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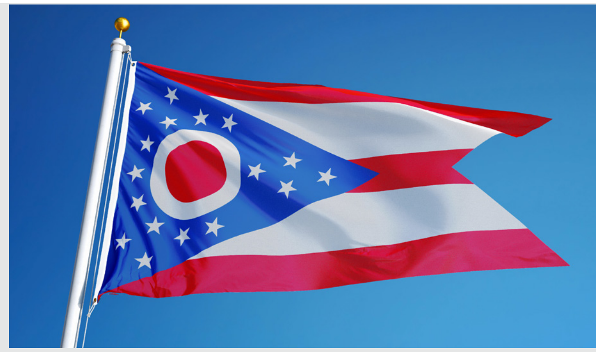
IMPACTS OF THE REIMAGINE APPALACHIA & CLEAN ENERGY TRANSITION PROGRAMS FOR OHIO

Job Creation, Economic Recovery, and Long-Term Sustainability



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SUMMARY OF STUDY

The COVID-19 pandemic has generated severe public health and economic impacts in Ohio, as with most everywhere else in the United States. This study proposes a recovery program for Ohio that is capable of exerting an effective counterforce against the state's economic collapse in the short run while also building a durable foundation for an economically viable and ecologically sustainable longer-term recovery. Even under current pandemic conditions, we cannot forget that we have truly limited time to take decisive action around climate change. As we show, a robust climate stabilization project for Ohio will also serve as a major engine of economic recovery and expanding opportunities throughout the state.

The study is divided into five parts:

1. Pandemic, Economic Collapse, and Conditions for Reopening Ohio
2. Clean Energy Investments, Job Creation and Just Transition
3. Investment Programs for Manufacturing, Infrastructure, Land Restoration and Agriculture
4. Total Job Creation in Ohio through Combined Investments
5. Financing a Fair and Sustainable Recovery Program

The most detailed discussions are in Part 2. We develop here a clean energy investment project through which Ohio can achieve climate stabilization goals which are in alignment with those set out by the Intergovernmental Panel on Climate Change (IPCC) in 2018—that is, to reduce CO_2 emissions by 45 percent as of 2030 and to achieve net zero emissions by 2050. We show how these two goals can be accomplished in Ohio through large-scale investments to dramatically raise energy efficiency standards in the state and to equally dramatically expand the supply of clean renewable energy supplies, primarily including solar, wind, low-emissions bioenergy, geothermal and small-scale hydro power. We also show how this climate stabilization program for Ohio can serve as a major new engine of job creation and economic well-being throughout the state, both in the short- and longer run. We estimate that, as an average over 2021 – 2030, a clean energy investment program scaled at about $21 billion year will generate roughly 165,000 per year in Ohio.

In Part 3, we present investment programs for Ohio in the areas of public infrastructure, manufacturing, land restoration and agriculture. Specific investment areas include manufacturing R&D, broadband development, regenerative agriculture, and plugging orphaned oil and gas wells. We have scaled this overall set of investments at $7 billion per year over 2021 – 2030, equal to about 1 percent of Ohio's 2019 GDP. We estimate that the full program would generate about 70,000 jobs per year in the state.

Overall, as we highlight in the brief Part 4, the combination of investments in clean energy, manufacturing/infrastructure, and land restoration/agriculture will therefore create about 235,000 jobs in Ohio, while providing the foundation for a long-term sustainable growth path for the state. This program builds from the Re-Imagine Appalachia Blueprint developed and endorsed by a wide range of organizations in the region.[1]

This summary first provides a brief overview of the entire study. It then presents a more detailed set of highlights of the main findings of Part 2.

Establishing effective public health interventions. This will generate hundreds of thousands of jobs through allowing the state to recover safely. The state's hospitality and tourism industries have been hardest hit by the pandemic, accounting for 30 percent of all job losses in the state resulting from the pandemic. These industries will therefore also benefit disproportionately from a safe and sustainable recovery. The health care industry has also experienced sharp job losses since March, despite the pandemic. It will therefore benefit greatly from a safe and sustainable reopening. Workers in all industries need to be provided with adequate Personal Protection Equipment so they can perform their jobs safely. They also need their rights at work to be fully protected, including the right to paid sick leave.

