespersons	6,000	3.4%
Construction laborers	5,350	10.4%
Automotive service technicians and mechanics	3,540	8.4%
First-line supervisors of construction trades and extraction workers	3,530	9.6%
Electrical power-line installers and repairers	3,110	49.0%
General and operations managers	2,950	2.0%
Carpenters	2,470	4.6%
Parts salespersons	2,440	14.6%
Construction managers	2,140	9.6%
Project management specialists	2,060	5.0%
First-line supervisors of mechanics, installers, and repairers	1,930	8.1%
Electrical, electronic, and electromechanical assemblers	1,890	15.8%
Operating engineers and other construction equipment operators	1,810	12.9%
General office clerks	1,780	1.8%
Miscellaneous assemblers and fabricators	1,550	1.2%
First-line supervisors of retail sales workers	1,410	3.0%
Light truck drivers	1,370	3.6%
Telecommunications line installers and repairers	1,250	35.8%
Bookkeeping, accounting, and auditing clerks	1,230	1.8%
Electricians	1,170	7.8%
Customer service representatives	1,130	1.2%
Hand laborers and freight, stock, and material movers	1,120	1.1%
Wholesale and manufacturing sales representatives	1,070	2.0%
Secretaries and administrative assistants	1,020	1.4%
Cleaners of vehicles and equipment	950	5.3%
Stockers and order fillers	950	1.4%
Heavy and tractor-trailer truck drivers	930	1.2%
Software developers	920	1.6%
Inspectors, testers, sorters, samplers, and weighers	880	2.6%
Accountants and auditors	860	1.5%
All top 30 occupations	58,810	
Across all occupations	99,521	2.1% of 4.8 million Michigan workers*

Notes: See Appendix 6 for details. *4.8 million is the number of employed workers in Michigan in 2024 (U.S. Bureau of Labor Statistics, 2024a). Level numbers are rounded to nearest ten; percentages are rounded to nearest one-tenth percent. Some BLS occupational titles have been modified to simplify presentation.

TABLE 5.3
Percentage Labor Demand Increases

30 Occupations with Largest Percentage Increases in Labor Demand Increases due to Scenario 1/Phase 1 Investment Activities

Occupation title	Number of annual direct jobs	Annual direct jobs as % of 2024 employment*
Semiconductor processing technicians	440	50.0%
Electrical power-line installers and repairers	3,110	49.0%
Telecommunications line installers and repairers	1,250	35.8%
Wind turbine service technicians	140	35.5%
Derrick operators	30	31.7%
Earth drillers	110	27.6%
Radio, cellular, and tower equipment installers and repairers	120	25.9%
Roustabouts	90	24.1%
Rotary drill operators	20	21.4%
Oil and gas service unit operators	90	20.3%
Solar photovoltaic installers	110	19.9%
Structural iron and steel workers	310	19.3%
Boilermakers	50	16.8%
Electrical, electronic, and electromechanical assemblers	1,890	15.8%
Parts salespersons	2,440	14.6%
Electrical and electronics repairers, powerhouse, substation, and relay	170	13.4%
Recreational vehicle service technicians	140	13.0%
Operating engineers and other construction equipment operators	1,810	12.9%
Tire repairers and changers	820	12.9%
Extraction worker helpers	10	12.2%
Tapers	20	12.1%
Coil winders, tapers, and finishers	60	11.9%
Reinforcing iron and rebar workers	40	11.8%
Small engine mechanics	140	11.6%
Computer hardware engineers	370	10.9%
Wellhead pumpers	20	10.7%
Electrician helpers	80	10.5%
Construction laborers	5,350	10.4%
Pile driver operators	10	10.2%
Electrical and electronic engineering technologists and technicians	430	10.0%
All top 30 occupations	19,670	100.0%
Across all occupations	99,521	2.1% of 4.8 million Michigan workers*

Notes: See Appendix 6 for details. *4.8 million is the number of employed workers in Michigan in 2024 (U.S. Bureau of Labor Statistics, 2024a). Level numbers are rounded to nearest ten; percentages are rounded to nearest one-tenth percent. Some BLS occupational titles have been modified to simplify presentation.

in absolute numbers and in percentage terms. Among these occupations are electrical powerline installers and repairers, in which the labor demand increase of 3,110 workers represents 49 percent of the 2024 workforce in this occupation. Another case in which both the absolute and percentage increase in labor demand will be high is telecommunications line installers. These workers install and repair the telecommunication cables and networking equipment needed to provide buildings and utilities structures with, for example, ethernet and internet services.[27] Similar to electrical powerline installers and repairers, the telecommunications line installers are prevalent in the activities related to building out utility solar and onshore wind capacity. Here we estimate that labor demand will increase by 1,250 jobs, equal to about 36 percent of Michigan's total workforce in this occupation as of 2024.

TABLE 5.4

Absolute Level or Percentage Labor Demand Increases

54 Occupations with Either Largest Absolute Amount or Percentage Increases in Labor Demand due to Scenario 1/ Phase 1 Investment Activities

Occupation title	Number of annual direct jobs	Annual direct jobs as % of 2024 employment	Annual direct jobs as % of total direct jobs
Retail salespersons	6,000	3.4%	6.0%
Construction laborers	5,350	10.4%	5.4%
Automotive service technicians and mechanics	3,540	8.4%	3.6%
First-line supervisors of construction trades and extraction workers	3,530	9.6%	3.6%
Electrical power-line installers and repairers	3,110	49.0%	3.1%
General and operations managers	2,950	2.0%	3.0%
Carpenters	2,470	4.6%	2.5%
Parts salespersons	2,440	14.6%	2.5%
Construction managers	2,140	9.6%	2.2%
Project management specialists	2,060	5.0%	2.1%
First-line supervisors of mechanics, installers, and repairers	1,930	8.1%	1.9%
Electrical, electronic, and electromechanical assemblers	1,890	15.8%	1.9%
Operating engineers and other construction equipment operators	1,810	12.9%	1.8%
General office clerks	1,780	1.8%	1.8%
Miscellaneous assemblers and fabricators	1,550	1.2%	1.6%
First-line supervisors of retail sales workers	1,410	3.0%	1.4%
Light truck drivers	1,370	3.6%	1.4%
Telecommunications line installers and repairers	1,250	35.8%	1.3%
Bookkeeping, accounting, and auditing clerks	1,230	1.8%	1.2%
Electricians	1,170	7.8%	1.2%
Customer service representatives	1,130	1.2%	1.1%
Hand laborers and freight, stock, and material movers	1,120	1.1%	1.1%
Wholesale and manufacturing sales representatives	1,070	2.0%	1.1%

continued on next page

TABLE 5.4 *continued*

Absolute Level or Percentage Labor Demand Increases

54 Occupations with Either Largest Absolute Amount or Percentage Increases in Labor Demand due to Scenario 1/ Phase 1 Investment Activities

Occupation title	Number of annual direct jobs	Annual direct jobs as % of 2024 employment	Annual direct jobs as % of total direct jobs
Secretaries and administrative assistants	1,020	1.4%	1.0%
Cleaners of vehicles and equipment	950	5.3%	1.0%
Stockers and order fillers	950	1.4%	1.0%
Heavy and tractor-trailer truck drivers	930	1.2%	0.9%
Software developers	920	1.6%	0.9%
Inspectors, testers, sorters, samplers, and weighers	880	2.6%	0.9%
Accountants and auditors	860	1.5%	0.9%
Tire repairers and changers	820	12.9%	0.8%
Semiconductor processing technicians	440	50.0%	0.4%
Electrical and electronic engineering technologists and technicians	430	10.0%	0.4%
Computer hardware engineers	370	10.9%	0.4%
Structural iron and steel workers	310	19.3%	0.3%
Electrical and electronics repairers, powerhouse, substation, and relay	170	13.4%	0.2%
Recreational vehicle service technicians	140	13.0%	0.1%
Wind turbine service technicians	140	35.5%	0.1%
Small engine mechanics	140	11.6%	0.1%
Radio, cellular, and tower equipment installers and repairers	120	25.9%	0.1%
Earth drillers	110	27.6%	0.1%
Solar photovoltaic installers	110	19.9%	0.1%
Roustabouts	90	24.1%	0.1%
Oil and gas service unit operators	90	20.3%	0.1%
Electrician helpers	80	10.5%	0.1%
Coil winders, tapers, and finishers	60	11.9%	0.1%
Boilermakers	50	16.8%	0.05%
Reinforcing iron and rebar workers	40	11.8%	0.04%
Derrick operators	30	31.7%	0.03%
Rotary drill operators	20	21.4%	0.02%
Tapers	20	12.1%	0.02%
Wellhead pumpers	20	10.7%	0.02%
Extraction worker helpers	10	12.2%	0.01%
Pile driver operators	10	10.2%	0.01%
All 54 occupations	62,630		62.9%

Notes: See Tables 5.2 and 5.3.

Occupational Job Requirements as Indicators of Potential Labor Supply Shortages

In Tables 5.5 – 5.7, we report on the occupational job requirements for the 54 occupations with the largest demand increases in either absolute or percentage terms. The data we report includes the training, experience and educational requirements for each of these 54 occupations.

Table 5.5 includes 27 occupations in which the educational, training and experience requirements are relatively low. In each of these 27 occupations, the formal educational requirement is, at most, a high school diploma (or equivalent). None of the occupations require prior work experience in a related job. The level of on-the-job training is only short- or moderate term in all cases, as defined by the U.S. Labor Department.[28]

TABLE 5.5

Occupations with Low Entry Requirements

27 of the 54 Occupations with Largest Absolute Level or Percentage Increase in Labor Demand due to Scenario 1/Phase 1 Investments

	Entry-level requirements		
Occupation title	**Typical education needed**	**Work experience in a related occupation**	**Typical on-the-job training needed to attain competency in the occupation**
Retail salespersons	No formal educational credential	None	Short-term on-the-job training
Construction laborers	No formal educational credential	None	Short-term on-the-job training
Hand laborers and freight, stock, and material movers	No formal educational credential	None	Short-term on-the-job training
Cleaners of vehicles and equipment	No formal educational credential	None	Short-term on-the-job training
Derrick operators	No formal educational credential	None	Short-term on-the-job training
Parts salespersons	No formal educational credential	None	Moderate-term on-the-job training
Roustabouts	No formal educational credential	None	Moderate-term on-the-job training
Oil and gas service unit operators	No formal educational credential	None	Moderate-term on-the-job training
Rotary drill operators	No formal educational credential	None	Moderate-term on-the-job training
Tapers	No formal educational credential	None	Moderate-term on-the-job training
General office clerks	High school diploma or equivalent	None	Short-term on-the-job training

continued on next page

TABLE 5.5 *continued*

Occupations with Low Entry Requirements

27 of the 54 Occupations with Largest Absolute Level or Percentage Increase in Labor Demand due to Scenario 1/Phase 1 Investments

	Entry-level requirements		
Occupation title	Typical education needed	Work experience in a related occupation	Typical on-the-job training needed to attain competency in the occupation
Light truck drivers	High school diploma or equivalent	None	Short-term on-the-job training
Customer service representatives	High school diploma or equivalent	None	Short-term on-the-job training
Secretaries and administrative assistants	High school diploma or equivalent	None	Short-term on-the-job training
Stockers and order fillers	High school diploma or equivalent	None	Short-term on-the-job training
Tire repairers and changers	High school diploma or equivalent	None	Short-term on-the-job training
Electrician helpers	High school diploma or equivalent	None	Short-term on-the-job training
Miscellaneous assemblers and fabricators	High school diploma or equivalent	None	Moderate-term on-the-job training
Electrical, electronic, and electromechanical assemblers	High school diploma or equivalent	None	Moderate-term on-the-job training
Wholesale and manufacturing sales representatives	High school diploma or equivalent	None	Moderate-term on-the-job training
Pile driver operators	High school diploma or equivalent	None	Moderate-term on-the-job training
Operating engineers and other construction equipment operators	High school diploma or equivalent	None	Moderate-term on-the-job training
Inspectors, testers, sorters, samplers, and weighers	High school diploma or equivalent	None	Moderate-term on-the-job training
Semiconductor processing technicians	High school diploma or equivalent	None	Moderate-term on-the-job training
Solar photovoltaic installers	High school diploma or equivalent	None	Moderate-term on-the-job training
Coil winders, tapers, and finishers	High school diploma or equivalent	None	Moderate-term on-the-job training
Extraction worker helpers	High school diploma or equivalent	None	Moderate-term on-the-job training

Notes: These include occupations that typically require a high school degree or less, no work experience, and at most moderate-term on-the-job training (i.e., more than 1 month and less than 1 year; see U.S. Bureau of Labor Statistics, 2025d). Some BLS occupational titles have been modified to simplify presentation.

Source: See Table 5.4. Entry-level requirements and typical on-the-job training are from Michigan Center for Data and Analytics (2024).

Given the relatively modest entry-level requirements for these 27 occupations, it is likely that most of the labor demand increase for workers in these occupations resulting from the 2026 – 2030 clean energy investment (i.e. Scenario 1/Phase 1) scenario could be met from the overall pool of unemployed or underemployed people in Michigan's existing labor force. Thus, as we show in Table 5.6, the total level of increased labor demand among these 27 occupations amounts to about 31,000 jobs. By comparison, the level of official unemployment in the 2024 Michigan labor market was 237,798. The level of unemployed plus discouraged and underemployed workers totaled to 434,799.

From these results, it follows that, for estimating potential areas of labor shortages, we should focus on the 27 occupations in Table 5.4 that have significant entry requirements. We list these 27 occupations in Table 5.7. With these 27 occupations, the entry requirements include at least one of the following: 1) more than a high school degree; 2) significant on-the-job training; or 3) work experience in a related occupation.

As we see in Table 5.7, these 27 listed occupations include a range of requirements. Some require a high-school degree only but also some significant on-the-job training. Others entail higher levels of formal education. Seven of the 27 occupations require significant work experience. Up to, but less than, 5 years of prior experience are required for 5 of the occupations, while 2 occupations require five years or more experience. These latter 2 are first-line supervisors of construction workers and general managers.

TABLE 5.6
Job Creation through 2026 – 2030 Investments (Scenario 1/Phase 1) Relative to Michigan Unemployment Levels

Increased Labor Demand for 27 Occupations with Low Entry Requirements Relative to Unemployment Levels
Increase in Labor Demand for 27 Occupations = 31,090

Michigan unemployment level (U-3), 2024	237,798
Increased labor demand for 27 occupations relative to unemployment level	13.1% (=31,090/237,798)
Michigan unemployment, underemployment, discouraged worker level (U-6), 2024	434,799
Increased labor demand for 27 occupations relative to unemployment, underemployment, discouraged worker level	7.2% (=31,090/434,799)

Source: Michigan unemployment level is from the U.S. Bureau of Labor Statistics (2024a). Estimates of underemployment and discouraged worker levels are derived from U.S. Bureau of Labor Statistics (2025a).

TABLE 5.7
Occupations with Significant Entry Requirements

27 of the 54 Occupations with Largest Absolute Level or Percentage Increase in Labor Demand due to Scenario 1/Phase 1 Investments

Occupation title	Entry-level requirements: Typical education needed	Entry-level requirements: Work experience in a related occupation	Typical on-the-job training needed to attain competency in the occupation
Electrical power-line installers and repairers	High school diploma or equivalent	None	Long-term on-the-job training
Recreational vehicle service technicians	High school diploma or equivalent	None	Long-term on-the-job training
Telecommunications line installers and repairers	High school diploma or equivalent	None	Long-term on-the-job training
First-line supervisors of mechanics, installers, and repairers	High school diploma or equivalent	Less than 5 years	None
First-line supervisors of retail sales workers	High school diploma or equivalent	Less than 5 years	None
Wellhead pumpers	High school diploma or equivalent	Less than 5 years	Moderate-term on-the-job training
Earth drillers, except oil and gas	High school diploma or equivalent	Less than 5 years	Long-term on-the-job training
First-line supervisors of construction trades and extraction workers	High school diploma or equivalent	5 years or more	None
Boilermakers	High school diploma or equivalent	None	Apprenticeship
Carpenters	High school diploma or equivalent	None	Apprenticeship
Electricians	High school diploma or equivalent	None	Apprenticeship
Reinforcing iron and rebar workers	High school diploma or equivalent	None	Apprenticeship
Structural iron and steel workers	High school diploma or equivalent	None	Apprenticeship
Automotive service technicians and mechanics	Postsecondary non-degree award	None	Short-term on-the-job training
Heavy and tractor-trailer truck drivers	Postsecondary non-degree award	None	Short-term on-the-job training
Small engine mechanics	Postsecondary non-degree award	None	Short-term on-the-job training
Wind turbine service technicians	Postsecondary non-degree award	None	Long-term on-the-job training
Electrical and electronics repairers, powerhouse, substation, and relay	Postsecondary non-degree award	Less than 5 years	Moderate-term on-the-job training
Bookkeeping, accounting, and auditing clerks	Some college, no degree	None	Moderate-term on-the-job training

continued on next page

TABLE 5.7 *continued*

Occupations with Significant Entry Requirements

27 of the 54 Occupations with Largest Absolute Level or Percentage Increase in Labor Demand due to Scenario 1/Phase 1 Investments

	Entry-level requirements		
Occupation title	**Typical education needed**	**Work experience in a related occupation**	**Typical on-the-job training needed to attain competency in the occupation**
Electrical and electronic engineering technologists and technicians	Associate's degree	None	None
Radio, cellular, and tower equipment installers and repairers	Associate's degree	None	Moderate-term on-the-job training
Accountants and auditors	Bachelor’s degree	None	None
Computer hardware engineers	Bachelor's degree	None	None
Project management specialists	Bachelor's degree	None	None
Software developers	Bachelor's degree	None	None
Construction managers	Bachelor's degree	None	Moderate-term on-the-job training
General and operations managers	Bachelor's degree	5 years or more	None

Notes: These include occupations that typically require: (1) work experience in a related occupation, (2) long-term on-the-job training, (3) an apprenticeship, or (4) post-secondary education (for definitions, see U.S. Bureau of Labor Statistics, 2025d). Some BLS occupational titles have been modified to simplify presentation.

Source: See Table 5.4. Entry-level requirements and typical on-the-job training are from Michigan Center for Data and Analytics (2024).

Labor Demand Increases from 2030 Clean Energy Investment Scenario as Share of Overall Labor Market Conditions

To identify possible areas of labor shortages resulting from the 2030 clean energy investment scenario (Scenario 1/Phase 1), we also need to estimate the extent to which demand for workers in these occupations could be growing due to normal labor market factors in addition to the increased demand generated by the state’s clean energy investment expansion. Thus, in Table 5.8, we report estimates of increases in overall labor demand for the 27 occupations that incorporates 1) the average economic growth trajectory in the relevant sectors; and 2) normal retirement and exit rates for workers in the relevant sectors.[29] We then combine these sources of increased labor demand with the increased demand generated by the 2030 clean energy investment scenario. These are the figures we report in columns 1 – 2 and add up in column 3 of Table 5.8.