Clean Energy Investments and Job Creation. We estimate that the public and private investments needed in Ohio to achieve emission reduction targets consistent with the IPCC's goals are capable of producing an average of about 165,000 jobs per year in Ohio — i.e. 165,000 jobs in 2021, which then would carry over, on average, in 2022, 2023, etc. These investments will entail both: 1) greatly enhancing the state's level of energy efficiency, including through deep energy retrofits to public buildings; and 2) massively expanding the state's supply of clean renewable energy sources, starting with wind power and solar power. New job opportunities will open for, among other occupations, carpenters, machinists, environmental scientists, secretaries, accountants, truck drivers, roofers and agricultural laborers.

Just Transition for Displaced Workers in Fossil Fuel-Based Industries. Nearly 50,000 people are employed in Ohio in fossil fuel-based industries, including oil and gas extraction, support activities for oil and gas, coal mining, and other ancillary sectors, such as fossil fuel-based power generation. Workers in the state's fossil fuel-based will therefore experience job losses as the state dramatically reduces consumption of these CO_2-generating energy sources. We estimate that about 1,000 workers per year will be displaced in these industries between 2021 – 2030 while another roughly 1,000 will voluntarily retire each year. It is critical that all of these workers receive pension guarantees, health care coverage, re-employment guarantees, wage insurance, and retraining support, as needed.

Upgrading Ohio's Economic Base through Manufacturing, Infrastructure, Land Restoration and Agriculture Investments. Ohio's economy would receive an additional major boost, in terms of both short-run stimulus and longer-term productivity, by undertaking a large-scale investment—at about $7 billion per year, or 1 percent of the state's GDP—in these areas. The roughly 70,000 jobs that will be generated through these investments will include a wide range of occupations. In the manufacturing/infrastructure areas, nearly 30 percent of all employment in manufacturing/infrastructure will be in the construction industry, including jobs for pipelayers, electricians, and supervisors. The R&D investment areas will of course create employment for chemical, life science and engineering technicians. Jobs will also expand for truck mechanics, water treatment plant operators, and freight movers, as well as receptionists and bookkeeping clerks. With land restoration/agriculture, the largest expansion of employment will be for farmers, farm managers, and agricultural workers. These will be in addition to the expansion of jobs in the areas of office support and transportation.

Financing a Sustainable Recovery. The Ohio state budget, like all state and municipal-level budgets, face, at the least, great uncertainty with their prospects over the coming year. They also face the real possibility that they could experience massive revenue shortfalls as a result of the ongoing recession. Given this uncertainty, it is not possible to know what funding amounts from sources other than tax revenues within the state will be sufficient to move Ohio onto a viable recovery path.

Starting last March with the CARES Act, the federal government has injected about $46 billion into the state's economy, equal to nearly 7 percent of state GDP, to support state and local government budgets, private businesses and individual residents. We estimate that the state will need an additional $29 billion over the 2021 fiscal year (about 4 percent of 2019 GDP) to finance the initiatives we describe in this study — i.e. in the areas of cash assistance, unemployment insurance, Medicare support for unemployed workers, expanded public health and safety interventions, support for municipal governments, as well as the first phases of the investment programs in the areas of clean energy, manufacturing/infrastructure and land restoration/agriculture.

As of this writing in October, it is not clear how much additional support the federal government will provide through a second round of stimulus measures to meet these needs in Ohio. As such, we recommend that the state and local governments in Ohio develop contingency plans to support a strong recovery. It is critical to recognize that, by statute, the state does have the legal authority as well as the capacity to issue bonds to support capital projects. This capacity has been enhanced through the U.S. Federal Reserve Board's recently created "Municipal Liquidity Facility" which enables the Fed to purchase bonds from state and municipal governments. To date, the state government and municipalities in Ohio are able to sell up to $10.7 billion in bonds to the Fed. Ohio is also able to borrow at extremely low rates on the open market, with yields on Ohio's municipal bonds ranging between 0.6 and 0.7 percent as of 10/8/20. With Ohio's state and municipal governments being able to borrow at such low rates, the prospects are favorable for these public entities to support large-scale programs to counteract the crisis and move Ohio onto a sustainable long-term recovery path.