Finally, in column 4 of Table 5.8, we report our estimate of the share of overall labor demand by occupation generated by Michigan’s 2030 clean energy investment scenario. We estimate this by dividing figures in column 1 by those in column 3. As we see in column 4, our estimate of the share of overall labor demand increase generated

TABLE 5.8

Overall Increase in Labor Demand for 27 Occupations with Significant Entry Requirements

(Scenario 1/Phase 1, 2026 - 2030)

Occupation title	Number of annual direct jobs	Annual demand increase from labor force exits, occupational transfers, and growth	Total annual labor demand increase (col. 1 + col. 2)	% of increased labor demand from direct jobs (col. 1/col. 3)
General and operations managers	2,950	7,150	10,100	29.2%
Heavy and tractor-trailer truck drivers	930	6,420	7,350	12.7%
Automotive service technicians and mechanics	3,540	2,000	5,540	63.9%
Bookkeeping, accounting, and auditing clerks	1,230	4,155	5,385	22.8%
First-line supervisors of construction trades and extraction workers	3,530	1,395	4,925	71.7%
First-line supervisors of retail sales workers	1,410	3,100	4,510	31.3%
Carpenters	2,470	2,005	4,475	55.2%
Software developers	920	3,360	4,280	21.5%
Accountants and auditors	860	3,210	4,070	21.1%
Project management specialists	2,060	1,715	3,775	54.6%
Electricians	1,170	2,595	3,765	31.1%
Electrical power-line installers and repairers	3,110	320	3,430	90.7%
First-line supervisors of mechanics, installers, and repairers	1,930	1,100	3,030	63.7%
Construction managers	2,140	810	2,950	72.5%
Telecommunications line installers and repairers	1,250	200	1,450	86.2%
Electrical and electronic engineering technologists and technicians	430	290	720	59.7%
Structural iron and steel workers	310	190	500	62.0%
Computer hardware engineers	370	60	430	86.0%
Electrical and electronics repairers, powerhouse, substation, and relay	170	110	280	60.7%
Recreational vehicle service technicians	140	70	210	66.7%
Wind turbine service technicians	140	65	205	68.3%
Small engine mechanics	140	50	190	73.7%
Earth drillers, except oil and gas	110	70	180	61.1%
Radio, cellular, and tower equipment installers and repairers	120	45	165	72.7%
Boilermakers	50	90	140	35.7%
Reinforcing iron and rebar workers	40	10	50	80.0%
Wellhead pumpers	20	15	35	57.1%

Source: Estimates of "Labor Force Exits, Occupational Transfers, and Growth" are taken from data published by the Michigan Labor Market Information program of the Department of Technology, Management & Budget, Michigan Center for Data and Analytics (2024).

by the growth in clean energy investments varies widely among the 27 listed occupations. The lowest share is 12.7 percent of the 7,350 increase in labor demand in the case of Heavy and Tractor-Trailer Truck Drivers. The highest figure is 90.7 percent of the increase of 3,430 Electric Power-Line Installers and Repairers. Overall, the average share for Michigan's expanded clean energy investment project as a source of overall labor demand increase for these 27 occupations is 55.2 percent.

Estimating Labor Surplus versus Labor Shortage Occupations

In Tables 5.9 and 5.10, we divide up the full set of 27 high-demand occupations with significant entry requirements—the occupations we list in Tables 5.7 and 5.8—according to whether these occupations are likely to experience labor surpluses or shortages resulting from the large-scale clean energy investment program in Michigan. As noted at the outset of this section, we estimate the possible extent of labor surpluses or shortages for the 27 occupations based on two measures. The first measure is the number of possibly available workers in any of the 27 occupations within the statewide Michigan workforce.[30] With the second measure, we broaden the pool of possibly available workers to include the entire Midwest labor market. Our assumption in broadening the pool of available workers to include the entire Midwest workforce is that a reasonable share of workers in other Midwest states are likely to be willing to relocate to Michigan to accept an available employment opportunity that opens up in their respective occupations.

Table 5.9 lists 8 occupations in which we estimate there are likely to be labor surpluses—that is, the supply of labor in the given occupation, in Michigan alone or over the fuller Midwest labor market, is significantly larger than our estimate of the overall labor demand resulting both from Michigan's clean energy investment program as well as overall changes in labor market conditions. These include Software Developers, in which we estimate increased overall labor demand at 4,280 workers while the available labor supply is 4,456 workers within Michigan and 46,847 throughout all Midwest states. It also includes Project Management Specialists, in which we estimate increased labor demand at 3,775 workers while available labor supply includes 6,265 workers in Michigan and 54,398 throughout the Midwest.

In Table 5.10, we include 19 occupations in which we estimate labor shortages could result. As we described above, we further divide these 19 occupations according to whether we estimate these occupations will be experiencing "modest" or "significant" labor shortages. We list 15 occupations with "modest" shortages in Table 5.10A and 4 occupations in Table 5.10B with "significant" labor shortages. By our measure, again, the occupations with "modest" shortages would be those in which there would likely be shortages relative to the workforce in Michigan alone, but there would not be shortages relative to the broader Midwest workforce. The 4 occupations that we estimate would likely experience "significant" shortages would be those in which labor demand would outstrip supply even after we broaden the available pool of workers to include those in the fuller Midwest workforce.[31]

TABLE 5.9
Estimates of Labor Surpluses for 8 Occupations with Significant Entry Requirements
Occupations with Likely Labor Surpluses Associated with Scenario 1/Phase 1 Investments

	Increased labor demand	Labor supply available		Labor supply relative to labor demand increases **Level**: supply – demand; **Percent**: (supply-demand)/demand			
		Within Michigan	Across Midwest	Within Michigan		Across Midwest	
Software developers	4,280	4,456	46,847	176	4.1%	42,567	994.6%
Project management specialists	3,775	6,265	54,398	2,490	66.0%	50,623	1341.0%
Construction managers	2,950	6,050	59,737	3,100	105.1%	56,787	1925.0%
Computer hardware engineers	430	1,962	9,040	1,532	356.3%	8,610	2002.3%
Electrical and electronics repairers, powerhouse, substation, and relay	280	372	2,891	92	32.9%	2,611	932.5%
Recreational vehicle service technicians	210	250	718	40	19.0%	508	241.9%
Wind turbine service technicians	205	455	3,570	250	122.0%	3,365	1641.5%
Boilermakers	140	178	1,363	38	27.1%	1,223	873.6%

Source: Tables 5.8 and A6.1.

In focusing on the 15 occupations with modest labor shortages, we see in Table 5.10A that the shortages within the Michigan labor market range between 9 – 90 percent. But in all cases, these labor shortages are eliminated when we broaden the available labor supply to include the full Midwest labor market. This result is especially significant in considering occupations in which the absolute level of labor demand will be high, such as with the Heavy and Tractor-Trailer Truck Drivers. For this job category, we estimate overall increased labor demand at 7,350 positions, while there are only 2,268 workers available in the Michigan labor market, generating a labor shortage of 5,082 workers. But we estimate the labor supply of these truck drivers across the Midwest at 20,317 workers. Thus, taking account of this full Midwest labor market, our estimate is that there will be a labor surplus of 12,967 workers.

Of course, the situation becomes more challenging with respect to the 4 occupations in which we estimate labor shortages will result even after taking account of the supply of workers throughout the full Midwest labor market. In 3 of these 4 occupations, the absolute increase in labor demand is also relatively high. As Table 5.10B shows, these three occupations are:

TABLE 5.10
Estimates of Labor Shortages for Occupations with Significant Entry Requirements

A. 15 Occupations with Modest Labor Shortage Associated with 2026 – 2030 Investments (Scenario 1/Phase 1)

	Increased labor demand	Labor supply available		Labor supply relative to labor demand increases **Level**: supply – demand; **Percent**: (supply-demand)/demand			
		Within Michigan	Across Midwest	Within Michigan		Across Midwest	
General and operations managers	10,100	9,020	80,086	-1,080	-10.7%	69,986	692.9%
Heavy and tractor-trailer truck drivers	7,350	2,268	20,317	-5,082	-69.1%	12,967	176.4%
Automotive service technicians and mechanics	5,540	788	14,766	-4,752	-85.8%	9,226	166.5%
Bookkeeping, accounting, and auditing clerks	5,385	1,863	12,689	-3,522	-65.4%	7,304	135.6%
First-line supervisors of construction trades and extraction workers	4,925	1,758	9,398	-3,167	-64.3%	4,473	90.8%
First-line supervisors of retail sales workers	4,510	2,153	18,365	-2,357	-52.3%	13,855	307.2%
Carpenters	4,475	3,165	22,762	-1,310	-29.3%	18,287	408.6%
Accountants and auditors	4,070	2,085	18,030	-1,985	-48.8%	13,960	343.0%
Electricians	3,765	966	10,921	-2,799	-74.3%	7,156	190.1%
Electrical and electronic engineering technologists and technicians	720	364	3,299	-356	-49.4%	2,579	358.2%
Structural iron and steel workers	500	39	898	-461	-92.2%	398	79.6%
Small engine mechanics	190	51	449	-139	-73.2%	259	136.3%
Earth drillers	180	83	1,080	-97	-53.9%	900	500.0%
Radio, cellular, and tower equipment installers and repairers	165	150	503	-15	-9.1%	338	204.8%
Reinforcing iron and rebar workers	50	5	590	-45	-90.0%	540	1080.0%

Source: Tables 5.8 and A6.1.

continued on next page

TABLE 5.10 *continued*
Estimates of Labor Shortages for Occupations with Significant Entry Requirements

B. 4 Occupations with Significant Labor Shortages Associated with 2026 – 2030 Investments (Scenario 1/Phase 1)

	Increased labor demand	Labor supply available		Labor supply relative to labor demand increases **Level**: supply – demand; **Percent**: (supply-demand)/demand			
		Within Michigan	Across Midwest	Within Michigan		Across Midwest	
Electrical power-line installers and repairers	3,430	193	2,008	-3,237	-94.4%	-1,422	-41.5%
First-line supervisors of mechanics, installers, and repairers	3,030	280	708	-2,750	-90.8%	-2,322	-76.6%
Telecommunications line installers and repairers	1,450	28	428	-1,422	-98.1%	-1,022	-70.5%
Wellhead pumpers	35	5	5	-30	-85.7%	-30	-85.7%

Source: Tables 5.8.

- *Electrical Power-Line Installers and Repairers.* Increased labor demand is for 3,430 workers, while the available labor supply is 193 workers within Michigan and 2,008 workers for the full Midwest.
- *First-Line Supervisors of Mechanics, Installers and Repairers.* Increased labor demand is 3,030, while the available labor supply is 280 workers within Michigan and 708 for the full Midwest.
- *Telecommunications Line Installers and Repairers.* Increased labor demand is for 1,450 workers, most of this demand (86 percent) is generated from expanding clean energy production, specifically utility solar and wind energy production. These workers install and repair the networking infrastructure needed to monitor and control solar panel arrays and wind turbines. The relative supply of workers with adequate training—i.e., more than one year of on-the-job training—is low, with only 28 workers within Michigan and 428 through the Midwest. This supply of adequately trained telecommunication line installers and repairers is low because most workers with experience in this occupation were employed as of the most recent 2024 data on which we have drawn in this section. More specifically, within both Michigan itself and across the Midwest region, only about one percent of such workers were unemployed as of 2024.

The fourth occupation in which we estimate significant labor shortages is Wellhead Pumpers. But in this case the absolute level of increased demand is negligible, at 35 workers in total. It is not likely to be difficult to recruit something like 30 additional workers from outside Michigan and the Midwest to fill these available jobs.

Table 5.11 summarizes these findings with respect to potential labor surpluses and shortages for occupations with large demand increases and significant entry requirements. As we see again, now in summary form, we estimate that Michigan's clean energy investment project, scaled to achieve a 52 percent emissions reduction as of 2030 relative to the state's 2005 emissions level, would result in 8 occupations with labor surpluses, 15 with modest labor shortages and only 4 with significant shortages.

Overall then, as the *MI Healthy Climate Plan* proceeds towards achieving its 2030 emissions reduction target, we estimate that the most significant areas for labor shortages will be with electrical power and telecommunication line installers and their supervisors. Other areas of labor shortages could emerge, given that with many of the 15 occupations that would face "modest" shortages by our estimates, the process of attracting workers from Midwestern states other than Michigan could produce some bottlenecks. But these labor shortages will be easier to manage than with those occupations in which significant shortages would result relative to the full Midwest labor market.

In Table 5.12, we show the gender and race composition of the 15 occupations that are most likely to experience modest labor shortages and the 4 occupations likely to experience significant shortages. The key finding that emerges from these figures is that most of the occupations likely to face shortages are dominated by men. The only exceptions are the jobs for bookkeepers, accountants and retail sales workers. The remaining occupations included in Table 5.12 are primarily in various construction and manufacturing fields. Among these, the respective shares of female workers is mostly close to zero.

These jobs are also mostly held by White (non-Latinx) males. In fact, in most occupations, White workers are over-represented with shares exceeding 80 percent as compared to their 74 percent share of the overall Michigan workforce. The three exceptions are heavy truck drivers and radio, cellular and tower equipment installers/repairers,

TABLE 5.11
Summary Figures for Labor Surplus and Labor Shortage occupations among 27 Occupations with Significant Entry Requirements

	Occupations with labor surpluses		Occupations with modest labor shortages		Occupations with significant labor shortages	
Number of occupations	8		15		4	
	Surplus in Michigan	Surplus across Midwest	Shortage in Michigan	Surplus across Midwest	Shortage in Michigan	Shortage across Midwest
Overall extent of surpluses/shortages (as % of demand)	7,718	166,294	-27,167	162,228	-7,439	-4,796
	62.9%	1355.3%	-52.3%	312.4%	-93.6%	-60.4%

Source: Tables 5.9 and 5.10.

TABLE 5.12
Gender and Race Composition of Workers in Occupations with Likely Labor Supply Shortages, 2024

A. Occupations with **Modest** Labor Shortages Associated with 2026 - 2030 Investments (Scenario 1/Phase 1)

	Gender composition	Racial composition						
	Women	White, non-Latinx	BIPOC, including Latinx					
			All BIPOC, including Latinx	Black, non-Latinx	Asian, non-Latinx	American Indian, Aleut/Eskimo, non-Latinx	Other non-Latinx	Latinx
General and operations managers	37.2%	83.4%	16.6%	3.3%	4.4%	0.3%	3.2%	5.5%
Heavy and tractor trailer truck drivers	9.8%	40.8%	59.2%	36.9%	1.8%	0.0%	5.1%	15.4%
Automotive service technicians	2.3%	87.4%	12.6%	8.4%	0.0%	0.2%	2.7%	1.3%
Bookkeeping, accounting, and auditing clerks	84.0%	86.2%	13.8%	4.6%	0.2%	0.4%	5.6%	3.0%
First-line supervisors of construction trades and extraction workers	0.6%	88.0%	12.0%	4.0%	0.9%	1.6%	2.5%	3.0%
First-line supervisors of retail sales workers	50.8%	83.7%	16.3%	6.4%	1.7%	0.2%	3.6%	4.4%
Carpenters	1.9%	82.1%	17.9%	4.0%	1.1%	1.8%	4.5%	6.4%
Accountants and auditors	64.8%	79.6%	20.4%	7.7%	4.3%	0.3%	2.7%	5.4%
Electricians	2.2%	88.8%	11.2%	2.6%	0.0%	0.0%	3.3%	5.4%
Electrical and electronic engineering technologists and technicians	5.8%	79.5%	20.5%	5.2%	5.3%	1.4%	2.1%	6.4%
Structural iron and steel workers	2.4%	82.0%	18.0%	5.4%	1.2%	0.0%	3.9%	7.5%
Small engine mechanics	2.9%	84.8%	15.2%	2.4%	0.0%	0.0%	3.2%	9.6%
Earth drillers	0.0%	79.5%	20.5%	0.0%	0.0%	1.2%	19.3%	0.0%
Radio, cellular, and tower equipment installers and repairers	3.3%	35.9%	64.1%	16.3%	1.6%	0.0%	35.2%	11.1%
Reinforcing iron and rebar workers	2.4%	82.0%	18.0%	5.4%	1.2%	0.0%	3.9%	7.5%

continued on next page

TABLE 5.12 *continued*
Gender and Race Composition of Workers in Occupations with Likely Labor Supply Shortages, 2024

B. Occupations with **Significant** Labor Shortages Associated with 2026 - 2030 Investments (Scenario 1/Phase 1)

	Gender composition	Racial composition						
			BIPOC, including Latinx					
	Women	White, non-Latinx	All BIPOC, including Latinx	Black, non-Latinx	Asian, non-Latinx	American Indian, Aleut/Eskimo, non-Latinx	Other non-Latinx	Latinx
Electrical power-line installers and repairers	0.0%	97.2%	2.8%	0.0%	0.0%	0.0%	2.4%	0.4%
First-line supervisors of mechanics, installers, and repairers	4.2%	82.2%	17.8%	7.2%	0.1%	0.6%	2.6%	7.4%
Telecommunications line installers and repairers	4.6%	92.8%	7.2%	4.5%	0.0%	0.0%	1.0%	1.7%
Wellhead pumpers	0.0%	61.9%	38.1%	21.4%	0.0%	3.4%	7.5%	5.9%

Note: The American Community Survey aggregates "Structural Iron and Steel Workers" and "Reinforcing Iron and Rebar Workers" into one occupational category.

Source: See Appendix 5.

and wellhead pumpers. In these three occupations Black workers, in particular, tend to be over-represented.

Given these demographic patterns, the expansion of clean energy investments in the areas where labor shortages are most likely to emerge can be seen as an opportunity to expand high-quality training programs, as well as efforts to recruit women and non-whites into entry-level positions and onto job ladders in what are currently White male-dominated occupations in construction and manufacturing. Enforcing fair hiring policies will also be important in these efforts.

Potential Labor Shortages during Scenario 1/Phase 2 or over Scenario 2

Following from the results in this section, focused on the 2026 – 30 period in which clean energy investments would reach approximately 4 percent of the state's GDP, we can be confident that labor demand increases are not likely to create any significant labor shortages in Michigan during Scenario 1/Phase 2, over 2031 – 2050, or throughout both Phase 1, 2026 – 35, or Phase 2, 2036 – 50 of Scenario 2. During these alternative time periods, we estimate that clean energy investments would range between 1.4 and 1.9 percent of Michigan's GDP, i.e. less than half the clean energy investment level relative to the 2026 – 30 period. But as we have seen, even during this compressed

5-year time period for Michigan to achieve its 52 percent emissions reduction target, we estimate that labor shortages are likely to be modest throughout the state's various clean energy-related sectors. These results can be one factor to consider with respect to setting the state's 52 percent emissions reduction goal within 10 years, by 2035, as opposed to 5 years, as of 2030.

6. Contraction of Michigan's Fossil Fuel Industries and Just Transition for Fossil Fuel Workers

As we have reviewed above, in order for Michigan to bring total CO_2 emissions down from its 2022 level of 168 million tons to no more than about 96 million tons by 2030, we have described a 5-year program of reducing the consumption of natural gas, oil, and high-emissions bioenergy in Michigan by 25 percent each as of 2030, and to phase out coal consumption completely. As we have seen, natural gas, oil, and coal provided 86 percent of Michigan's overall energy supply in 2022, including electricity exports to other states. High-emissions bioenergy contributed another 6 percent, so that, as of 2022, all emissions-generating energy sources, including bioenergy, provided 92 percent of Michigan's overall energy supply.

The issue on which we focus in this section is the impact of Michigan's emissions reduction program on workers in industries in the state that are currently dependent on statewide consumers purchasing fossil fuels. As we have discussed in Section 3, we assume that production activity and employment in the natural gas, oil and coal sectors will decline at rates equal to their respective declines in consumption—i.e. natural gas and oil production activity will decline by 25 percent each, and coal production activity will end altogether. We do not take account of the 25 percent decline in high-emissions bioenergy here, since, in our illustrative framework, this contraction will be roughly matched by an equivalent expansion in the production and consumption of *low-emissions* bioenergy sources. As regards Michigan's fossil fuel sector workers, we develop in this section an illustrative just transition program through which these workers can move out of their existing jobs to alternative employment opportunities without experiencing significant changes in their incomes and overall living standards.

Our primary focus in this section is on the *direct* jobs that will be lost in Michigan through the contraction of the state's fossil fuel-based 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 Michigan are the jobs that, at present, are 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 Michigan 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 Michigan'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 Michigan who experience unemployment. We return to this issue below, after we first review here job figures and policy measures 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 Michigan as of 2024. As we see, as of 2024, there are 21,380 people employed in the fossil fuel and ancillary industries in Michigan. Of these, 5,909 (28 percent) are employed in oil and gas extraction, 4,318 (20 percent) in the petroleum wholesale trade, 3,471 (16 percent) in fossil fuel electric power generation, and 2,583 (12 percent) in natural gas distribution. Thus, these four sectors together account for about 76 percent of total employment in all of Michigan's fossil fuel-based industries. Taken as a whole, the 21,380 people employed in Michigan's fossil fuel-based industries account for only 0.5 percent of all employment in the state.