Parts 2 and 3 Highlights: Investments in Clean Energy Manufacturing, Infrastructure, and Land Restoration

These parts of the study examine the prospects for a transformative investment program for Ohio. The centerpiece of the program is clean energy investments, undertaken in combination by the public and private sectors throughout the state. The program will advance two fundamental goals:

- Promoting global climate stabilization by reducing carbon dioxide (CO_2) emissions in Ohio without increasing emissions outside of the state.
- Creating roughly 165,000 new jobs per year in the state between 2021 – 2030.

As we have described above, a complementary set of investments in the areas of manufacturing/infrastructure and land restoration/agriculture, scaled at about 1 percent of Ohio's

GDP per year, will raise productivity and enhance well-being in the state, while also generating over 70,000 jobs per year.

Reducing CO_2 Emissions

- The first goal for clean energy investments will be to achieve, by 2030, a 50 percent reduction in CO_2 emissions in Ohio relative to the 2018 emissions level.
  - Emissions in Ohio in 2018 were at 220 million metric tons after including emissions produced by bioenergy sources as well as oil, coal and natural gas. The emissions level as of 2030 will therefore need to be no more than 110 million tons.[2]

Major Areas of Clean Energy Investments

- ***Energy Efficiency.*** Dramatically improving energy efficiency standards in Ohio's stock of buildings, automobiles and public transportation systems, and industrial production processes.
- ***Clean Renewable Energy.*** Dramatically expanding the supply of clean renewable energy sources—including solar, wind, low-emissions bioenergy, geothermal, and small-scale hydro power—available at competitive prices to all sectors of Ohio's economy.
- ***Total Investment Expenditures.*** The level of investment needed to achieve Ohio's energy goals will average roughly $21.4 billion per year between 2021 – 2030.
  - This estimate assumes that Ohio's economic growth proceeds at an average rate of 1.5 percent per year.
  - Clean energy investments will need to equal about 2.8 percent of Ohio's annual GDP.
  - The average annual clean energy investment level of 2.8 percent of GDP means that more than 97 percent of Ohio's economic activity will be directly engaged in activities *other than* clean energy investments.

Clean Energy Investments Will Deliver Lower Energy Costs

- Raising efficiency standards enable consumers to spend less for a given amount of energy services.
- The costs of wind, solar, geothermal, and hydro power are all presently roughly equal to or lower than those for fossil fuels and nuclear energy.
- The average Ohio household should be able to save nearly 40 percent on their overall annual energy bill. This would be after they have paid off their initial up-front efficiency investments, to purchase, for example an electric vehicle, over five years.

Job Creation through Clean Energy Investments

- Investing an average $21.4 billion per year in clean energy projects in Ohio over 2021 – 2030 will generate nearly 165,000 jobs per year in the state. That is, in 2021, the Ohio economy will operate with 165,000 more jobs than would have been available without the clean energy investments, and this same enhanced level of 165,000 job opportunities will continue on in 2022, 2023, etc.

- New job opportunities will be created in a wide range of areas, including construction, sales, management, production, engineering, and office support.
- Current average total compensation in these occupations mostly range between $50,000 - $70,000 per year.
- Employment growth in these areas should create increased opportunities for women and people of color to be employed and to raise unionization rates.
- Higher unionization rates should promote gains in compensation and better working conditions in the affected industries.
- Good-quality worker training programs will be needed to ensure that a wide range of workers will have access to the jobs created by clean energy investments and that the newly-employed workers can perform their jobs at high productivity levels.