Treatment of Gas Station Workers

We have not included gasoline stations in our set of fossil fuel and ancillary industries in Michigan shown in Table 6.1. This is despite the fact that they are, of course, an integral part of the industry. Among other factors, with the employment level of gasoline stations at roughly 24,000 in Michigan[32], this sector employs about 12 percent more people in the state than the 21,380 people who work in all other fossil fuel and ancillary industries in the state combined.

There are two reasons why we have, nevertheless, excluded them in this particular grouping of the state's fossil fuel and ancillary industries. The first is that gasoline stations have evolved over time, so that, at present, the majority of both the work being performed by station employees as well as the profits generated in the sector are derived from their operating also as convenience stores.[33] Their capacity to operate profitably as convenience stores will be impacted by losing the gasoline sales side of their business, since a significant share of their customers come to the stations because they need to fill their cars with gasoline, even while, once at the station, they may also purchase convenience items. But the demand for the stations' convenience store items will continue even as their gasoline sales decline. Moreover, many of these stations have already been adjusting their business model to include electric vehicle charging stations along with convenience store products.

The second factor for excluding gas stations from our grouping of fossil fuel and ancillary industries follows from the job requirements for station employees. That is, the entry requirements for employment in gas stations/convenience stores are low in terms of formal educational levels, previous work experience or their on-the-job training level. The people employed in gas stations can therefore transition into other jobs outside of this sector that are similarly available to people with relatively low credentials. As such, the impact of the phase down of gasoline consumption on gas

TABLE 6.1
Number of Jobs in Michigan's Fossil Fuel-Based Industries in 2024

Industry	2024 Employment levels	Industry share of total fossil fuel-based employment
Oil and gas extraction	5,909	27.6%
Petroleum and petroleum products wholesale	4,318	20.2%
Fossil fuel electric power generation	3,471	16.2%
Natural gas distribution	2,583	12.1%
Pipeline transportation	1,657	7.7%
Support activities for oil and gas operations	1,343	6.3%
Pipeline construction	819	3.8%
Petroleum refineries	442	2.1%
Drilling oil and gas wells	284	1.3%
Mining machinery and equipment manufacturing	284	1.3%
All other petroleum and coal products manufacturing	250	1.2%
Support activities for coal mining	21	0.1%
Coal mining	-	0.0%
Oil and gas field machinery and equipment manufacturing	-	0.0%
Fossil Fuel industry total	21,380	100.0%
Total fossil fuel employment as share of Michigan State Employment (Michigan 2024 employment = 4.5 million)	0.5%	

Source: See Appendix 5. Michigan state employment is published at U.S. Bureau of Labor Statistics (2025b).

station employees will be broadly similar to that faced by workers who are impacted by the fossil fuel industry phase-down through the indirect employment channel. As we discussed above with respect to the workers impacted by the indirect job creation channel, these job losses can be effectively managed through the same set of policies that are available to all workers in Michigan who experience unemployment.

Characteristics of Fossil Fuel-Based Industry Jobs

Table 6.2 provides basic figures on the characteristics of the direct jobs in Michigan for workers in fossil-fuel based sectors. We first see that, on average, these are high-paying jobs. The average hourly wage is about $53 an hour. This is 36 percent higher than the weighted average figure of $39 an hour that workers in Michigan's clean energy sectors are currently paid.

In terms of private health insurance coverage, the fossil fuel industries are, for the most part, providing coverage for their workers, with 62 percent of workers receiving

TABLE 6.2
Characteristics of Workers Employed in Michigan's Fossil Fuel-Based Industries

Industry	Fossil-fuel based industries
Indicators of job quality	
Mean hourly wage	$53.20
Health insurance coverage, %	62.4%
Retirement plans, %	49.0%
Union coverage, %	16.2%
Educational credentials	
Less than a high school degree	4.5%
High school degree or equivalent	32.4%
Some postsecondary education but no degree	16.9%
Associates degree	14.7%
BA degree or higher	31.5%
Gender composition	
Women	25.3%
Racial composition	
White, non-Latinx	78.3%
All BIPOC, including Latinx	21.7%
Black, non-Latinx	8.4%
Asian, non-Latinx	2.6%
American Indian, Aleut/Eskimo, non-Latinx	0.5%
Other non-Latinx	3.9%
Latinx	6.1%

Source: See Appendix 5.

employer-based insurance. This level of health insurance coverage is also higher than the 55 percent weighted average for clean energy jobs. Also, 49 percent of the fossil fuel-based workers are offered retirement benefits from their jobs, which is modestly higher than the 44 percent average for clean energy workers. Finally, the union coverage rate for Michigan's fossil fuel workers, at 16 percent is the same as the average for the state's clean energy workforce.

Table 6.2 also reports figures on educational credential levels for workers in Michigan's fossil fuel-based sectors, as well the percentages of workers who are women and people of color. These figures correspond closely with the averages for the state's clean energy sectors. Thus, the share of fossil fuel sector workers whose educational level is high school degree is 32 percent, while the average for the clean energy sectors is 36 percent. The share of workers in the fossil fuel sectors with BA degrees or higher is, again, 32 percent, while this figure is 26 percent for the clean energy workforce.

As we saw with respect to Michigan's clean energy sectors, the share of female employees in the state's fossil fuel sectors is quite low, at 25 percent. The figure is 27 percent for the clean energy sectors. The share of White non-Latinx employees is identical in Michigan's fossil fuel and clean energy sectors, at about 78 percent.

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

The key finding that emerges from these tables is that the fossil fuel industries in Michigan provide a wide range of employment opportunities for the roughly 21,000 workers currently employed in these industries. As we see, the largest share of jobs, at about 15 percent , are in extraction, including, as examples, oil and gas service unit operators, supervisors of extraction workers and oil and gas roustabouts. The next

TABLE 6.3
Fossil Fuel-Based Industries: Prevalent Job Types in Michigan
Job categories with 5 percent or more employment

Job category	Percentage of direct jobs	Representative occupations
Extraction	14.8%	Oil and gas service unit operators; first-line supervisors of construction trades and extraction workers; oil and gas roustabouts
Transportation and material moving	13.6%	Heavy and tractor-trailer truck drivers; wellhead pumpers; hand laborers and freight, stock, and material movers
Installation and maintenance	12.5%	Industrial machinery mechanics; control and valve installers and repairers; electrical power-line installers and repairers
Production	11.7%	Power plant operators; petroleum pump system operators, refinery operators, and gaugers; gas plant operators
Management	10.5%	General and operations managers; construction managers; financial managers
Office and administrative support	9.7%	Customer service representatives; general office clerks; bookkeeping, accounting, and auditing clerks
Business operation specialists	8.0%	Accountants and auditors; project management specialists; buyers and purchasing agents
Architecture and engineering	7.2%	Petroleum engineers; electrical engineers; industrial engineers

Source: See Appendix 5.

largest category of workers, at 14 percent of the total, are in transportation and material moving. This includes heavy and tractor-trailer drivers, wellhead pumpers, and material movers. The third largest category of workers are in installation and maintenance. This includes industrial machinery mechanics, control and valve installers, and electric power-line installers and repairers. In terms of white-collar jobs in Michigan's fossil fuel sectors, about 35 percent of the jobs are in management, office and administrative support, business operations, and architecture/engineering.

Overall, from the data presented in Table 6.3, we see that there is 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 Michigan. But this will not be the case with *all occupations* in which workers are now employed in Michigan's fossil fuel-based activities. As such, a just transition program to support displaced workers in Michigan'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 considering this issue further through an illustrative just transition program to support the workers who will face displacement through Michigan's emissions reduction project.

Features of a Just Transition Program

We present here an illustrative just transition program within the framework of Michigan's Scenario 1/Phase 1 project of reducing CO_2 emissions by 52 percent between 2026 – 2030. This framework will entail that fossil fuel industry-based workers will face job losses through the 25 percent contraction of Michigan's oil and gas industries as of 2030 and the full phase out by 2030 of the state's coal industry. In considering the alternative Scenario 2, during which Michigan would achieve its 52 percent emissions reduction goal over 10 years, between 2026 – 35, the resulting job losses will be, on an annual basis, half those that we report here through the 5-year Scenario 1 time frame.

The specific policy measures we consider here 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, again by way of illustration, a basic policy package. We present the provisions of this illustrative policy package in Table 6.4.

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

Pension guarantees for workers (65+) voluntarily retiring	- Legal pension guarantees
Employment guarantee	- Jobs provided through clean energy 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 (assume for 50% of displaced workers)
Relocation support	- $75,000 as needed (assume for 50% of displaced workers

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 for 3 years 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.

Estimating Attrition by Retirement and Job Displacement Rates

In Table 6.5, we show figures on annual employment reductions in Michigan's fossil-fuel based industries over 2026 – 30 that would result from a steady contraction of these industries. 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 100 percent coal phase-out and 25 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.

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

	Fossil fuel workers
1) Total workforce as of 2024	21,380
1a) Coal-related activities	555
1b) All other	20,825
2) Job losses over 2026-2030	5,761
2a) Coal-related activities *(100% of row 1a)*	555
2b) All other *(25% of row 1b)*	5,206
3) Average annual job loss over 5-year production decline (=row 2/5)	1,152
4) Number of workers reaching 65 and over *(row 1 x % of workers 60 and over in 2024)*	2,929 *(13.7% of all workers)*
5) Number of workers per year reaching 65 during 5-year transition period *(row 4/5)*	586
6) Number of workers per year retiring voluntarily	469 *(80% of 60+ workers)*
7) Number of workers per year requiring re-employment *(=row 3-row 6)*	684

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.[34] 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.

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 2024 , 21,380 workers in Michigan employed in all fossil fuel-based industries. We then incorporate the assumptions that all 555 coal sector jobs and 25 percent of oil and gas jobs are phased out by 2030. As we see in row 2 of the table, this means that total employment in these sectors will fall by 5,761. The number of fossil fuel based jobs that will be retained as of 2030 will therefore be 15,619 (= 21,380 – 5,761). If we then assume that the contraction in these industries proceeds at a steady rate between 2026 – 2030, this means that 1,152 jobs in these industries will be lost each year, as we see in row 3 (i.e. 5,761 job losses in total/5 years of industry contraction = 1,152 job losses per year).

We see in row 4 that, of the workers presently employed in these sectors in Michigan, 2,929, or 13.7 percent, will be between 60– 65 over 2026 – 2030. If all these workers were to voluntarily retire at a steady rate over 2026 – 2030, this would mean that 586 workers will move into retirement every year over the 5-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 469 workers employed in these sectors will retire voluntarily every year between 2026 – 2030.

Given that total job losses each year will average 1,152 over the 2026 – 2030 period, that in turn means that the total number of workers currently employed in Michigan's fossil fuel-based sectors that will require re-employment will be 684 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 469 workers per year moving into voluntary retirement; and 2) Providing all the forms of re-employment support, including the re-employment guarantee, for the 684 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 have to recognize that the pattern of employment is not likely to be as smooth as is being assumed in our calculations.

Nevertheless, precise details aside, it is the overall finding from this steady contraction pattern that is most central: that the number of workers in Michigan who are likely to experience job displacement through the state's transitioning away from CO_2-generating energy sources will be small—certainly so in comparison with our estimate that clean energy investments in the state between 2026 – 2030 will generate about 185,000, i.e. more than two orders of magnitude greater than the number of workers that will face displacement.

It is also crucial to note that, if we consider a 2026 – 35 scenario for reducing Michigan's CO_2 emissions by 52 percent (i.e. Scenario 2/Phase 1), the extent of annual fossil fuel job displacements in the state would fall by half, to about 350 jobs per year. This is simply because Michigan's fossil fuel phase down to reach the 52 percent emissions reduction goal would be extended in Scenario 2 from 5 years (2026 – 2030) to 10 years (2026 – 2035). It also follows that under Phase 2 for reaching the state's 2050 zero emissions target, under either Scenario 1 (2031 – 2050) or Scenario 2 (2036 – 2050), the rate at which fossil fuel jobs would be phased out would also be in the lower range of about 300 jobs per year or less.

Cost Estimates for a Just Transition Program

Income Support through Wage Insurance

Overall then, it should not be difficult to find new employment opportunities for the roughly 700 fossil fuel-based workers who, through a steady contraction rate, will be displaced annually on average through the relatively compressed fossil fuel phase out period of 2026 – 2030 (Scenario 1/Phase 1). 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 6.6. As we see there, we estimate that the average compensation for displaced workers will be $139,000. This compares with the weighted average compensation for all the clean energy investment sectors, which, as Table 6.6 shows, is $92,000. That is, the difference in average pay is $47,000 between workers currently employed in Michigan'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.

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, $47,000 per worker for three years. From this difference in average compensation levels, we then calculate that the annual cost of compensation insurance for 684 displaced workers to be about $32.1 million.

TABLE 6.6
Estimating Costs of 100 Percent Compensation Insurance for Displaced Workers in Michigan's Fossil-Fuel Based Sectors

1. Number of fossil fuel-based displaced workers per year requiring re-employment	684
2. Average compensation for displaced workers	$139,000
3. Average compensation for clean energy sector jobs	$92,000
4. Average compensation difference between fossil fuel-based and clean energy jobs *(= row 2 – row 3)*	$47,000
5. Annual cost of compensation insurance for 684 workers *(= row 4 x row 1)*	$32.1 million
6. Total cost of compensation insurance for 3 years *(= row 5 x 3)*	$96.4 million

Note: See Appendix 5 for details on average compensation.

Retraining Support

As we have seen above (Tables 4.5 – 4.7), 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 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. We assume that roughly half of the displaced workers—that is 342 displaced workers—would benefit through retraining. The 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 these 342 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 Michigan is around $7,400.[35] We then also allow an additional $2,000 per year per worker to cover other expenses during their training program, such as purchases of textbooks and equipment. We assume that the workers enrolled in these programs 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 342 workers would be about $3.2 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 342 workers per year (i.e., one half of the 684 workers displaced per year) will need relocation allowances, at an average of $75,000 per displaced worker.[36] That would bring the annual relocation budget to about $26 million for 342 workers each year.

Overall Costs for Supporting Displaced Workers under Steady Contraction

In Table 6.7, we show estimates of the full costs of providing this set of wage insurance, retraining and relocation support for 684 workers per year. As Table 6.7 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.

For example, in 2026, the first cohort of 684 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 $61 million in 2026. Costs increase in 2027, since we now have two cohorts of displaced

TABLE 6.7
Total and Annual Average Costs for Just Transition Support for Displaced Fossil Fuel-Based Workers in Michigan (millions of dollars), 2026 – 2030 (Scenario 1/Phase 1)

Year	Income support *(3 years of support for 684 workers)*	Retraining support *(2 years of support for 342 workers)*	Relocation support *(1 year of support for 342 workers)*	Total *(cols. 1+2+3)*
2026	$32.1 (1 cohort)	$3.2 (1 cohort)	$25.7	$61.0
2027	$64.3 (2 cohorts)	$6.3 (2 cohorts)	$25.7	$96.2
2028	$96.4 (3 cohorts)	$6.3 (2 cohorts)	$25.7	$128.4
2029	$96.4 (3 cohorts)	$6.3 (2 cohorts)	$25.7	$128.4
2030	$96.4 (3 cohorts)	$6.3 (2 cohorts)	$25.7	$128.4
2031	$64.3 (2 cohorts)	$3.2 (1 cohort)	---	$67.5
2032	$32.1 (1 cohort)	---	---	$32.1
Total	**$481.9**	**$31.6**	**$128.3**	**$641.8**
Average annual costs	**$68.8** *(7 years of support)*	**$5.3** *(6 years of support)*	**$25.7** *(5 years of support)*	**$91.7** *(7 years of support)*

Sources: See Appendix 5.

workers receiving income and retraining support, as well as one cohort receiving relocation support. Thus, total costs in 2027 rise to $96 million. In 2028, 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 $128 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 $68 million, then to $32 million.

In total, just transition benefits provided to 684 displaced workers per year in Michigan will total to $642 million, or an average of $92 million per year over 7 years, in total costs and about $190,000 per worker.

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 Michigan 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 Michigan even as the fossil fuel-based industries themselves contract.

The Auto Industry Transition to Electric Vehicles

Automobile manufacturing has been a foundation of Michigan's economy for over a century. As of 2025, total auto manufacturing employment in Michigan was 48,600 jobs.[37] This is more than double the employment level for all fossil fuel sector jobs in the state. As such, it is critical to assess what the likely impact will be within Michigan's economy as the automobile industry transitions from building primarily internal combustion engine vehicles (ICEVs) to battery electric vehicles (BEVs). Of course, making this transition from ICEVs to BEVs is necessary for the state to achieve its 2030 and 2050 emissions reduction goals. It will not be possible to achieve these emissions reduction goals if Michigan's automobile fleet continues to be powered by combusting oil.

To consider the full range of issues associated with this transition from ICEV to BEV manufacturing in Michigan is beyond the scope of this study. But in conjunction with our discussion in this section on just transition for displaced fossil fuel sector workers, it is appropriate for us to also consider how the transition from ICEV to BEV manufacturing will impact employment conditions for the state's auto manufacturing workforce. This specific question has been examined in detail in several recent research projects.[38] Our discussion here will be confined to presenting a brief review of the main findings of these recent studies. We focus on four studies, which consider, with different approaches and points of reference, employment issues with both auto parts and vehicle assembly manufacturing.

Weng et al. (2024, p. 7) note that parts manufacturing comprise about two-thirds of all auto manufacturing jobs, with assembly operations generating the other one-third. In terms of potential job losses resulting from the ICEV to BEV transition, they further observe that:

> For some parts manufacturing activity such as electrical steering, suspension, brakes, seats and interior trim, worker demand will persist within the context of BEV production. However, disruption in transmission and engine-related parts manufacturing jobs is expected since these components are simplified or absent in BEV powertrains. Engine manufactur-

> ing jobs will especially be impacted, considering the lack of combustion engines in BEVs (Weng et al., 2024, p. 7).

Weng et al. (2024) estimate that, in the U.S., engine manufacturing jobs accounted for 7 percent of all U.S. auto manufacturing employment as of 2022, amounting to a total of about 56,000 jobs. According to Weng et al. (2024), the workers holding these jobs are the most vulnerable to displacement through the BEV transition.

The 2024 study by Cotterman et al. provides a detailed breakdown of the labor requirements for manufacturing ICEV versus BEV powertrains (Cotterman et al., 2024). The authors compiled new data from major auto manufacturers on 252 process steps necessary to produce key ICEV and BEV powertrain components. They then combined their original data with existing data from the literature on an additional 78 processes. Their overall conclusion is that the labor requirements for the manufacturing of BEV powertrain components is larger than that for ICEV powertrain components. The extent of the labor demand differential they observe varies according to the level of efficiency within a given manufacturing operation. Under their base case, they find that labor demand with BEV powertrain operations entails more than twice the number of worker hours per unit of production as with ICEV powertrain production (Cotterman et al., 2024, p. 12).

At the same time, Cotterman et al. (2024) recognize that most of the increase in labor demand in BEV powertrain production will be in the area of battery manufacturing. As such, workers now employed in ICEV powertrain manufacturing are not positioned to smoothly shift into BEV powertrain manufacturing, since the respective production processes require different skill sets from their workforce. It is also the case that the BEV powertrain manufacturing operations will not necessarily be located within the same plants or even the same geographic areas as the existing ICEV powertrain manufacturing plants. The authors recognize these concerns in their conclusion, writing as follows:

> We find that vehicle electrification leads to more labor intensity in terms of manufacturing worker-hours per vehicle produced, at least in the short- to medium-term. This finding suggests that BEV powertrain manufacturing has the scale of labor demand to absorb potentially displaced ICEV production workers. It also highlights that battery manufacturing specifically is a major driver of these employment opportunities, and that policies seeking to establish a workforce transition pipeline should focus on this segment of the supply chain (Cotterman et al., 2024, p. 12).