Just Transition for Fossil Fuel Industry Dependent Workers and Communities

- About 85 percent of all energy consumption in Ohio comes from burning natural gas, oil, coal and high-emissions bioenergy. Consumption of oil, gas and biomass will all need to fall by 40 percent and coal by 70 for the state to reduce CO_2 emissions by 50 as of 2030.
- Almost 50,000 workers in Ohio are presently employed in the state's fossil fuel-based and bioenergy industries.
- We estimate that total job displacements will average 1,010 per year.
  - This is after allowing that an average of 1,105 workers per year will voluntarily retire.
- A just transition program for these roughly 1,000 workers per year presently employed in Ohio's fossil fuel-based and bioenergy industries should include five components:
  - Pension guarantees for retired workers who are covered by employer-financed pensions;
  - Retraining to assist displaced workers to obtain the skills needed for a new job;
  - Re-employment for displaced workers through an employment guarantee, with 100 percent wage insurance.
  - Relocation support for all workers who require this support; and
  - Full just transition support for older workers who choose to continue past the traditional retirement age of 65.
- The average costs of supporting these workers will amount to about $145,000 per worker. Overall costs will amount to about $145 million per year over the duration of the just transition program.

Achieving Net Zero Emissions by 2050

- Ohio can become a zero emissions economy by 2050 through continuing its clean energy investment program.

- Ohio will be able to also absorb significant amounts of the existing stock of CO_2 in the atmosphere through programs to support organic agriculture and afforestation.
- Average clean energy investments would need to equal about 1.8 percent of state GDP per year over 2031 – 2050.
- Average job creation through these clean energy investments will range between 120,000 – 130,000 jobs per year.
- Just transition support for displaced workers over 2031 – 2050 will amount to an average of about $120 million per year. We estimate this amount will equal about 0.01 percent of Ohio's average GDP between 2031 – 2050.

Investments in Manufacturing, Infrastructure, Land Restoration and Agriculture

- In 2019, the American Society of Civil Engineers (ASCE) gave an overall grade of D+ to Northeastern Ohio's public infrastructure, and provided a similar assessment for the rest of the state's infrastructure in 2017.
- Reimagine Appalachia has proposed to revitalize and update the 1930s-era Civilian Conservation Corps into a modern-day employment creation, job training and conservation program.
- We outline an investment program to address these and related concerns at a level of about $7 billion per year, equal to 1 percent of Ohio's current GDP. Major areas of focus include broadband; water management; manufacturing and bioplastics R&D; repairing leaky gas pipelines; regenerative agriculture; farmland conservation; plugging orphaned oil and gas wells; and land restoration.
- Investing $ 7 billion per year in these areas would generate about 73,000 jobs per year within Ohio.

Overall Net Job Creation through Clean Energy, Manufacturing, Public Infrastructure, Land Restoration and Agriculture Investments

- Our annual average job estimates for 2021 – 2030 include:
    - 165,000 jobs per year $21 billion in spending on energy efficiency and clean renewable energy.
    - 30,000 jobs per year through investing $3.5 billion in manufacturing and public infrastructure.
    - 43,000 jobs per year through investing $3.5 billion in land restoration and agriculture.
- The total employment creation through clean energy, manufacturing/infrastructure and land restoration/agriculture will total to about 235,000 jobs.
- Net job creation will average about 4 percent of Ohio's workforce as of 2019.

PART 1:

PANDEMIC, ECONOMIC COLLAPSE, AND CONDITIONS FOR REOPENING OHIO

1.1 The Pandemic in Ohio

The State of Ohio, like the rest of the United States, has been experiencing an historically unprecedented public health and economic crisis since the COVID-19 pandemic emerged full force in mid-March.

Table 1.1 provides some basic statistics on infection and death rates from COVID in Ohio, and for comparison, neighboring states, the U.S. overall as well as selected other high income countries. As we see, as of 9/6/20, there have been 130,558 reported cases in Ohio, and 4,259 deaths attributed to COVID. Of course, these figures are tragically high. But it is notable that the infection and death rates in Ohio are more modest than in the U.S. overall. As Table 1 shows, in terms of infections per million, Ohio's figure, at 11,609, is roughly 39 percent lower than the U.S. figure of 19,121 per million. Ohio's death rate, at 379 deaths per million, is roughly 34 percent lower than the U.S. figure of 576 per million. In comparison with neighboring states, Ohio also trends in the lower half. Cases and fatalities per million in Ohio are respectively 24 and 26 percent lower than in Indiana and respectively 6 and 47 percent lower than in Michigan. Ohio is on par with Pennsylvania in terms of infections per million but has a 39 per cent lower death rate.