In addition to the issue of overall labor demand between ICEV versus BEV powertrain manufacturing, Cotterman et al. (2024) also emphasize three other factors that will be critical for supporting current ICEV workers in the transition process. These are:

> The skill content of battery production in comparison with ICEV production (i.e. whether ICEV workers can perform the jobs created in BEV powertrain manufacturing); the wage level of the new versus the old jobs; and the co-location of EV production with existing

> automotive manufacturing communities (and most generally for U.S. overall, the onshore production of EV components, including batteries) (Cotterman et al., 2024, p. 12).

By contrast with the Cotterman et al. (2024) study's focus on powertrain manufacturing, Weng et al. (2024) examine primarily how the shift from ICEV to BEV manufacturing impacts the one-third of overall auto manufacturing employment engaged in assembly operations. Weng et al. (2024) conducted a detailed plant-level analysis of employment impacts resulting from the shift from ICEV to BEV assembly activity. They gathered production and employment data from three U.S. auto assembly plants that had transitioned from ICEV to BEV production. Weng et al. (2024) found that during the production ramp-up to BEV assembly, employment per vehicle increased by more than tenfold. They also found that after a decade of BEV assembly production, employment in the three plants they studied remained three times higher than what it had been when these plants were assembling ICEVs.

Weng et al. (2024) found that there were three main drivers of this major employment increase per vehicle in BEV assembly. These were: 1) Heavy upfront R&D and process-engineering staffing; 2) Production of more complex premium BEV models early in the rollout; and 3) A shift to more in-house production ("vertical integration") of motors, seats and power electronics.

The findings by Weng et al. (2024) are certainly positive in terms of creating new job prospects for displaced ICEV workers. However, it is still the case that the assembly jobs on which Weng et al. focus constitute only one-third of overall auto manufacturing employment. The primary job displacement threats are with powertrain manufacturing operations, in which battery production amounts to 75 percent of overall powertrain employment. Moreover, part of the employment expansion observed by Weng et al. resulted not through expanding assembly work itself, but, as the authors note, through moving other operations in-house. Consolidating a larger share of overall manufacturing activity in-house is itself a favorable development, since it mitigates the relocation challenges workers will otherwise face when BEV drivetrain manufacturing jobs are not located where ICEV manufacturing work had been concentrated, including in Michigan.

The policy implications that emerge from both the Weng et al. and Cotterman et al. studies are addressed in detail in studies by Barrett and Bivens (2021) and Dupuis et al. (2024). Barrett and Bivens (2021) focus on measures to strengthen U.S. leadership in BEV production. These include "providing manufacturing incentives to onshore investments, enhancing the share of BEV drivetrain components that are produced domestically, securing and strengthening advanced manufacturing capacity, and crafting better trade agreements with more reliable enforcement measures," (Barrett & Bivens, 2021, p. 2).

Barrett and Bivens (2021) find that through such robust industrial policies in the US to support the transition to BEV manufacturing, BEVs could rise to 50 percent of domestic sales of autos as of 2030 and U.S production of powertrain components could bring U.S. manufacturers' share of BEV powertrain market up to their share of their ICEV market share. If these two benchmarks are achieved, Barrett and Bivens (2021) estimate that, in turn, employment in the U.S. auto sector could rise by over 150,000 jobs. However, if BEVs sales were to rise to 50 percent of the domestic auto market by 2030, and effective industrial policy measures are not implemented, then employment losses in U.S. auto manufacturing would reach 75,000 jobs as of 2030.

The Dupuis et al. (2024) study examines the German experience in transitioning from ICEV to BEV manufacturing to identify measures that can support U.S. workers with this transition. They mainly focus on ways to strengthen the protections, rights, and bargaining position of workers as the transition proceeds. The primary way they identify for achieving these gains for workers is strengthening, through multiple channels, the influence of labor unions in the U.S. auto manufacturing sector. Their conclusions follow from the fact that unions in Germany represent a significantly larger share of the industrial workforce and exercise greater influence than in the U.S. They write that "Policymakers in the United States and Canada need to strengthen workers' capacities to participate in workplace restructuring and navigate through the labor market," (Dupuis et al., 2024, p. 788).

Working from their review of the German experience, they propose four main areas where union engagement can critically impact the conditions for workers in this transition. These are: 1) making it easier for unions to organize the unorganized; 2) give unions more rights to participate in corporate decision-making; 3) involving unions in industrial policies to encourage BEV expansion; and 4) expanding the use of existing policy measures for managing the transition process.

Overall, these recent studies describe pathways through which the transition from ICEV to BEV manufacturing could potentially expand employment levels and improve conditions for auto workers within Michigan and throughout the U.S. economy. But whether this happens will depend on the effectiveness of policies to locate BEV manufacturing operations, battery production in particular, at current ICEV manufacturing locations or, at least, within Michigan more generally.

Taking a still broader perspective, the extent of employment creation in Michigan generated by its clean energy investment program will generate more than enough jobs to compensate for the job losses that the state could experience during the phase down of both its fossil fuel and ICEV manufacturing sectors. As we have estimated, the overall extent of job creation through Michigan advancing its clean energy investment program ranges between about 61,000 to 185,000 jobs, depending on the investment levels associated with the emissions reduction target for a given time period and the rate of labor productivity growth. But the fact that new job opportunities will be created through clean energy investments does not mean that these newly created jobs are viable replacements for the jobs that will have been lost through the phase down of fossil fuel production and ICEV manufacturing. Whether the newly-created clean energy sector jobs are reasonable substitutes for the displaced fossil fuel and auto manufacturing workers will depend on the features of the just transition programs that are implemented within the overall *MI Healthy Climate Plan*.

APPENDIX 1.

Considerations on Nuclear Energy, Carbon Capture, Geoengineering and Bioenergy

Nuclear Energy

Three nuclear power plants began operating in Michigan between 1966 and 1975—the Fermi plant in 1966, the Palisades plant in 1971 and the Cook plant in 1975.[39] Since 1976, they supplied a significant share of Michigan's energy supply used for generating electricity. As of 2021, the three plants supplied 356 T-BTUs of energy in Michigan. This amounted to about 14 percent of Michigan's overall energy consumption and 33 percent of energy used to generate electricity in the state that year.[40]

In 2022, nuclear energy supply in Michigan declined by 24 percent, to 272 T-BTUs, due to the closing of the Palisades plant that year. However, in mid-2025, the federal Nuclear Regulatory Commission granted Holtec, the owner of the Palisades plant, permission to restart operations. The restart date has been delayed. As of this writing, Holtec still anticipates supplying power from Palisades in 2026.

In terms of advancing a clean energy transition in Michigan, nuclear energy provides the important benefit that it does not generate CO_2 emissions or air pollution of any kind while operating. Nevertheless, the plan to reopen the Palisades plant has been controversial.[41] The controversy centers around 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 Administration (EIA) "can remain radioactive and dangerous to human health for thousands of years." (2022, 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 increases the possibility 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.

Concerns over these environmental and public safety issues with nuclear power were amplified following Russia's invasion of Ukraine in 2022, in particular when the Russian military took control of the Zaporizhzhia nuclear plant in Ukraine, the largest plant in Europe. In August 2022, the Director General of the International Atomic Energy Agency, Rafael Grossi, stated that conditions at Zaporizhzhia were "completely out of control," underlining "the very real risk of a nuclear disaster." UN Secretary General Antonio Guterres warned at that time that "any potential damage to Zaporizhzhia is suicide."[42]

In addition to these environmental and public safety concerns, the costs of generating electricity with nuclear energy are, at present, roughly double those for onshore wind and solar energy. Thus, according to the U.S. Energy Information Administration's 2025 *Annual Energy Outlook*, the projected levelized cost of electricity for nuclear power installations coming on-stream in 2030 are 10.3 cents per kilowatt hour. By contrast, the EIA projects these costs at 5.1 cents per kilowatt hour for both onshore wind and solar energy.[43]

How to weigh the benefits of nuclear energy for Michigan relative to both the costs and the environmental and public safety concerns is a critical challenge for determining the state's future energy trajectory. It is beyond the scope of this study to examine these issues in depth. In weighing both these concerns as well as the strong support for nuclear among some proponents in the state, we will assume for the purposes of our energy supply analysis that the Palisades plant will reopen in 2026 and that the energy supplied by nuclear power in Michigan will remain through 2050 at a stable average level comparable to that generated prior to the 2022 closing of the Palisades plant.

Carbon Capture and 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, as mentioned above, the natural growth of trees in forests is, of course, a natural and proven carbon removal technology. Even though, as discussed above, tree growth cannot absorb CO_2 released within a comparable time frame as the CO_2 released through wood-burning, large forests still serve as a major long-term carbon sink. Michigan is the most heavily forested U.S. state, with 53 percent of its total land area covered by forest. According to the 2019 study *Carbon Offsets in Michigan State Forests* (Willis et al., 2019), Michigan's forested areas absorb approximately 15 million tons of CO_2 per year. Thus, as of 2022, the state's current forest cover is offsetting about 9 percent of the state's 168 million tons of total CO_2 emissions. Assuming this level of CO_2 absorption is maintained in Michigan—i.e. that Michigan does not undertake a significant deforestation program—it follows that this natural carbon removal process can play a significant role in achieving Michigan's overall emissions reduction targets. Specifically, it implies that the state can reach a net-zero CO_2 emissions threshold by 2050 even while energy consumers in the state continue to rely on fossil fuels to a modest extent. We return to this point in Section 3, which focuses on the path for Michigan to reach both its intermediate and net-zero emissions targets.

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^{0}C for 15 months.[44] 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^{0}C temperature limit—and probably even the 2^{0}C limit—especially if mitigation efforts after 2030 do not substantially exceed the planned efforts of the next decade, (Lawrence et al., 2018, pp. 13–14).

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 5.7 percent of Michigan'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.[45] 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. A 2018 study by Sterman et al. estimates that the time required for tree growth to absorb the CO_2 generated by wood-burning combustion ranges between 44 – 104 years, depending on the forest type, and assuming that a given area of land remains forested (Sterman et al., 2018).

Allowing that we are operating within the emissions-reduction timeframe set out in the *MI Healthy Climate Plan*, this means that we have only 5 – 10 years to reduce CO_2 emissions by 43 percent relative to the 2022 level (depending on whether we operate within a 2030 or 2035 scenario) and 25 years to reach net zero emissions. As such, the 40 – 100 year process through which newly planted trees absorb CO_2 will not deliver carbon neutrality within a 30-year time frame, much less a 43 percent emissions reduction within 5 - 10 years.

This point was emphasized in a May 2020 letter to the Members of Congress by 200 leading environmental scientists (Moomaw et al., 2020). 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 (Moomaw et al., 2020, p. 1).[46]

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.[47] Even when including the refining and energy-generating processes, these bioenergy fuel sources can become low-emissions energy sources. However, to date, Michigan does not either produce or consume low-emissions bioenergy to any significant extent.[48]

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 Michigan. In fact, emissions from biomass and biofuels vary widely.[49] As a rough approximation, we assume that emissions levels from bioenergy in Michigan are, at present, approximately 90 million tons per Q-BTU of energy generated, i.e. approximately equal to the emissions generated by combusting coal. But as we discuss in the main text, we include low-emissions bioenergy as among the clean renewable energy sources that can contribute toward transforming Michigan into a net zero emissions economy.

Appendix 2
Calculations for Estimating Capital Costs for Solar, Onshore Wind, and Geothermal Energy Installations

The International Energy Agency (IEA) reports capital cost figures for solar PV, onshore wind, and geothermal energy as of 2024, 2035 and 2050. The unit in which these figures are reported is U.S. dollars per kilowatt (kW). For our purposes, we convert the IEA reported figures into gigawatts (GW), gigawatt hours (GWh) and quadrillion British Therman Units (Q-BTUs) of energy. The GW figures are costs to build a *stock* of electricity-generating capacity. The GWh and Q-BTU figures represent *flows* of electricity generated by the given stock of equipment.

To convert the GW stock figures into GWh and Q-BTU flow figures, we first need to incorporate the *capacity factors* for each of the renewable energy sources. Capacity factors are the average share of total hours per year that a given stock of energy-generating equipment produces electricity. For example, with solar energy, the average capacity factor reported by the IEA between 2024 and 2050 is 22 percent. This figure means that, because sunshine reaches solar equipment only intermittently during daylight hours due to cloud cover and shade, and not at all during nighttime hours, a given solar installation will produce electricity for 22 percent of the full 8,760 hours that comprise one year's time.

From this annual flow of electricity generation, we can calculate the capital costs of solar installations in terms of GWh. We can then also convert GWh figures to Q-BTUs based on the conversion factor 1 Q-BTU = 293,000 GWh. Table A2.1 shows these calculations for utility, commercial and residential solar, onshore wind, and geothermal installations.

The IEA does not report comparable capital cost figures for our other clean renewable energy source, low-emissions bioenergy. We generated this estimate from the levelized cost of electricity (LCOE) figures for biomass energy reported by the U.S. Energy Information Administration (EIA). The EIA reports that capital costs for biomass amount to 46 percent of total LCOE costs (U.S. Energy Information Administration, 2025b). We converted that LCOE cost proportion into a lump sum figure—i.e. how much investors need to spend upfront to put this bioenergy capital equipment in place and in running order. Our full methodology for calculating this lump sum figure for bioenergy capital costs is presented in Pollin et al. (2014, pp. 136–137).

TABLE A2.1
Derivation of Capital Investment Costs for Clean Renewable Energy Sources

	1) Capital costs per GW	2) Capacity factor	3) GWh/year generated by 1 GW of capacity *(= capacity factor x 8,760 hours)*	4) Capital costs per electricity generated electricity flow *(columns 1/3; conversion: 1 Q-BTU = 293,000 GWh)*	
				Costs per GWh	Costs per Q-BTU
Solar PV					
Utility scale	$627 million	22%	1,927	$325,000	$95 billion
Commercial scale	$880 million	22%	1,927	$460,000	$134 billion
Residential scale	$1.7 billion	22%	1,927	$880,000	$260 billion
Wind- onshore	$1.4 billion	43%	3,767	$372,000	$109 billion
Geothermal	$4.0 billion	90%	7,884	$507,000	$150 billion
Low-emissions bioenergy	$4.0 billion	90%	7,884	$507,000	$150 billion

Sources and Notes: Capital Costs and Capacity Factors per GW for solar, wind, and geothermal are weighted averages of 2023, 2030 and 2050 figures from the International Energy Agency (2024, p. 335). The weights are derived as follows: ((2023 figure + 2030 figure)/2 x 7 years) + ((2030 figure + 2050 figure)/2 x 20 years))/(27 years). Figures on commercial and residential solar installation costs relative to utility-scale solar are derived from the U.S. Department of Energy (2024). Commercial/utility ratio estimated at 1.4; Residential/utility ratio estimated at 2.7. Low-emissions bioenergy costs are derived from the U.S. Energy Information Administration (2025b), as described in the appendix text

Appendix 3

Methodology and References for Estimating Employment Creation through Clean Energy Investments

The employment estimates for Michigan were developed using an input-output model. Here, we used the IMPLAN cloud software for economic impact analysis, an input-output model that uses data from the U.S. Department of Commerce and other public sources (IMPLAN, 2026). The data set used for the estimates in this report is the 2023 Michigan 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 Pollin et al. (2014, Appendix 4).

One important point to note here is that I-O models to date do not identify, for example, renewable energy sectors such as wind, solar, or geothermal, or energy efficiency sectors such as building retrofits, industrial efficiency, or grid upgrades.[50] However, all the components that make up these sectors are included in the existing industries in the models. For example, the hardware, glass production, and installation industries, which are all activities within "solar," are existing industries in the I-O model. By identifying the relevant industries and assigning weights to each, we can create "synthetic" industries that represent the renewable energy and energy efficiency sectors within the model. A complete discussion of the methodology can be found in Garrett-Peltier (2017). The weights of each component used in this study are shown in Table A3.1 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 some activities may keep pace with the rapid scaling up of clean energy consumption in Michigan, we assume most facilities will take longer to develop. For example, while manufacturing activity will expand within the state, some clean energy manufacturing will grow out of state during the clean energy expansion. At the same time, the Michigan government is also planning to expand its support for clean energy activities, which would help the within-state expansion of these industries. Hence, we assume that all sectors will grow at a midpoint between their full potential, i.e., 100 percent local (within-state) content, and their existing local content. Thus, the employment multipliers will be lower in this scenario than if we assume that all sectors, including manufacturing, are produced within Michigan's geographical boundaries. From the IMPLAN model, we take the midpoint of these two estimates: a) one at the regional purchasing content at their existing levels, and b) the other at the 100 percent local content to incorporate this change to arrive at our employment estimates.

While modelling in the IMPLAN Cloud version, to incorporate this change in local content into our model, IMPLAN recommends focusing the analysis on the product rather than the producer. Hence, in our model, we use commodity codes instead of industries. According to IMPLAN, an industry is a group of establishments engaged in the same or similar types of economic activity. These industries produce and sell goods or services, which are also known as products or commodities. Hence, by definition, a commodity may be produced by one or multiple industries or institutions, and therefore an industry or institution can make more than one commodity.

TABLE A3.1
Composition and Weights for Modelling Sectors within the Input-Output Model

Clean renewables	Composition and weights of commodities within the I-O Model
Batteries	100% Batteries
Bioenergy	15% Grains, 10% Sugarcane and sugar beets, 5% Petrochemicals, 15% Industrial process variable instruments, 20% Newly constructed nonresidential structures, 10% newly constructed commercial structures including farm structures, 10% Wet corn, 15% Power boilers and heat exchangers.
Commercial and residential solar	2.5% Glass products made of purchased glass, 2.5% Nonferrous metals, 5% Fabricated structural metal products, 10% Semiconductors and related devices, 5% Electricity and signal testing instruments; 5% Other electrical components, 15% Capacitors, resistors, coils, transformers, and other inductors, 15% Batteries, 10% Other communication and energy wires, 5% Electricity, 20% Construction of new nonresidential structures, 5% Scientific research and development .
Geothermal	15% Oil and gas wells, 35% Construction of new nonresidential structures, 10% Fluid power pumps and motors, 10% Power boiler and heat exchangers, 30% Scientific research and development.
Onshore wind	26% Newly constructed power and communication structures, 12% Plastics materials and resins, 12% Fabricated structural metal products, 37% turbine and turbine generator unit sets, 3% Mechanical power transmission equipment; 3% Electronic connectors; 7% Scientific research and development.
Utility solar	2.5% Glass products made of purchased glass, 2.5% Nonferrous metals, 5% Fabricated structural metal products, 12% Semiconductors and related devices, 5% Electricity and signal testing instruments; 5% Other electrical components, 10% Capacitors, resistors, 15% batteries, 8% Other communication and energy wires, 10% Electricity, 20% Newly constructed power and communication structures, 5% Scientific research and development
Energy efficiency	**Composition and weights of commodities within the I-O Model**
Building retrofits	50% Maintained and repaired residential structures, 50% Maintained and repaired nonresidential structures.
Industrial efficiency with CHP	20% Environmental and other technical consulting services, 10% Maintained and repaired nonresidential structures, 5% Industrial and commercial fan and blower air purification equipment, 5% Heating equipment (except warm air furnaces), 5% Air conditioning, refrigeration, and warm air heating equipment, 10% All other industrial machinery, 25% Turbine and turbine generator set units, 7.5% Power boilers and heat exchangers, 2.5% Electricity and signal testing instruments , 10% Architectural engineering, and related services.
Grid upgrades	25% Newly constructed power and communication structures, 25% Mechanical Power transmission equipment, 25% Commercial and industrial machinery and equipment repair and maintenance, 25% Other electronic components
Public transport / rail	30% Newly constructed nonresidential structures, 21% Motor vehicle bodies, 6% Railroad rolling stock, 43% Transit and ground passenger transportation services.
Expanding electric / hybrid vehicles	50% Automobile and light duty motor vehicles, 12.5% Batteries, 5% Motor vehicle electrical and electronic equipment, 10% Other motor vehicle parts, 2% Motor vehicle stamped metal, 8% Motor vehicle bodies, 12.5% Motor vehicle gasoline engine and engine parts.

In IMPLAN, most commodities are coded according to the industry for which the commodity is the primary product by adding 3000 to the industry number (e.g., commodity 3001 is the primary product of industry 1). Some industries do not produce a unique primary commodity because multiple industries and institutions can produce the same commodity. For example, all electricity-producing industries produce the same commodity, "electricity," even though they do so via different methods (fossil fuels, wind, solar, etc.). Consequently, there are fewer commodities than industries in IMPLAN's U.S. Industry Scheme. There are only 530 commodities in the 546-industry scheme.

We have reported estimates for both 100 per cent and existing local content for some sectors of clean, renewable energy in Table A3.2. We used the average of the 100 per cent and existing local content employment numbers for all sectors as shown in the right-hand column of Table A3.2.

TABLE A3.2
Employment Multipliers per $1 Million in Unconstrained, Constrained and Mid-Point Cases: Clean, Renewable Energy Sector

	1) All sectors expand to 100 per cent state content	2) All sectors expand at existing state content level	3) Average of two state content levels *(= (columns 1 + 2)/2)*
	Direct, indirect, and induced jobs per $1 million		
Wind (onshore)	7.0	4.3	5.7
Utility solar	7.1	4.5	5.8
Geothermal	9.2	6.7	8.0
Low emissions bioenergy	8.1	5.7	6.9

Source: Appendix 3 text.

Appendix 4

Full Estimates for Clean Energy Investments and Job Creation under Scenario 2

Scenario 2/Phase 1 = 2026 – 35; Scenario 2/Phase 2 = 2036 – 50

In this appendix, we present the full set of estimates for Scenario 2. Over Scenario 2, Michigan would achieve its 52 percent emissions reduction target relative to the 2005 emissions level between 2026 – 35 and then reach net zero emissions between 2036 – 50. The tables in this appendix replicate in form those for Scenario 1, presented in Tables 3.1 – 3.13 of the main text. The summary tables for Scenario 2 presented in the main text, Tables 3.15 – 3.16, are derived from the tables in this appendix.

TABLE A4.1
Sources of CO_2 Emissions for Michigan: *2022 Actuals and 2035 Projection*

	2022 Actuals			2035 Projections	
	1) 2022 Energy consumption *(in T-BTUs)*	2) 2022 CO_2 emissions *(in million metric tons)*	3) CO_2 emissions per Q-BTU *(in million metric tons) (=column 2/ (1/1000))*	4) 2035 Energy consumption *(in T-BTUs)*	5) 2035 CO_2 emissions *(in millions metric tons) (=column 3 x column 4/1000)*
Fossil fuels					
Petroleum	822	57	69	614	43
Natural gas	1,088	57	52	813	43
Coal	424	40	94	0	0
High-emissions bioenergy	161	14	90	120	11
Fossil fuels total	2,334	154	66	1,427	85
Totals, including bioenergy	2,495	168	68	1,547	**96**

Source: See Section 2.

TABLE A4.2
Michigan State GDP Levels: *2022 Actual and Projections for 2026 – 2035*

Figures are in 2024 dollars

2022 GDP	*$665.3 billion*
Projected average growth rate 2026-2035	*1.5%*
Projected 2026 GDP	$706.1 billion
Projected 2035 GDP	$807.4 billion
Projected midpoint GDP between 2026-2035	$756.7 billion

Source: See Section 3.

TABLE A4.3
Michigan State Energy Consumption and Emissions: *2022 Actuals and 2035 BAU and Alternative Projections*

	1) 2022 actuals	2) 2035 BAU *(assumed all categories grow at 1.5% annual rate)*	3) 2035 through Clean Energy Investment Program
1) Real GDP *(in 2024 billion dollars)*	665.3	807.4	807.4
2) Energy consumption *(T-BTUs)*	2,712	3,291	2,471
3) Energy intensity ratio *(Q-BTUs / $1 trillion of GDP)*	4	4	3.1
4) Electricity exports to other U.S. states and Canada	98	119	89
Energy mix for in-state supply			
5) Non-renewables and bioenergy (T-BTUs)	*2,495*	*3,028*	*1,547*
6) Petroleum	822	998	614
7) Natural gas	1088	1320	813
8) Coal	424	515	0
9) High-emissions bioenergy	161	195	120
10) Nuclear	272	319	319
11) Clean renewables (T-BTUs = row 2 – (row 4 + row 5 + row 10))	*43*	*63*	*694*
12) Solar	4	5	413
13) Wind	30	36	207
14) Low-emissions bioenergy	0	0	34
15) Geothermal	5	6	34
16) Hydro	5	5	5
Emissions			
17) Total CO_2 emissions *(million metric tons)*	168	204	96
18) Emissions Intensity Ratio *(CO_2 emissions per in-state-consumed Q-BTUs = row 17 / row 2/1000)*	62	62	39

Source: See Section 3.

TABLE A4.4
Michigan Clean Energy Investment Program for 2026 – 2035 (Scenario 2/Phase 1)

A) Energy Efficiency Investments

1. 2035 Energy intensity ratio	3.1 Q-BTUs per $1 trillion GDP *(15% improvement over 3.98 Q-BTU per $1 trillion GDP BAU figure)*
2. Total energy consumption	2,471 T-BTUs *(15% improvement over 3,055 Q-BTU BAU figure)*
3. Energy savings relative to BAU	821 T-BTUs *(3,291 - 2,471 T-BTUs)*
4. Average investment costs per Q-BTU in efficiency gains	$15 billion per Q-BTU
5. Costs of energy savings	$12.3 billion *(=15 x 0.821)*
6. Average annual costs over 2026 – 2035	$1.2 billion *(=12.3/10)*
7. Average annual costs of efficiency gains as % of midpoint GDP	0.16%

B) Clean Renewable Energy Investments

1. Total renewable supply necessary	694 T-BTUs
2. Expansion of renewable supply relative to 2022 level	651 T-BTUs
3. Average investment costs per Q-BTU for expanding renewable supply	$200 billion per Q-BTU
4. Costs of expanding renewable supply	$130.1 billion
5. Average annual costs over 2026 – 2035	$13 billion
6. Average annual costs of renewable supply expansion as % of midpoint GDP	1.7%

C) Overall Clean Energy Investments: Efficiency + Clean Renewables

1. Total clean energy investments	$142.4 billion
2. Average annual investments	$14.2 billion
3. Average annual investments as share of midpoint GDP	1.9%
4. Total energy savings or clean renewable capacity expansion	1,471 T-BTUs

Sources: See Section 3.

TABLE A4.5

Annual Job Creation in Michigan through Combined Clean Energy Investment Program

Average annual figures for 2026 – 2035 (Scenario 2/Phase 1)

Industry	Number of direct and indirect jobs created	Number of direct, indirect and induced jobs created
$1.2 billion in energy efficiency investments		
Building retrofits	1,711	2,250
Industrial efficiency with CHP	1,244	1,799
Grid upgrades	1,509	2,013
Public transportation	2,489	3,017
Expanding electric/ hybrid vehicles	902	1,252
Total energy efficiency job creation	*7,855*	*10,232*
$13.0 billion in clean renewable investments and battery storage		
Renewables--$11.7 billion in investments		
Solar *($6.60 billion--60% of renewables)*	29,512	40,350
Utility scale (*$3.0 billion—25% of renewables)*	12,570	17,358
Commercial scale *($2 billion—17.5% of renewables)*	8,471	11,496
Residential scale *($2 billion—17.5% of renewables)*	8,471	11,496
Onshore wind *($3.6 billion---30% of renewables)*	14,938	20,767
Geothermal *($520 million—5% of renewables)*	3,019	4,164
Low-emissions bioenergy *($520 million—5% of renewables)*	2,706	3,591
Battery storage *($1.3 billion--10% of overall renewable and battery investments)*	5,465	7,677
Total job creation from clean renewables and battery storage	*55,639*	*76,549*
Total job creation—energy efficiency, renewables, battery storage	**63,494**	**86,782**
Total as a share of 2024 Michigan labor force *(labor force at 5.1 million)*	**1.2%**	**1.7%**

Source: See Section 3. Totals may not added exactly to sum of individual categories due to rounding.

TABLE A4.6

Michigan Average Economic Growth Projections for 2036-2050

Assumption is 1.5% average annual GDP growth rate

Projected 2035 GDP level	$807.4 billion
Projected 2036 GDP level	$819.5 billion
Projected 2050 GDP level	$1.0 trillion
Midpoint GDP level for investment spending estimates *(2036 GDP level + 2050 GDP level)/2)*	$914.5 billion

Source: See Section 3.

TABLE A4.7

Energy Efficiency Investment Needed to Achieve Michigan Energy Intensity Ratio to 2.3 by 2050

2050 GDP Assumption	$1.0 trillion
Total 2050 energy consumption at 3.1 energy intensity ratio	3,129 T-BTUs
Total 2050 energy consumption at the 2.3 energy intensity ratio	2,281 T-BTUs
Reduced energy demand through 2036 – 2050 efficiency investments	848 T-BTUs
Cost of investment in energy efficiency	$12.7 billion
Costs per year over a 15-year investment cycle	$850 million

Source: See Section 3.
Notes: Energy Intensity Ratio = Q-BTUs of energy/ GDP in trillions of dollars. Assumption is 1.5% average GDP growth rate.

TABLE A4.8

Clean Renewable Energy Investments Needed to Reach Zero Emissions in Michigan by 2050

Total 2050 energy consumption at the 2.3 energy intensity ratio	2,281 T-BTUs
Total clean renewable supply required	2,044 T-BTUs
Clean renewable supply as of 2035	694 T-BTUs
Clean renewable energy expansion needed by 2050	1,350 T-BTUs
Cost per Q-BTU of expanding energy supply	$180 billion
Total cost of reaching 1.35 Q-BTU in renewable	$243.1 billion
Average annual costs of a 15-year investment cycle	$16.2 billion

Source: See Section 3, Table A4.3 and Table A4.7.

TABLE A4.9
Overall Estimated Costs of Achieving Zero Emissions in Michigan by 2050

Total energy efficiency costs	$12.7 billion
Total renewable energy investment costs	$243 billion
Total clean energy investment costs	$256 billion
Average annual costs over 15-year investment cycle	$17.1 billion
Average annual costs as a percentage of mid-point GDP	1.9%

Source: See Section 3, Tables A4.6-A4.8.

TABLE A4.10
Annual Job Creation in Michigan through Combined Clean Energy Investment Program

Average annual figures for 2036 – 2050 (Scenario 2/Phase 2)

Industry	Number of direct and indirect jobs created	Number of direct, indirect and induced jobs created
$850 million in energy efficiency investments		
Building retrofits *($170 million—20% of efficiency)*	1,209	1,590
Industrial efficiency with CHP *($170 million—20% of efficiency)*	879	1,201
Grid upgrades *($170 million—20% of efficiency)*	1,066	1,422
Public transportation *($170 million—20% of efficiency)*	1,759	2,132
Expanding electric/ hybrid vehicles *($170 million—20% of efficiency)*	637	885
Total energy efficiency job creation	*5,550*	*7,230*
$16.2 billion in clean renewable investments and battery storage		
Renewables--$13.5 billion in investments		
Solar *($8.1 billion--60% of renewables)*		
Utility scale (*$2.7 billion—20% of renewables)*	10,890	15,038
Commercial scale (*$2.7 billion—20% of renewables)*	10,890	15,038
Residential scale (*$2.7 billion—20% of renewables)*	10,890	15,038
Onshore wind *($4.0 billion---30% of renewables)*	15,946	22,169
Geothermal *($700 million—5% of renewables)*	3,760	5,186
Low-emissions bioenergy *($700 million—5% of renewables)*	3,371	4,473
Battery storage *($2.7 billion--20% of overall renewable and battery investments)*	13,612	19,122
Total job creation from clean renewables and battery storage	*69,358*	*95,545*
Total job creation—energy efficiency, renewables, battery storage	**74,908**	**102,776**
Total as a share of 2024 Michigan labor force *(labor force at 5.1 million)*	**1.5%**	**2.0%**

Source: See Section 3. Totals may not added exactly to sum of individual categories due to rounding.

Appendix 5
Estimating Job Quality and Worker Demographics

Clean Energy Sectors

Our strategy for identifying the types of jobs that would be added to the economy due to a clean energy investment (e.g., on-shore wind) begins with IMPLAN's estimates of the number of jobs created in each of 845 different occupations.[51] We use the occupational distribution of clean energy employment generated by IMPLAN to weight occupation-level estimates of wages, benefits, educational credentials, and demographics of workers currently in those jobs from other data sources, as described below.

Wages

IMPLAN provides estimates of the pay rates by occupation for the jobs generated by each clean energy investment. These wage data are based on the U.S. Department of Labor's Occupational Employment and Wage Statistics (U.S. Bureau of Labor Statistics, 2024b) and reflect the pay of wage and salary workers employed in Michigan in 2023.[52] Importantly, the occupational wages reflect the specific mix of *industries* in which these clean energy jobs are generated as opposed to occupational wages across all industries. Note that we have inflated all dollar figures to 2024 dollars.

Job benefits, union status, and educational attainment

We link the occupational distribution of the new employment created by each clean energy investment to microdata provided by the U.S. Labor Department's Current Population Survey (CPS).[53] The CPS is a household survey administered by the U.S. Census Bureau, on behalf of the Bureau of Labor Statistics (BLS) of the U.S. Labor Department. The CPS collects information from about 60,000 households monthly on a wide range of topics, including various employment-related issues and is the data source for the U.S.'s official labor force estimates.[54] Each set of measures--job benefits, union status, and educational attainment--come from various portions of the CPS, as described below. To produce reliable estimates, we pooled more than one year of data and set a minimum threshold of 30 observations per occupation. Some occupations had less than 30 observations even after pooling multiple years of data. In those instances, we estimated our measures from successively larger geographic units until we reached at least 30 observations. These geographic units include the East North Central region, the Midwest region, and the U.S.[55]

Job benefits. The CPS includes questions about jobs benefits in its March Supplemental Survey only, also referred to as its Annual Social and Economic Survey (ASEC) (U.S. Census Bureau, 2025). To generate sufficient sample sizes for occupation-level estimates, we pooled data from the 2017, 2018, 2019, 2023, 2024 ASEC surveys.[56] We exclude the 2020-2022 ASEC data files to avoid problems associated with administering the survey at the height of the COVID pandemic, as well as to avoid the corresponding exceptional pandemic-related labor market conditions. Note that the ASEC survey asks about job benefits associated with employment during the calendar year preceding the survey (i.e., the 2022 ASEC asks about job benefits in 2021).

Union status. The CPS asks only one-quarter of its basic monthly survey sample—referred to as the Outgoing Rotation Group (ORG)—about union membership and coverage. To generate sufficient sample sizes for occupation-level estimates, we pooled data from August 2022-July 2025 (i.e., three full years of data).

Educational attainment. The CPS asks about educational attainment across all its basic monthly survey samples. As with the union status measure, we base our education estimates on pooled data from August 2022- July 2025 (i.e., three full years of data).

Worker Demographics[57]

We link the occupational distribution of the new employment created by each clean energy investment to microdata provided by the U.S. Census Bureau's American Community Survey (ACS) 1% Sample for 2023. The ACS administers 3.5 million surveys annually and therefore has the largest samples of all the data files we have described thus far. As with the other measures, some occupations did not reach our threshold of 30 observations by relying on Michigan data alone. In those instances, we also estimated worker demographics from successively larger geographic units until we reached 30 observations (i.e., East North Central region, the Midwest region, and the U.S.).

We note here that the ACS data include only the binary gender categories that appear in our tables. Additionally, with regard to ethnicity, the ACS survey asks respondents to identify whether they are "Spanish, Hispanic, or Latino." We use the label "Latinx" in our tables because of the growing usage of this ethnic category to identify people with Latin American, as opposed to Spanish heritage, and to be more inclusive across gender categories. Our "Other" racial category includes the following groups: Hawaiian/Pacific Islanders and multi-racial.

A Note about IMPLAN Employment Estimates

Using IMPLAN with CPS and ACS Microdata Sets. Relative to past PERI reports, this report uses a slightly different methodology for estimating the job quality characteristics and worker demographics of clean energy sector employment. Our past estimates have been based on IMPLAN's modeling of the *industrial* distribution of clean energy employment, whereas this report's estimates are based on IMPLAN's modeling of the *occupational* distribution.

Previously, IMPLAN only produced estimates of the industrial composition of jobs generated from an investment activity that we then linked to CPS and ACS microdata sets which include information about job and worker characteristics (as described above). Linking IMPLAN's job creation estimates by industry to the CPS and ACS microdata sets entails combining IMPLAN's 524 industry categories to fit into the 266 industry categories available in the microdata sets. This industry aggregation results in some loss of information about the types of jobs generated by clean energy investments. An important example of this involves the construction sector, an industry that is prominent among clean energy jobs. To link IMPLAN estimates to the CPS and ACS by industry, we have to aggregate the types of jobs created from clean energy investments across IMPLAN's 13 different construction sub-sectors to the one construction sector available in the CPS and ACS.

IMPLAN's more detailed set of construction sectors make important distinctions between the types of occupations that will add jobs due to clean energy investments. We can see this by examining the most prevalent types of occupations present in two of the construction subsectors available in IMPLAN: "power and communication line and related structures construction" and "construction of buildings." Table A5.1 lists the top ten most prevalent types of occupations

TABLE A5.1
Comparing Top 10 Occupations by Construction Sub-Sector

Power and communication line and related structures construction	% of Jobs within sector	Construction of buildings	% of Jobs within sector
Electrical power-line installers and repairers	15.7%	Carpenters	18.1%
Construction laborers	15.7%	Construction laborers	14.0%
First-line supervisors of construction trades and extraction workers	7.8%	First-line supervisors of construction trades and extraction workers	10.3%
Operating engineers and other construction equipment operators	6.9%	Construction managers	7.7%
Telecommunications line installers and repairers	6.4%	Project management specialists	5.9%
First-line supervisors of mechanics, installers, and repairers	5.7%	General and operations managers	4.1%
Electricians	4.2%	General office clerks	3.2%
Construction managers	3.3%	Bookkeeping, accounting, and auditing clerks	2.1%
General and operations managers	2.8%	Secretaries and administrative assistants	1.9%
Project management specialists	2.5%	Cost estimators	1.9%
Total % across top ten occupations:	71%	Total % across top ten occupations:	69%

Source: U.S. Bureau of Labor Statistics (2024b).

in these two different construction subsectors based on national data from the BLS Occupational Employment and Wages Survey (OEWS)—one of IMPLAN's main sources of occupational data (U.S. Bureau of Labor Statistics, 2024b). The former construction subsector—"power and communication line and related structures construction" figures prominently in the clean energy investments described in this report, whereas the latter—"construction of buildings"—does not.

We can see from Table A5.1, that "electrical power-line installers and repairers" is the most prevalent occupation in "power and communication line and related structures construction." This occupation does not appear among the top ten occupations in the "construction of buildings." Likewise, "carpenters," the most prevalent occupation in the construction of buildings, does not appear among the top ten occupations in power and communication line and related structures construction. In addition, the top ten occupations within the power and communication line and related structures construction are dominated by *construction occupations* e.g., operating engineers, line installers and so on. This contrasts with how the top ten occupations within the construction of building are largely *not* construction occupations, such as general office clerks, bookkeeping clerks, general managers, and secretaries.