At the same time, Ohio's experience is not favorable in comparison with high-income countries that have managed the COVID pandemic effectively. As we also see in Table 1, Ohio's infection rate is more than 3 times higher than that for Canada and its death rate is 55 percent higher. Ohio's experience is still less favorable relative to Australia, Japan, and South Korea. As Table 1.1 shows, Ohio's infections per million are over 11 times higher than those

TABLE 1.1
Ohio COVID-19 Infection and Death Rates in Comparison with USA, Other New England States, and Other Countries
Figures as of 9/6/20

	Confirmed infections		Confirmed deaths	
	# of Infections	Infections per million	# of Deaths	Deaths per million
Ohio	130,558	11,609	4,259	379
United States *overall*	6,276,213	19,121	188,938	576
Indiana	99,804	15,213	3,364	513
Michigan	117,191	12,333	6,806	716
Pennsylvania	143,824	11,572	7,750	624
Canada	133,877	3,562	9,193	245
Australia	26,321	1,038	762	30
Japan	71,918	570	1366	11
South Korea	21,296	412	336	7

Sources: Johns Hopkins University 8/23/20 and 9/6/20 data files. World Bank for other countries' population data. Per million and percentage figures have been rounded.

for Australia (11,609 vs. 1,038), 20 times higher than Japan's 570 infections per million, and 28 times higher than South Korea's 412 infections per million. Ohio's deaths per million are 13 times higher than Australia's (379 versus 30), 35 times higher than Japan's 11 deaths per million and 58 times higher than South Korea's 7 deaths per million.

In short, despite the relatively favorable results in Ohio within the U.S., the comparative evidence from Canada and especially Australia, Japan and South Korea make clear that Ohio's public health interventions during the COVID pandemic could have been far more effective. What more can be done in Ohio becomes especially clear when examining more detailed evidence that focuses on the more heavily affected groups within the state.

To begin with, nursing homes and other care facilities are a tragic focal point in Ohio, as throughout the U.S. As of September 2, 13,347 nursing residents had been infected with COVID-19, and 2,341 died of the disease.[3] These deaths account for 55 percent of all fatalities in Ohio. Moreover, 6,573 nursing home staff have been infected, or 5 percent of all infections.[4] Health care workers in Ohio more generally have been heavily exposed to COVID infections, as elsewhere in the country. Though up-to-date figures are not available, we do know that, as of April 13, 1,300 health care workers in the state had been infected. This accounted for 20 percent of all statewide infections.[5] The Black, indigenous and people of color (BIPOC) communities are experiencing far higher rates of infections than whites. For instance, while 12 percent of Ohio's population identifies as Black or African American, 25 percent of all infections and 19 percent of all deaths in the state are reported by Black or African Americans.[6]

People working in lower income jobs also face a higher likelihood of being exposed to COVID infections. While no systematic data for Ohio have been published to date, evidence from elsewhere in the U.S. illustrates the point. In Los Angeles County, in areas where more than 30 percent of residents live in poverty, 303 people per 100,000 residents were infected, compared with 156 people per 100,000 in areas where less than 10 percent live in poverty. Residents of those low-income communities also are more likely to die of the virus, at a rate of 15 deaths per 100,0000 residents, twice the rate of people in the wealthier areas.[7] Similar infection-rate disparities between low- and high-income zip codes have been confirmed across the U.S.[8] Further, a study for Western Massachusetts found that workers earning less than $20 per hour were 2-3 times more likely than those earning above $40 per hour to lack access to protective measures.[9]

This finding is even more significant since lower income workers are also much less likely to be able to work from home. According to the U.S. Bureau of Labor Statistics, only 6.6 percent of full-time workers in the lowest quartile of earnings have been able to work remotely in their primary place of employment, while 55.5 percent of those in the highest quartile of earnings have been able to work remotely.[10] Since the intersection between low income workers and BIPOC communities is high, these communities face much higher levels of risk from COVID than the population overall.[11]

1.2 Ohio's Economic Collapse

Current Conditions

As with the U.S. economy overall, the Ohio economy has experienced an unprecedented collapse resulting from the COVID pandemic. As one clear measure of this, we show in Table 1.2 figures on job losses in Ohio since the onset of the pandemic in mid-March. Specifically, we report on initial unemployment insurance claims by workers in Ohio from March 10 until September 5. As Table 1.2 shows, this figure for numbers of people in the state who lost their jobs and filed to receive unemployment insurance over this period totals to 1.7 million. This figure amounts to 29.2 percent of Ohio's workforce as of February 2020. That is, over the six-month period beginning with the onset of the pandemic, nearly 30 percent of all workers in Ohio experienced job loss and filed for unemployment insurance.