IMPLAN's occupational categories are also more fine-grained than what is available in the CPS and ACS but the difference is to a lesser extent than in the case of industries: there are 825 occupational codes in IMPLAN vs. 570 in the CPS and ACS. Importantly, the occupational distribution of jobs estimated by IMPLAN will convey information from IMPLAN's fine-grained set of industry categories. As a result, linking IMPLAN's job creation estimates by occupation to the microdata sets allows us to extract more accurate information about the types of jobs created by clean energy investments than by linking IMPLAN's job creation estimates by industry. Again, this is particularly true for employment in the various construction industries.

IMPLAN's occupational distribution of employment, however, excludes proprietor employment (i.e., the self-employed). For the purposes of our estimates, we assume that the occupational distribution of clean energy employment is approximately the same when self-employed workers are included with wage and salary workers. As we will discuss below, we take special care to identify occupations that figure prominently in clean energy activities and have high shares of self-employed workers in our labor supply/labor demand and potential labor shortages analysis.

Employment Definitions. The employment estimates derived from IMPLAN's modeling are based on the employment definition used by the Bureau of Economic Analysis. The BEA's concept of employment includes jobs held by:

- wage and salaried workers
- self-employed workers in incorporated businesses, and
- proprietors which includes self-employed workers in unincorporated businesses.[58]

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, do 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 unit of employment. Proprietors include sole proprietors, partnerships, and tax exempt cooperatives. Self-employed workers in unincorporated businesses—such as independent contractors--are included among these proprietors.[59] 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 counts 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 unless otherwise noted.

Analyzing Economic Activity by Industry vs. Commodities. As noted in Appendix 3, our employment estimates are based on assigning investment spending on commodities as opposed to investment spending within industries to take account how expanding the domestic production of clean energy will occur over time. This methodological choice—to model investment spending on commodities as opposed to spending in industries—results in a higher level of economic activity involved in the trade of goods and services. This economic activity is reflected in a more prominent role for employment in wholesale and retail sales, as is apparent in Tables 4.5-4.7 that list prevalent job types.

Total Michigan Workforce

We estimate the average wages for the total Michigan workforce using IMPLAN's occupational pay and employment data from 2023. Specifically, we weight IMPLAN's average wages by occupation by IMPLAN's estimate of employment by occupation. Note again that we inflate all dollar figures to 2024 dollars.

Fossil Fuel Sectors

We apply the same basic methodology that we used to estimate the job quality and worker characteristics of clean energy jobs to estimate the same attributes of the Michigan fossil fuel sector workforce. The main difference between the clean energy sector and fossil fuel sector analysis is that we use the current levels of fossil fuel sector employment, as reported by IMPLAN, as our starting point as opposed to any employment impact resulting from specific investment activities. In other words, we start with the occupational distribution of employment across the 14 fossil fuel sectors in Michigan as they existed in 2024 and then use this occupational distribution to estimate wages, benefits, and union representation of the current workforce, along with measures of workers' educational attainment and demographics.

Just Transition Program Costs Estimates

Compensation. The compensation figures in Table 6.6 are based on IMPLAN data on employee compensation. IMPLAN defines employee compensation as "the total remuneration of employees in return for their work on domestic production, and is the sum of Wage and Salary Income + Supplements. Wages and salaries primarily consist of the monetary remuneration of employees, and are broadly defined to include commissions, tips, and bonuses; voluntary employee contributions to deferred compensation plans, such as 401(k) plans; employee gains from exercising stock options; and receipts-in-kind that represent income. Supplements consist of employer contributions for employee pension and insurance funds and of employer contributions for government social insurance." (IMPLAN Data Team, 2017).

Retraining. Our estimates for retraining costs are based on the annual tuition and fees for Michigan community colleges for 2025, or $7,380 (UnivStats, 2026).

Relocation. Our estimate for relocation costs are based on data from Moneyzine (2023) and Salary.com (2024).

Appendix 6
Estimating Labor Demand and Supply by Occupation for Michigan's Clean Energy Sectors

Estimating Labor Demand by Occupation

The focus of our labor supply/labor demand/potential labor shortage analysis is to assess the potential for specific occupations to experience labor supply shortages relative to the increase in labor demand from clean energy investments. As a result, we modify slightly how we estimate these changes in labor demand by occupation from what we describe in Appendix 5. In Appendix 5, we describe how we assume that IMPLAN's estimate of the occupational distribution of jobs created--based on wage and salary workers only--is the same as the occupational distribution for wage and salary workers combined with proprietors (self-employed). For this analysis, we take a closer look at each of the clean energy investment areas that have a high share of proprietor employment among the direct jobs created (i.e., proprietor employment makes up more than 15 percent of direct jobs) and make adjustments to the occupational distribution to avoid underestimating the labor demand for occupations frequently filled with self-employed workers. All investment areas, aside from batteries and expanding electric/hybrid cars, are expected to have at least 15 percent of direct jobs filled by proprietors. Among these investment areas, we identified the specific industries that are both significant in the economic activity generated by clean energy investments (i.e., representing at least 10 percent of the spending within an investment area) and which had at least 20 percent proprietor employment.

For each of these industries, we compared the occupational distribution with wage and salary workers only to that with wage and salary and self-employed workers using CPS data. Through this comparison we identify the occupations within these industries that may be under-represented by looking at wage and salary workers alone. We then scale up the direct job shares of these occupations in the occupational distribution of the relevant industry so that they equal what exists for wage and salary and self-employed workers combined. These include the following occupations:

- Farmers
- Management analysts
- Physical scientists
- Architects
- Small engine mechanics

Several areas of construction (e.g., power and communication structures; nonresidential structures; commercial structures including farm structures; maintenance and repair of residential structures) are significant across several clean energy investment areas and have high shares of proprietor employment. However, the occupational distribution among wage and salary workers in construction resembles the occupational distribution among wage and salary workers and proprietors in construction. As a result, we do not make any adjustments to the occupational distribution of jobs added from construction activity.

Additionally, public transit investments generate significant employment in transit and ground passenger transportation services which has a high share of proprietor employment. However, the only *occupations* that showed high shares of self-employment in transit and ground passenger transportation services were taxi drivers and other motor vehicle drivers. Jobs among these occupations are not directly significant in clean energy investment activities. As a result, we do not make any adjustments to the occupational employment figures resulting from transit and ground passenger transportation services activity.

We use these adjusted occupational employment figures for our estimates of the increased labor demand due to clean energy investments by occupation. These estimates are presented in the first columns of Tables 5.2 and 5.3

Finally, to produce the estimates of the percentage increase in labor demand, by occupation (see column 2 of Tables 5.2 and 5.3), we need to estimate 2024 levels of employment by occupation. To do this we begin with IMPLAN's occupational employment estimates based on 2023 data which are based on wage and salary workers only. We then use CPS data to approximate the share of self-employed by occupation.[60] We apply these shares to IMPLAN's figures of wage and salary employment to take account of proprietor employment by occupation. We use these adjusted occupational employment figures to re-calculate the 2023 occupational distribution of employment. We then apply this 2023 occupational distribution of employment to our estimate of 2024 employment. To estimate 2024 employment, we apply Michigan's employment growth between 2023 and 2024 as estimated by the BEA—0.7 percent—to IMPLAN's 2023 employment level of 5,952,314. Our estimate for 2024 employment figure is 5,993,980.[61]

Job Openings Rate

We use the annual job openings rates published by the Labor Market Information division of the Michigan Center for Data and Analytics (MCDA) to capture the increase in labor demand by occupation due to on-going factors apart from the clean energy investments we propose in this report. These job openings rates incorporate information about the patterns of workers transferring out of occupations, as well as trends in economic growth and retirements.[62] These MCDA projections do not reflect the employment impact of the clean energy investments discussed in this report as these investments are not part of legislated spending bills and are intended to increase current levels of planned investment. The figures we present in column 3 of Table 5.8 are the annual rates of job openings by occupation from the "Long-Term Occupational Employment Projections 2022 to 2032," produced by the MCDA (Michigan Center for Data and Analytics, 2024).

Estimating Labor Supply by Occupation

Our estimates of the current labor supply available to meet the increase in labor demand due to clean energy investments, by occupation, are based on two basic sources: the unemployed and newly trained workers.

Unemployed Workers

We use two measures to estimate the potential labor supply of qualified workers coming from unemployed workers. The first is the main definition of unemployment used by the Labor Department—its U-3 measure of unemployment--which includes only those workers who do not have a job, have actively sought employment in the preceding four weeks, and are available to work.[63] The second measure is a more expansive concept of unemployment, which takes into account employed workers who would like to work more but cannot get additional employment and workers who have left the labor force because they became discouraged about their job opportunities.

More specifically, this second measure is the Labor Department's "U-6" measure.[64] The U-6 measure of unemployment adds to its U-3 measure the following two additional groups of workers. The first is "marginally attached workers." These marginally attached workers include those who are currently neither working nor looking for work but indicate that they want and are available for a job and have looked for work sometime in the past 12 months. Also included in this group of marginally attached workers are "discouraged workers." Discouraged workers are those who have given a job-market related reason for not currently looking for work. The second group of workers included in the U-6 measure are the "under-employed." Under-employed workers are workers employed part time for economic reasons and who want and are available for full-time work but have had to settle for a part-time schedule. Finally, the labor force for each of these unemployment rates by occupation is limited to those with some current or past experience working in that occupation.[65]

Our unemployment figures are presented by occupation in Table A6.1, col. 1. We have grouped occupations in a similar way as in Table 5.7 in the main text, that is, by the job requirements. We estimate that the number of sufficiently skilled workers available from the pool of unemployed workers will range between the number of unemployed workers by the official U-3 definition and the number of unemployed workers by the expanded U-6 definition and therefore use the midpoint of this range in our labor supply estimate. These figures are based on the same basic monthly data files of the CPS as described above. As with the other measures, some occupations did not reach our threshold of 30 observations by relying on Michigan data alone. In those instances, we estimated unemployment and labor force status observations in successively larger geographic units until we reached 30 observations. These geographic units include the East North Central region, the Midwest region, and the U.S. Note that some of the occupational categories differ between IMPLAN and the CPS and require substitution.[66]

Newly Trained Workers

We have two basic categories of newly trained workers: those completing apprenticeships and those completing a post-secondary educational program.

For data on apprenticeships, we rely on state data included in the Registered Apprenticeship Partners Information Database System (RAPIDS) maintained by the U.S. Labor Department Office of Apprenticeship (2025). The database includes data on all apprenticeships registered with the U.S. Department of Labor or the relevant state apprenticeship agency. Such apprenticeships are subject to an approval process by the U.S. Labor Department or state agency, as well as industry representatives. This database publishes apprenticeship completions by year and occupation. Our figures are apprenticeship completers who reside in Michigan for Fiscal Year 2024 and are presented in Panel B of Table A6.1.

For data on completers of post-secondary education, including certificates and degrees, we rely on the National Center for Education Statistics (NCES) Integrated Postsecondary Education Data System (IPEDS) database (National Center for Educational Statistics, 2025). This database includes information on program completions from every postsecondary institution that participates in the federal student financial aid programs, including colleges, universities, and technical and vocational institutions. Specifically, the NCES IPEDS database includes degree and non-degree credentials acquired through credit-bearing programs. These data have two limitations. First, they do not include non-credit-bearing programs.[67] Unfortunately, data on non-credit bearing programs are generally not available. According to a 2023 National Skills Coalition report:

TABLE A6.1
Indicators of Labor Supply: Occupations with Significant Job Requirements

A) Occupations with Training or Experience Requirements, High School Diploma Only

	Michigan unemployment levels			Midwest unemployment levels			Range of midpoint unemployment levels	
Occupational title	**U-3**	**U-6**	**Midpoint**	**U-3**	**U-6**	**Midpoint**	**Michigan**	**Midwest**
Electrical power-line installers and repairers	180	205	193	1,880	2,135	2,008	193	2,008
Recreational vehicle service technicians	250	250	250	490	945	718	250	718
Telecommunications line installers and repairers	20	35	28	275	580	428	28	428
First-line supervisors of mechanics, installers, and repairers	280	280	280	695	720	708	280	708
First-line supervisors of retail sales workers	1,390	2,915	2,153	13,870	22,860	18,365	2,153	18,365
Wellhead pumpers	5	5	5	5	5	5	5	5
Earth drillers	80	85	83	1,045	1,115	1,080	83	1,080
First-line supervisors of construction trades and extraction workers	1,495	2,020	1,758	7,175	11,620	9,398	1,758	9,398

Note: Unemployment level estimates are rounded to nearest multiple of 5, with no cell entry less than 5. Midwest region includes Michigan, Ohio, Indiana, Wisconsin, Illinois, Iowa, Kansas, Minnesota, Missouri, Nebraska, North and South Dakota. Source: CPS 2023-2025 Basic Monthly Files (IPUMS Center for Data Integration, 2025a)

B) Occupations with Apprenticeship Requirements, High School Diploma Only

	Unemployment levels						Apprenticeship completers		Range of annual level of labor supply *(Unemp. level midpt.+apprentices)*	
	Michigan			Midwest						
Occupational title	**U-3**	**U-6**	**Midpoint**	**U-3**	**U-6**	**Midpoint**	**Michigan**	**Midwest**	**Michigan**	**Midwest**
Boilermakers	140	160	150	1,155	1,335	1,245	28	118	178	1,363
Carpenters	2,005	4,040	3,023	12,980	28,795	20,888	142	1874	3,165	22,762
Electricians	250	380	315	5,145	7,725	6,435	651	4,486	966	10,921
Reinforcing iron and rebar workers	5	5	5	440	650	545	0	45	5	590
Structural iron and steel workers	5	5	5	440	650	545	34	353	39	898

Note: Unemployment level estimates are rounded to nearest multiple of 5, with no cell entry less than 5. Unemployment levels are the same for "Reinforcing iron and rebar workers" and "Structural iron and steel workers" because the CPS does not provide separate estimates for these two occupations. Source: CPS 2023-2025 Basic Monthly Files (IPUMS Center for Data Integration, 2025a). Apprenticeship completions are for FY2024 (U.S. Department of Labor, Office of Apprenticeship, 2025).

C) Occupations with Postsecondary Educational Requirements

	Unemployment levels								Annual level of labor supply *(Unemp. level midpt.+education completers)*	
	Michigan			Midwest			Postsecondary/ degree completers			
Occupational title	U-3	U-6	Midpoint	U-3	U-6	Midpoint	Michigan	Midwest	Michigan	Midwest
Automotive service technicians and mechanics	5	510	258	4,100	7,920	6,010	530	8,756	788	14,766
Heavy and tractor-trailer truck drivers	945	1,520	1,233	13,125	18,300	15,713	1,035	4,604	2,268	20,317
Small engine mechanics	5	65	35	40	695	368	16	81	51	449
Wind turbine service technicians	165	165	165	1,505	2,120	1,813	290	1,757	455	3,570
Electrical and electronics repairers, powerhouse, substation, and relay	135	180	158	420	555	488	214	2,403	372	2,891
Bookkeeping, accounting, and auditing clerks	840	1,995	1,418	6,900	10,870	8,885	445	3,804	1,863	12,689
Electrical and electronic engineering technologists and technicians	50	90	70	200	355	278	294	3,021	364	3,299
Radio, cellular, and tower equipment installers and repairers	150	150	150	425	565	495	0	8	150	503
Accountants and auditors	235	885	560	4,660	8,055	6,358	1,525	11,672	2,085	18,030
Computer hardware engineers	5	5	5	5	5	5	1,957	9,035	1,962	9,040
Project management specialists	780	885	833	3,560	3,835	3,698	5,432	50,700	6,265	54,398
Software developers	1,020	1,985	1,503	12,420	14,785	13,603	2,953	33,244	4,456	46,847
Construction managers	230	690	460	4,330	9,350	6,840	5,590	52,897	6,050	59,737
General and operations managers	1,210	1,325	1,268	6,390	7,340	6,865	7,752	73,221	9,020	80,086

Note: Unemployment level estimates are rounded to nearest multiple of 5, with no cell entry less than 5. Source: CPS 2023-2025 Basic Monthly Files (IPUMS Center for Data Integration, 2025a). Degree and certificate program completion data based on report from NCES/IPEDS (National Center for Educational Statistics, 2025).

> Data are generally not available for programs and credentials offered by education and training providers that do not receive state or federal funding. Additionally, for programs and credentials which are not eligible for federal aid, including noncredit programs and industry certifications, robust data on enrollment, attainment, and educational and labor market outcomes are lacking. These gaps in data and reporting on the full range of NDCs [non-degree credentials] limit the ability to identify high-impact credentials that benefit both credential seekers and employers (Cruse et al., 2023, p. 23).

To identify the relevant credential programs for each occupation, we use the NCES' crosswalk between the Standard Occupational Classification (SOC codes) used by IMPLAN and the NCES' Classification of Instructional Programs (CIP) database. For example, the NCES matches the occupation, "Bookkeeping, accounting, and auditing clerks" to postsecondary programs and fields of study that educational institutions categorize as, “Accounting Technology/Technician and Bookkeeping.” As another example, the occupation “Software Developers” is matched with postsecondary fields of study and programs including: “Artificial Intelligence,” “Information Technology,” “Informatics”, “Computer Programming/Programmer, General,” “Data Science,” and so on. We include in our number of degree or certificate completers all those that the NCES reports have been awarded in 2024 a relevant post- secondary credential that meets or exceeds an occupation’s educational entry-level requirement as reported by the Labor Department (see Table 5.7 in main text). Our figures on degree and certificate completers are presented in Table A6.1, panel C, col. 2. The second limitation to these data is that they identify the geographic location of the educational institutions, not that of the students receiving the education.

Endnotes

1 According to the December 2026 *MI Healthy Climate Plan Annual Report,* CO_2 emissions from fossil fuels accounted for 81 percent of overall GHG emissions in Michigan, as of the most recent 2021 data (p. 17). Including CO_2 emissions from bioenergy sources brings the share of CO_2 to roughly 90 percent of Michigan's overall GHG emissions as of these most recent figures. The other major sources of GHG emissions are methane and nitrous oxide.

2 https://www.eia.gov/environment/emissions/state/. Throughout the rest of this study, we reference CO_2 emissions levels, as a shorthand, in terms of "millions" of tons, by which we mean, more formally, "millions of *metric* tons."

3 That is, 200 x (1-.52) = 96.

4 In fact, Michigan has already achieved major progress in advancing a large-scale clean energy investment project throughout the state. According to a January 2025 report by Climate Power, new clean energy projects in the state had reached $27.8 billion, the third largest among all U.S. states. The Clean Power report notes that these projects are primarily in six sectors, solar energy, electric vehicles, batteries, hydrogen, grid and transmission (https://climatepower.us/wp-content/uploads/2025/01/Clean-Energy-Boom-Jan-2025_Michigan.pdf).

5 Appendix 1 discusses the distinction between high- and low-emissions bioenergy sources. We include low-emissions bioenergy sources as among the "clean energy" sources.

6 These categories of clean energy are included in the November 2023 clean energy legislation, Enrolled Senate Bill 271, pp. 2 - 7 (State of Michigan Legislature, 2023).

7 Thomas (2026).

8 As of the May 2026 publication date for this study, the U.S. Energy Information Agency (EIA) has published its initial estimates on total energy consumption in the state for 2023. This 2023 total energy consumption figure is 2,544.7 T-BTUs. Thus, according to this 2023 figure, Michigan's total primary energy consumption in 2023 is about 6 percent lower than the 2022 figure of 2,712.4 T-BTUs (exclusive of electricity exports to other states and Canada). This most recent figure for Michigan's total energy consumption suggests a relatively modest but still significant reduction in the state's total energy consumption between 2022 and 2023. But this most recent consumption figure is not large enough relative to the 2022 figure to require any revisions in the analysis we present here.

9 In its October 2025 study *Status of Renewable Energy, Distributed Generation and Legacy Net Metering in Michigan*, the Michigan Public Service Commission documents significant progress in expanding the supply of clean renewable energy in the state in 2024. The study reports that "A total of 1,698 megawatts (MW) of renewable energy was added to the grid in 2024, bringing the total installed capacity to 7,580 MW. This represents an increase of 28.9% over the 5,882 MW of renewable energy that was online at the end of 2023." This is a significant advance, which is, of course, in full alignment with the goals of the *MI Heathy Climate Plan*. At the same time, this expansion in Michigan's clean renewable energy-generating capacity is relative to what remains a very low base of supplied energy. As Table 2.1 shows, the total energy supplied in Michigan from wind, solar, geothermal and hydropower was 45.3 T-BTUs. This was equal to 1.5 percent of total energy consumption in Michigan in 2022.

10 Various approaches to reduce energy losses in electricity generation are described in Prentiss (2015).

11 As of the May 2026 publication date for this study, the EIA has published figures for Michigan's CO_2 emissions as of 2023. The situation with these most recent EIA figures are thus similar to the updated 2023 on Michigan's primary energy consumption that we described in endnote #8. As of the 2023 figures, the EIA reports that Michigan's total CO_2 emissions were 141 million tons exclusive of bioenergy. Emissions rise to approximately 151 million tons when we account for bioenergy emissions at the level of 90 million tons per Q-BTU, with bioenergy consumption for 2023 at 0.154 Q-BTUs (we review our method for calculating bioenergy emissions in Appendix 1). This 2023 overall emissions figure amounts to an approximately 10 percent reduction in Michigan's emissions relative to the 2022 figure of 168 million tons, including bioenergy. Of course, a 10 percent reduction in emissions in one year is a major achievement. But to date, we do not have sufficient information to

assess the extent to which this reported emissions figure for 2023 reflects an actual major decline in Michigan's emissions trajectory. One other possibility is that the decline reflects a one-year event, with emissions for 2024 then reverting closer to the 2022 level. Another possibility is that the EIA's statistical methods to measure emissions levels by states underwent a revision of some kind with the figures they reported for 2023. We will follow up in ongoing work to obtain greater clarity on this question.

12 See International Energy Agency (2025b), especially pp. 335 – 337.

13 See the discussion and references in Pollin et al. (2015), pp. 92 – 96.

14 State of Michigan Legislature (2023), p. 16 .

15 IEA (2026), Renewable-Energy-Industry.com (2024); LZY Energy (2026).

16 These figures are from the U.S. Energy Information Administration (2023).

17 See Musial et al. (2023).

18 See also the summary of the NREL study in a 1/24/22 *PV Magazine* article (Weaver, 2022). The *PV Magazine* summary includes this passage: "US researchers suggest that by 2050, when 94% of electricity comes from renewable sources, approximately 930GW of energy storage power and six and a half hours of capacity will be needed to fully cover demand for electricity in the United States."

19 That is, (an 80 percent cost increase per kWh) x (a 25 percent requirement of storage capacity as a share of overall energy supply) = a 20 percent cost increase in renewable supply capital costs.

20 Appendix 2 provides details on our calculations, including converting capital cost figures from gigawatts to Q-BTUs.

21 In fact, we are also overestimating overall costs by applying the 20 percent battery storage markup to 100 percent of the renewable energy investment costs. However, geothermal and low-emissions bioenergy—amounting to 10 percent of Michigan's total renewable capacity in this illustrative schema—are non-intermittent energy sources. Therefore, unlike solar and wind energy, they do not require additional investments in storage capacity.

22 According to the IEA's most recent Net Zero Emissions by 2050 Scenario (International Energy Agency, 2025b), capital costs for solar installations fall by 44 percent between 2024 and 2035 and by 18 percent between 2035 and 2050. Capital costs for wind fall by 8 percent between 2024 and 2035 and by 3 percent between 2035 and 2050. Geothermal capital costs fall by 56 percent between 2024 and 2035 and by 46 percent between 2035 and 2050.

23 This estimate takes account of a 20 percent higher average capital cost figure as well as a lower requirement as of 2030 in the battery storage investment level, to 10 percent of average renewable capital costs. Details are presented in Appendix 2.

24 We present details on our methodology and references for deriving employment estimates in Appendix 3.

25 Information specific to each occupation's job requirements can be found in the BLS Occupational Outlook Handbook (U.S. Bureau of Labor Statistics, 2025e).

26 According to the U.S. Census Bureau, Geography Division (2025), the Midwest region includes Michigan, Ohio, Indiana, Wisconsin, Illinois, Iowa, Kansas, Minnesota, Missouri, Nebraska, North and South Dakota.

27 National Center for O*NET Development (2026) and U.S. Bureau of Labor Statistics (2025e).

28 According to the U.S. Labor Department, "short-term" on-the-job training is one month or less of on-the-job experience and informal training. "Moderate-term" on-the-job training is more than one month but less than one year of combined on-the-job experience and informal training (U.S. Bureau of Labor Statistics, 2025d).

29 These job openings rates are published by the Labor Market Information division of the Michigan Center for Data and Analytics (2024). See Appendix 6 for details.

30 For a detailed discussion of how we define "possible, available workers", see Appendix 6.

31 In principle, it would be useful to also identify occupations in which increased labor demand through Michigan's 2026 - 2030 clean energy investment scenario (i.e. Scenario 1/Phase 1) are in approximate balance with the available labor supply in these occupations. A reasonable measure for an occupation in approximate demand/supply balance would be when the difference between labor demand and supply is no more than 10 percent either way—i.e. labor demand is no more than 10 percent greater than labor supply or labor supply is no more than 10 percent greater than labor demand. By this definition, as we will see, only two occupations are in balance relative to the Michigan labor market and none are in balance after taking account of the larger Midwest labor market. It is therefore reasonable for us to focus on the cases in which we observe either labor surpluses or shortages resulting from the Michigan clean energy investment project.

32 See the IBISWorld (2025) market research report.

33 NACS (2026)

34 According to data published by the U.S. Labor Department, 20 percent of 65+ year-olds remain in the workforce. See U.S. Bureau of Labor Statistics (2025c).

35 See UnivStats (2026).

36 According to the 2023 article in *Moneyzine* "Job Relocation Expenses," that provides their most recent estimates, these expenses for an average family range between $25,000 and $75,000 (Moneyzine, 2023). 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.

37 U.S. Bureau of Labor Statistics (2026a).

38 Weng et al. (2024), Cotterman et al. (2024), Barret and Bivens (2021), and Dupuis et al. (2024).

39 Michigan State Police MIREADY Program (2026).

40 U.S. Energy Information Administration (2025e).

41 See Canary Media and Bridge Michigan articles (Wesoff, 2025; House, 2025).

42 See ABC News Australia (2022) and BBC (2022) articles.

43 U.S. Energy Information Administration (2025b).

44 See NASA Earth Observatory (2001).

45 See, for example, Booth (2018), Schlesinger (2018), and Sterman et al. (2018).

46 Among the research findings cited in this letter is that by Sterman et al. (2018), who conclude 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," (Sterman et al., 2018, p. 8).

47 Details on the economics of switchgrass as a bioenergy source are reviewed by Perrin and Harlow (2019).

48 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 Michigan's bioenergy industry, including both high- and low-emissions sources, see U.S. Department of Energy (2015).

49 See Partnership for Policy Integrity (2011).

50 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.

51 These are the most detailed occupations available in IMPLAN. Examples of these occupational titles are presented in Tables 4.5 – 4.7 in the main text.

52 For details, see the "Occupation and Core Competency Data" note by the IMPLAN Data Team (2024a).

53 We use the CPS data files published by IPUMS CPS, University of Minnesota (IPUMS Center for Data Integration, 2025a).

54 See, for example, U.S. Bureau of Labor Statistics (2026b).

55 The East North Central Census region includes: Michigan, Wisconsin, Ohio, Illinois, and Indiana. The Midwest Census region includes: the East North Central region plus the West North Central region, which includes North and South Dakota, Nebraska, Kansas, Minnesota, Iowa, and Missouri.

56 These estimates should be reasonable for such measures because job benefits tend to be relatively stable, particularly among larger employers (at least 50 workers) which employ the large majority of workers (See KFF, 2024, p. 50, Figure 2.4; Stephens, 2024). Also note, a worker is considered to have health insurance benefits from their employer if they indicated in the CPS-ASEC survey that they had health insurance last year, and that they accessed that insurance plan through their employer.

57 This material also applies to the worker demographic data presented in Sections 5 and 6.

58 These include, for example, "sole proprietors"—self-employed people such as farmers who draw earnings from their business but who do not pay themselves a salary (See ADP, 2018). As another example, proprietor employment includes partners in a business—such as a law firm—who draw earnings from their business and cannot pay themselves salaries as employees (Internal Revenue Service, 2025).

59 See Pickenpaugh and Adder (2022) and IMPLAN Data Team (2024b).

60 This is a rough approximation as the CPS' count of self-employed workers is a subset of the BEA's count of proprietor employment, the basis for IMPLAN's proprietor employment estimates.

61 This employment level for Michigan in 2024 is nearly equal to the BEA's 2024 estimate of 5,980,562. See U.S. Bureau of Economic Analysis (2026).

62 The Projections Central website (Projections Managing Partnership, 2025), which houses the U.S. Labor Department-sponsored State Employment Projections program, provides this definition of average annual openings:

> Average annual openings represent the number of openings per year, expected for a respective occupation or sum of occupations. Annual average openings are the sum of two employment calculations, the average annual numeric employment change (the increase or decrease in the number of jobs associated with the occupation), and average annual separations.
>
> Here, separations represent the number of workers who either leave the labor force or make a significant occupational change. An example of a non-significant occupational change would be a move from Teachers Assistant (25-9041) to Secondary Teacher (25-2031), staying within the same major group (indicated in the first two digits of the SOC code). A significant change would be to move from Secondary Teacher (25-2031) to Lawyer (23-1011), by changing the minor group or the broad or detailed occupation.

63 See U.S. Bureau of Labor Statistics (2015).

64 See U.S. Bureau of Labor Statistics (2025f).

65 See IPUMS Center for Data Integration (2025b).

66 These include using "Pumping station operators" for "Well-head pumpers"; "Miscellaneous vehicle and mobile equipment mechanics, installers," for "Recreational Vehicle Service Technicians"; "Structural iron and steel workers" for "Reinforcing Iron and Rebar Workers"; "Small engine mechanics" for "Motorcycle mechanics"; and "Other installation, maintenance, and repair workers" for "Wind turbine service technicians".

67 See National Center for Educational Statistics (2024).

References

ABC News Australia. (2022, August 3). UN nuclear watchdog warns Russian-controlled power plant in Ukraine "completely out of control." *ABC News Australia*. https://www.abc.net.au/news/2022-08-04/iaea-warns-russian-controlled-power-plant-is-out-of-control-/101298900

ADP. (2018, November 15). *Can A Sole Proprietor Have Employees?* https://www.adp.com/resources/articles-and-insights/articles/c/can-a-sole-proprietor-have-employees.aspx

Barrett, J., & Bivens, J. (2021). *The stakes for workers in how policymakers manage the coming shift to all-electric vehicles*. Economic Policy Institute. https://www.epi.org/publication/ev-policy-workers/

BBC. (2022, August 19). Ukraine war: Russia rejects call to demilitarise Zaporizhzhia nuclear plant area. *BBC*. https://www.bbc.com/news/world-europe-62602387

Booth, M. S. (2018). Not carbon neutral: Assessing the net emissions impact of residues burned for bioenergy. *Environmental Research Letters*, *13*(3), 035001. https://doi.org/10.1088/1748-9326/aaac88

Climate Power. (2025). *Entering 2025: Michigan ranks first in the nation for new clean energy projects, becoming a solar and EV battery manufacturing powerhouse*. Climate Power. https://climatepower.us/wp-content/uploads/2025/01/Clean-Energy-Boom-Jan-2025_Michigan.pdf

Cohn, C. (2021). *The Cost of Saving Electricity for the Largest U.S. Utilities: Ratepayer-Funded Efficiency Programs in 2018*. American Council for an Energy-Efficient Economy (ACEEE). https://www.aceee.org/topic-brief/2021/06/cost-saving-electricity-largest-us-utilities-ratepayer-funded-efficiency

Cotterman, T., Fuchs, E. R. H., Whitefoot, K. S., & Combemale, C. (2024). The transition to electrified vehicles: Evaluating the labor demand of manufacturing conventional versus battery electric vehicle powertrains. *Energy Policy*, *188*, 114064. https://doi.org/10.1016/j.enpol.2024.114064

Cruse, L. R., Stiddard, J., Taylor, R., & LaPrad, J. (2023). *The Non-Degree Credential Quality Imperative*. National Skills Coalition. https://nationalskillscoalition.org/wp-content/uploads/2023/07/The-NDCQ-Imperative-report_fnl2-1.pdf

Dupuis, M., Greer, I., Kirsch, A., Lechowski, G., Park, D., & Zimmermann, T. (2024). A Just Transition for Auto Workers? Negotiating the Electric Vehicle Transition in Germany and North America. *ILR Review*, *77*(5), 770–798. https://doi.org/10.1177/00197939241250001

Frick, N. M., Murphy, S., Miller, C., & Pigman, M. (2021). *Still the One: Efficiency Remains a Cost-Effective Electricity Resource*. Webinar presentation. https://eta-publications.lbl.gov/sites/default/files/cose_cspd_analysis_2021_final_v4.pdf

Frick, N. M., Murphy, S., Cappers, D., & Awuah, P. (2024). *Consumer Benefits of Clean Energy: Energy Efficiency*. Lawrence Berkeley National Laboratory. https://emp.lbl.gov/publications/consumer-impacts-clean-energy

Garrett-Peltier, H. (2017). Green versus brown: Comparing the employment impacts of energy efficiency, renewable energy, and fossil fuels using an input-output model. *Economic Modelling*, *61*, 439–447. https://doi.org/10.1016/j.econmod.2016.11.012

House, K. (2025, November 18). Anti-nuclear groups file suit against Palisades restart in southwest Michigan. *Bridge Michigan*. https://bridgemi.com/michigan-environment-watch/anti-nuclear-groups-file-suit-against-palisades-restart-in-southwest-michigan/

IBISWorld. (2025). *Gas Stations with Convenience Stores in Michigan* [Market research report]. https://www.ibisworld.com/united-states/industry/michigan/gas-stations-with-convenience-stores/13408/

IMPLAN. (2026). *IMPLAN, input-output modeling application for Economic Impact Analysis*. https://implan.com/

IMPLAN Data Team. (2017, June 27). *Employment Compensation*. IMPLAN - Support. https://support.implan.com/hc/en-us/articles/115009666268-Employee-Compensation

IMPLAN Data Team. (2024a, January 2). *Occupation and Core Competency Data*. IMPLAN - Support. https://support.implan.com/hc/en-us/articles/360051197853-Occupation-and-Core-Competency-Data

IMPLAN Data Team. (2024b, November 8). *Employment in IMPLAN*. IMPLAN - Support. https://support.implan.com/hc/en-us/articles/30779951167771-Employment-in-IMPLAN

Internal Revenue Service - IRS. (2025, November 21). *Are partners considered employees of a partnership or are they considered self-employed?* https://www.irs.gov/faqs/small-business-self-employed-other-business/entities/entities-1

International Energy Agency - IEA. (2024). *World Energy Outlook 2024*. IEA. https://www.iea.org/reports/world-energy-outlook-2024

International Energy Agency - IEA. (2025a). *Total CO_2 emissions, India, 1990-2023* [Dataset]. Greenhouse Gas Emissions from Energy. https://www.iea.org/data-and-statistics/data-tools/energy-statistics-data-browser?country=INDIA&fuel=CO2%20emissions&indicator=TotCO2

International Energy Agency - IEA. (2025b). *World Energy Outlook 2025*. IEA. https://www.iea.org/reports/world-energy-outlook-2025

International Energy Agency - IEA. (2026). *Global battery markets are growing strongly – and so are the supply risks*, IEA, Paris. https://www.iea.org/commentaries/global-battery-markets-are-growing-strongly-and-so-are-the-supply-risks

IPUMS Center for Data Integration. (2025a). *IPUMS*. Institute for Social Research and Data Innovation, University of Minnesota. https://www.ipums.org/

IPUMS Center for Data Integration. (2025b). *OCC2010: Occupation, 2010 basis, Universe section*. Institute for Social Research and Data Innovation, University of Minnesota. IPUMS CPS. https://cps.ipums.org/cps-action/variables/OCC2010#universe_section.

Jorgenson, J., Frazier, A. W., Denholm, P., & Blair, N. (2022). *Grid Operational Impacts of Widespread Storage Deployment*. National Renewable Energy Laboratory - NREL. https://www.nrel.gov/docs/fy22osti/80688.pdf

KFF. (2024). *2024 Employer Health Benefits Survey*. KFF. https://www.kff.org/health-costs/2024-employer-health-benefits-survey/

LZY Energy. (2026). *What is the Cost of BESS per MW?* 2026 Update! https://www.lzyess.com/news/649.html#

Lawrence, M. G., Schäfer, S., Muri, H., Scott, V., Oschlies, A., Vaughan, N. E., Boucher, O., Schmidt, H., Haywood, J., & Scheffran, J. (2018). Evaluating climate geoengineering proposals in the context of the Paris Agreement temperature goals. *Nature Communications*, *9*(1), 3734. https://doi.org/10.1038/s41467-018-05938-3

Michigan Center for Data and Analytics - MCDA. (2024). *Michigan Statewide Long-Term Employment Projections, 2022-2032* [Dataset]. Michigan Department of Technology, Management & Budget. https://milmi.org/DataSearch/Employment-Projections-Excel-Files

Michigan Department of Environment, Great Lakes, and Energy - EGLE. (2022). *MI Healthy Climate Plan*. EGLE. https://www.michigan.gov/egle/about/organization/climate-and-energy/mi-healthy-climate-plan

Michigan Department of Management and Budget, Office of the State Demographer. (2025). *Michigan and U.S. Population: 1970-2024*. https://sfa.senate.michigan.gov/economics/michigan&uspopulation.pdf

Michigan Public Service Commission (2025). *Status of Renewable Energy, Distributed Generation, and Legacy Net Metering in Michigan* (October 8), https://www.michigan.gov/mpsc/commission/news-releases/2025/10/08/mpsc-renewable-energy-distributed-generation-legacy-net-metering-report

Michigan State Police. (2026). *Nuclear Power*. MIREADY Program. https://www.michigan.gov/miready/be-informed/nuclear-power

Moneyzine. (2023, September 26). *Job Relocation Expenses*. Moneyzine. https://moneyzine.com/finding-a-job/job-relocation-expenses/

Moomaw, W. R., Hanson, C. T., DellaSala, D. A., Woodwell, G. M., Hansen, J. E., Schlesinger, W. H., Raven, P. H., Lovejoy, T., Ehrlich, A. H., Ehrlich, P. R., Ripple, W., Law, B., Harmon, M. E., Hudiburg, T., Goetz, S., Dorsey, M., Noss, R., Duffy, P. B., Birdsey, R. A., … Odion, D. C. (2020, May 8). *Scientists concerned about climate and biodiversity impact of logging* [Letter to Congress]. https://www.documentcloud.org/documents/6889670-Scientist-Letter-to-Congress-8May20/

Musial, W., Green, R., DeMeo, E., Cooperman, A., Housner, S., Marquis, M., MacDonald, S., McDowell, B., Hein, C., Rolph, R., Duffy, P., Zuckerman, G. R., Roberts, O., Stefek, J., & Rangel, E. (2023). *Great Lakes*

Wind Energy Challenges and Opportunities Assessment. National Renewable Energy Laboratory - NREL. https://www.nrel.gov/docs/fy23osti/84605.pdf

NACS. (2026). *U.S. Convenience Store Count.* https://www.convenience.org/Research/Convenience-Store-Fast-Facts-and-Stats/FactSheets/IndustryStoreCount

NASA Earth Observatory. (2001, June 15). *Global Effects of Mount Pinatubo—NASA Science*. https://science.nasa.gov/earth/earth-observatory/global-effects-of-mount-pinatubo-1510/

National Center for Educational Statistics - NCES. (2024). *Instructions for the IPEDS Completions Component*. U.S. Department of Education. IPEDS 2023-24 Survey Materials,. https://surveys.nces.ed.gov/ipeds/public/survey-materials/instructions?instructionid=30080

National Center for Educational Statistics - NCES. (2025). *Integrated Postsecondary Education Data System—IPEDS*. U.S. Department of Education, Institute of Education Sciences. https://nces.ed.gov/ipeds/summarytables

National Center for O*NET Development (2026). Telecommunications Line Installers and Repairers, 49-9052.00. U.S. Department of Labor, Employment & Training Administration. https://www.onetonline.org/link/summary/49-9052.00

Partnership for Policy Integrity - PFPI. (2011). *Carbon emissions from burning biomass for energy*. https://pfpi.net/wp-content/uploads/2011/04/PFPI-biomass-carbon-accounting-overview_April.pdf

Perrin, R., & Harlow, S. J. (2019, April 3). *The Economics of Switchgrass for Biofuel*. Farm Energy. https://farm-energy.extension.org/the-economics-of-switchgrass-for-biofuel/

Pickenpaugh, G. C., & Adder, J. M. (2022). Jobs, jobs, jobs: What's an analyst to do? *Monthly Labor Review*. https://doi.org/10.21916/mlr.2022.31

Pollin, R., Garrett-Peltier, H., Heintz, J., & Chakraborty, S. (2015). *Global Green Growth: Clean Energy Industrial Investments and Expanding Job Opportunities*. United Nations Industrial Development Organization, Global Green Growth Institute. https://peri.umass.edu/wp-content/uploads/2025/01/GLOBAL_GREEN_GROWTH_REPORT_vol1_final.pdf

Pollin, R., Garrett-Peltier, H., Heintz, J., & Hendricks, B. (2014). *Green Growth: A U.S. Program for Controlling Climate Change and Expanding Job Opportunities*. Center for American Progress. https://cdn.americanprogress.org/wp-content/uploads/2014/09/PERI.pdf

Prentiss, M. (2015). *Energy Revolution: The Physics and the Promise of Efficient Technology*. Harvard University Press.

Projections Managing Partnership - PMP. (2025). *About the Long-Term Numbers*. U.S. Department of Labor. Projections Central: State Employment Projections. https://projectionscentral.org/home

Renewable-Energy-Industry.com. (2024). IRENA: Storage as a Game Changer - Cost Reductions and Market Shifts Drive Global Expansion of BESS. https://www.renewable-energy-industry.com/countries/article-7036-irena-storage-as-a-game-changer-cost-reductions-and-market-shifts-drive-global-expansion-of-bess

Salary.com. (2024, November 15). *Typical Relocation Package: Costs and What to Include in 2024*. Salary.Com. https://www.salary.com/resources/hr-glossary/typical-relocation-package-costs-and-what-to-include-in-2024

Schlesinger, W. H. (2018). Are wood pellets a green fuel? *Science*, *359*(6382), 1328–1329. https://doi.org/10.1126/science.aat2305

State of Michigan Legislature. (2023). Enrolled Senate Bill 271 (Clean and Renewable Energy and Energy Waste Reduction Act, Act No. 235 of 2023). https:// www.legislature.mi.gov/documents/2023-2024/publicact/pdf/2023-PA-0235.pdf

Stephens, A. (2024). *96.2 Percent of Michigan's Private Businesses were Small Firms in First Quarter of 2024*. Michigan Center for Data and Analytics. https://www.michigan.gov/mcda/labor-market-information/michigans-labor-market-news/2024/12/12/qcew-q12024

Sterman, J. D., Siegel, L., & Rooney-Varga, J. N. (2018). Does replacing coal with wood lower CO_2 emissions? Dynamic lifecycle analysis of wood bioenergy. *Environmental Research Letters*, *13*(1), 015007. https://doi.org/10.1088/1748-9326/aaa512

Thomas, E. (2026). A $16 billion OpenAI and Oracle data center could decide whether Michigan power bills go up or stay put. *Business Insider*. https://www.businessinsider.com/oracle-open-ai-data-center-michigan-power-rates-2026-4

UnivStats. (2026). *2025 Tuition and Admission Statistics for Community Colleges In Michigan*. Community Colleges In Michigan. https://www.univstats.com/community-colleges/?state=MI

U.S. Bureau of Economic Analysis - BEA. (2025a). *Gross Domestic Product* [GDPA]. Federal Reserve Economic Data - FRED, Federal Reserve Bank of St. Louis. https://fred.stlouisfed.org/series/GDPA

U.S. Bureau of Economic Analysis - BEA. (2025b). *Gross Domestic Product: All Industry Total in California* [CANGSP]. Federal Reserve Economic Data - FRED, Federal Reserve Bank of St. Louis. https://fred.stlouisfed.org/series/CANGSP

U.S. Bureau of Economic Analysis - BEA. (2025c). *Gross Domestic Product: All Industry Total in Michigan* [MINGSP]. Federal Reserve Economic Data - FRED, Federal Reserve Bank of St. Louis. https://fred.stlouisfed.org/series/MINGSP

U.S. Bureau of Economic Analysis - BEA. (2025d). *Gross Domestic Product: All Industry Total in New York* [NYNGSP]. Federal Reserve Economic Data - FRED, Federal Reserve Bank of St. Louis. https://fred.stlouisfed.org/series/NYNGSP

U.S. Bureau of Economic Analysis - BEA. (2025e). *Gross Domestic Product: All Industry Total in Ohio* [OHNGSP]. Federal Reserve Economic Data - FRED, Federal Reserve Bank of St. Louis. https://fred.stlouisfed.org/series/OHNGSP

U.S. Bureau of Economic Analysis - BEA. (2025f). *Gross Domestic Product: All Industry Total in Pennsylvania* [PANGSP]. Federal Reserve Economic Data - FRED, Federal Reserve Bank of St. Louis. https://fred.stlouisfed.org/series/PANGSP

U.S. Bureau of Economic Analysis - BEA. (2025g). *Gross Domestic Product: All Industry Total in Wisconsin* [WINGSP]. Federal Reserve Economic Data - FRED, Federal Reserve Bank of St. Louis. https://fred.stlouisfed.org/series/WINGSP

U.S. Bureau of Economic Analysis - BEA. (2025h). *Gross Domestic Product: Implicit Price Deflator* [A191RD3A086NBEA]. Federal Reserve Economic Data - FRED, Federal Reserve Bank of St. Louis. https://fred.stlouisfed.org/series/A191RD3A086NBEA

U.S. Bureau of Economic Analysis - BEA. (2026). *SASUMMARY State annual summary statistics: Personal income, GDP, consumer spending, price indexes, and employment* [Dataset]. Interactive Data Tables, Regional Data: GDP and Personal Income. https://www.bea.gov/data/employment/employment-by-state

U.S. Bureau of Labor Statistics. (2015, October 8). *How the Government Measures Unemployment*. Labor Force Statistics from the Current Population Survey. https://www.bls.gov/cps/cps_htgm.htm

U.S. Bureau of Labor Statistics. (2024a). *Local Area Unemployment Statistics—LAUS*. Office of Employment and Unemployment Statistics. U.S. Bureau of Labor Statistics. https://www.bls.gov/lau/data-overview.htm

U.S. Bureau of Labor Statistics. (2024b, May). *State Occupational Employment and Wage Estimates (OEWS)*. U.S. Bureau of Labor Statistics. https://www.bls.gov/oes/2024/may/oessrcst.htm

U.S. Bureau of Labor Statistics. (2025a). *Alternative Measures of Labor Underutilization for States, 2024 Annual Averages* [Table]. Local Area Unemployment Statistics - LAUS. https://www.bls.gov/lau/stalt24q4.htm

U.S. Bureau of Labor Statistics. (2025b). *Employees on nonfarm payrolls in States and selected metropolitan areas by major industry* [Table]. 2024 Annual Average Tables. https://www.bls.gov/sae/tables/annual-average/table-1-employees-on-nonfarm-payrolls-in-states-and-selected-areas-by-major-industry.htm

U.S. Bureau of Labor Statistics. (2025c). *Employment status of the civilian noninstitutional population by age, sex, and race, 2024* [Table]. Labor Force Statistics from the Current Population Survey. https://www.bls.gov/cps/cpsaat03.htm

U.S. Bureau of Labor Statistics. (2025d, August 28). *Employment Projections Data Definitions*. Employment Projections. https://www.bls.gov/emp/documentation/definitions.htm

U.S. Bureau of Labor Statistics. (2025e, August 28). *Occupational Outlook Handbook*. Occupational Outlook Handbook. https://www.bls.gov/ooh/

U.S. Bureau of Labor Statistics. (2025f, December 11). *Concepts and Definitions (CPS), Alternative measures of labor underutilization (U-1 through U-6)*. Labor Force Statistics from the Current Population Survey. https://www.bls.gov/cps/definitions.htm#altmeasures

U.S. Bureau of Labor Statistics. (2026a). *All Employees: Manufacturing: Durable Goods: Motor Vehicle Manufacturing in Michigan* (No. SMU26000003133610001) [Dataset]. Federal Reserve Economic Data - FRED, Federal Reserve Bank of St. Louis. https://fred.stlouisfed.org/series/SMU26000003133610001

U.S. Bureau of Labor Statistics. (2026b, February 11). *Economic News Release: Employment Situation Summary*. Bureau of Labor Statistics. https://www.bls.gov/news.release/empsit.nr0.htm

U.S. Census Bureau. (2025, August 29). *Current Population Survey Annual Social and Economic Supplements (ASEC)*. Census.Gov. https://www.census.gov/data/datasets/time-series/demo/cps/cps-asec.html

U.S. Census Bureau, Geography Division. (2025). *Census Regions and Divisions of the United States*. https://www2.census.gov/geo/pdfs/maps-data/maps/reference/us_regdiv.pdf

U.S. Census Bureau, Population Division. (2024). *Annual Estimates of the Resident Population for the United States, Regions, States, District of Columbia, and Puerto Rico: April 1, 2020 to July 1, 2024* (NST-EST2024-POP) [Dataset]. https://www.census.gov/data/tables/time-series/demo/popest/2020s-state-total.html

U.S. Department of Energy - DOE. (2015). *Benefits of Biofuel Production and Use in Michigan*. Energy Efficiency and Renewable Energy - EERE, Bioenergy Technologies Office. https://www.energy.gov/sites/prod/files/2015/10/f27/michigan_biofuels_benefits.pdf

U.S. Department of Energy - DOE. (2024). *Solar Photovoltaic System Cost Benchmarks*. Energy.Gov. https://www.energy.gov/eere/solar/solar-photovoltaic-system-cost-benchmarks

U.S. Department of Labor, Office of Apprenticeship. (2025, September 23). *Apprentices by State, Registered Apprenticeship Partners Information Database System (RAPIDS)*. U.S. Department of Labor. https://www.apprenticeship.gov/data-and-statistics/apprentices-by-state-dashboard

U.S. Energy Information Administration - EIA. (2022, November 7). *Nuclear power and the environment*. Energy Explained. https://www.eia.gov/energyexplained/nuclear/nuclear-power-and-the-environment.php

U.S. Energy Information Administration - EIA. (2023). *Levelized Costs of New Generation Resources in the Annual Energy Outlook 2023* [Dataset]. https://www.eia.gov/outlooks/aeo/electricity_generation/xls/AEO2023_LCOE-LCOS-LACE_figures.xlsx

U.S. Energy Information Administration - EIA. (2025a). *International: India* [Dataset]. https://www.eia.gov/international/data/country/IND

U.S. Energy Information Administration - EIA. (2025b). *Levelized Costs of New Generation Resources in the Annual Energy Outlook 2025*. U.S. Energy Information Administration. https://www.eia.gov/outlooks/aeo/electricity_generation/

U.S. Energy Information Administration - EIA. (2025c). *State Energy Consumption Estimates: 1960 through 2023* (Version DOE/EIA-0214(2023)) [Dataset]. https://www.eia.gov/state/seds/sep_use/notes/use_print.pdf

U.S. Energy Information Administration - EIA. (2025d). *State Energy Data System 2023 Consumption Technical Notes* (p. 273). U.S. Department of Energy. https://www.eia.gov/state/seds/sep_use/notes/use_technotes.pdf

U.S. Energy Information Administration - EIA. (2025e). *State Energy Data System (SEDS): 1960-2023 (complete)* (Version 2023F) [Dataset]. https://www.eia.gov/state/seds/seds-data-complete.php

Weaver, J. F. (2022, January 24). US zero-carbon future would require 6TWh of energy storage. *Pv Magazine International*. https://www.pv-magazine.com/2022/01/24/us-zero-carbon-future-would-require-6twh-of-energy-storage/

Weng, A., Ahmed, O. Y., Ehrlich, G., & Stefanopoulou, A. (2024). Higher labor intensity in US automotive assembly plants after transitioning to electric vehicles. *Nature Communications*, *15*(1). https://doi.org/10.1038/s41467-024-52435-x

Wesoff, E. (2025, July 29). A retired nuclear plant in Michigan is about to restart, a first for US. *Canary Media*. https://www.canarymedia.com/articles/nuclear/holtec-palisades-restart-federal-approval

Willis, A., Clare Cutler, Swaroop, K., Jaruzel, M., Moore, M., & Kay, M. (2019). *Carbon Offsets in Michigan State Forests*. The Nature Conservancy. Dow Sustainability Fellows, University of Michigan. https://graham.umich.edu/activity/17751

World Bank. (2025a). *GDP (current US$)—India* [NY.GDP.MKTP.CD]. WB_WDI. https://data.worldbank.org/indicator/NY.GDP.MKTP.CD?locations=IN

World Bank. (2025b). *GDP deflator—India* [NY.GDP.DEFL.ZS]. WB_WDI. https://data.worldbank.org/indicator/NY.GDP.DEFL.ZS?locations=IN

World Bank. (2025c). *Population, total—India* [SP.POP.TOTL]. WB_WDI. https://data.worldbank.org/indicator/SP.POP.TOTL?locations=IN

About the Authors

Robert Pollin is Distinguished University Professor of Economics and Co-Director of the Political Economy Research Institute (PERI) at the University of Massachusetts Amherst. He is also the founder and President of PEAR (Pollin Energy and Retrofits), an Amherst, MA-based green energy company operating throughout the United States. His books include *The Living Wage: Building a Fair Economy* (co-authored 1998); *Contours of Descent: U.S. Economic Fractures and the Landscape of Global Austerity* (2003); *An Employment-Targeted Economic Program for South Africa* (co-authored 2007); *A Measure of Fairness: The Economics of Living Wages and Minimum Wages in the United States* (co-authored 2008), *Back to Full Employment* (2012), *Greening the Global Economy* (2015), and *Climate Crisis and the Global Green New Deal: The Political Economy of Saving the Planet* (co-authored 2020). In 2018, he co-authored *Economic Analysis of Medicare for All*. He has worked as a consultant for the U.S. Department of Energy, the International Labour Organization, the United Nations Industrial Development Organization and numerous non-governmental organizations in several countries and in U.S. states and municipalities on various aspects of building high-employment green economies. He has also directed projects on employment creation and poverty reduction in sub-Saharan Africa for the United Nations Development Program. He has worked with many U.S. non-governmental organizations on creating living wage statutes at both the statewide and municipal levels, on financial regulatory policies, and on the economics of single-payer health care in the United States. Between 2011–2016, he was a member of the Scientific Advisory Committee of the European Commission project on Financialization, Economy, Society, and Sustainable Development (FESSUD). He was selected by *Foreign Policy* magazine as one of the "100 Leading Global Thinkers for 2013."

Jeannette Wicks-Lim is a Research Professor at the Political Economy Research Institute at the University of Massachusetts Amherst, where she also earned her Ph.D. in economics. Wicks-Lim is a labor economist specializing in the low-wage labor market as well as the political economy of racism. Her research publications cover a wide range of topics, including minimum wage and living wage laws, overtime pay for agricultural workers, affirmative action policies, racial earnings inequality, the Earned Income Tax Credit, single payer programs, and clean energy policies. Her books include *The Political Economy of Racism: The Persistence of Anti-Blackness in the United States* (co-authored, 2025) and *A Measure of Fairness: The Economics of Living Wages and Minimum Wages in the United States* (co-authored, 2008). She also co-edited *Capitalism on Trial: Explorations in the Tradition of Thomas E. Weisskopf* (2013). Wicks-Lim frequently serves as an economic policy consultant for non-governmental organizations as well as state and municipal legislative committees in her areas of research expertise. She currently serves on the board of the National Economics Association and the executive committee of the 7th World Conference on Remedies for Racial and Ethnic Economic Inequality.

Shouvik Chakraborty is an Associate Research Professor at the Political Economy Research Institute (PERI) at the University of Massachusetts Amherst. His research examines the intersections of climate policy, economic inequality, and sustainable development, with a particular focus on how public policies can concurrently promote a green transition and rising mass living standards in both the United States and the Global South. His research work has appeared in *Nature Communications, Ecological Economics*, *Energy Policy, Economic and Political Weekly*, *Journal of Economic Surveys*, *Monthly Review*, *The Japanese Political Economy*, *The Indian Economic Journal, The Economic and Labour Relations Review*, and *Journal of South Asian Development*, among others. He is co-editor of the Routledge volume *Contradictions of Democracy, Inequality and Development* (2025) and co-editor of the Orient Blackswan volume *A Quantum Leap in the Wrong Direction?* (2019). At PERI, he has co-authored numerous studies analyzing the employment impacts of U.S. clean energy legislation, including the Inflation Reduction Act, Bipartisan Infrastructure Law, and CHIPS Act, as well as state-level clean energy transition programs for California, Colorado, Maine, West Virginia, Pennsylvania, South Korea, and Spain. His commentaries have appeared in *The Hindu*, *Hindustan Times*, *The Indian Express*, *The India Forum*, and *Truthout*.

Chirag Lala is the Vice President of Research and Chief Economist at the Center for Public Enterprise, where he works on building public sector capacity to promote economic development through investments in energy, transportation, and housing. His areas of expertise include macroeconomics, finance, the electricity sector, and industrial policy. His dissertation concerned the efficacy of derisking tools in facilitating decarbonization. He previously worked as a consultant at the Applied Economics Clinic, research fellow in Congress, and as a research assistant at the Political Economy Research Institute.

POLITICAL ECONOMY RESEARCH INSTITUTE

The Political Economy Research Institute (PERI) promotes human and ecological well-being through our original research. Our approach is to translate what we learn into workable policy proposals that are capable of improving life on our planet today and in the future. In the words of the late Professor Robert Heilbroner, we at PERI "strive to make a workable science out of morality."

Established in 1998, PERI is an independent unit of the University of Massachusetts, Amherst, with close ties to the Department of Economics. PERI staff frequently work collaboratively with faculty members and graduate students from the University of Massachusetts, and other economists from around the world. Since its founding, PERI has become a leading source of research and policy initiatives on issues of globalization, unemployment, financial market instability, central bank policy, living wages and decent work, and the economics of peace, development, and environmental sustainability.

POLITICAL ECONOMY RESEARCH INSTITUTE
PERI
University of Massachusetts Amherst

PERI.UMASS.EDU • GORDON HALL, 418 N. PLEASANT ST., SUITE A, AMHERST, MA 01002 • TEL: 413-545-6355