For comparison, we show in the second column of Table 1.2 the figures over the same time period in 2019. As we see, in the same time period a year ago, total initial unemployment claims over this three-month period totaled to 154,252, equal to 2.7 percent of Ohio's workforce at that time. In other words, job losses over March – September 2020 jumped *11-fold* over the same time period last year.

We also report the comparable figures for the U.S. overall in rows 3 and 4. As we see, the figures for Ohio match closely with those for the overall U.S. economy. With the overall U.S. economy, job losses between March 10 and September 5 2020 were at 34.2 percent of the labor force then, while over the same time period a year ago, that figure was at 3.2 percent.

TABLE 1.2
Job Losses in Ohio and U.S. During COVID-19 Pandemic and One Year Prior

Initial Unemployment Insurance Claims:
Weekly Figures Covering March 10 – September 5, 2020 and March 10 – September 7, 2019

	3/10/20 – 9/5/20 Figures	3/10/19 – 9/7/19 Figures
Figures for Ohio		
1. Number of people filing initial unemployment insurance claims	1.7 million	154,252
2. Number of claims as share of February workforce	29.2%	2.7%
Figures for U.S.		
3. Number of people filing initial unemployment insurance claims	56.3 million	5.2 million
4. Number of claims as share of February workforce	34.2%	3.2%

Sources: Federal Reserve Bank of St. Louis, FRED database.

These figures on job losses are consistent with survey evidence on how Ohioans have experienced the pandemic and recession. Thus, Ohio ranked third among all 50 U.S. states in terms of the degree of economic distress state residents have experienced due to the COVID-generated recession. The survey, conducted in May 2020 by SmartAsset, ranked states according to several indicators, including food insufficiency, housing insecurity, and the state's poverty rate, along with the state's unemployment rate. According to the survey nearly 13 percent of Ohioans were experiencing food insufficiency as of May, 14 percent were in poverty and 25 percent were experiencing housing insecurity.[12]

Prospects for 2021 and Beyond

Writing in September 2020, it is impossible to provide a confident forecast as to how rapidly or fully the Ohio economy is likely to recover from its collapse. Thus, in June, the Federal Reserve Bank of Cleveland developed three alternative scenarios for a post-COVID recovery, focused specifically on the issue of the tax revenues that the state has lost due to the recession and the prospect of revenues returning to their pre-COVID levels. The three scenarios were: 1) a rapid "V-shaped" recovery in which the state's tax revenues returns to its pre-crisis level by the end of 2020; 2) a "slow" recovery in which the state requires a full year to regain its pre-crisis revenue levels; and 3) a "second wave" scenario, in which the state is forced to move into a second lockdown mode before the end of 2020. Ohio does not fully recover its pre-COVID revenue base until the end of 2021.[13]

The Cleveland Fed report did not offer a judgement as to which of its three scenarios is most likely to result. However, writing in September, we can be close to certain that the most optimistic V-shaped recovery is not on track to occur. In fact, the assessment as of August of Kim Murnieks, the Director of the Ohio's Office of Budget and Management is more negative than even the Cleveland Fed's most pessimistic scenario. Murnieks predicted in August that the state's government revenue levels will not return to their pre-COVID levels until "calendar year 2024 and perhaps beyond."[14]

The fact that the state's highest budget office foresees three or more years for Ohio to achieve a full recovery to the level of 2019 underscores the imperative of enacting public policies to strengthen and accelerate the recovery. The policy measures advanced in this study can be understood as addressing this critical challenge.

Industry-Specific Contractions and Job Losses

We can obtain a more detailed perspective on Ohio's current economic crisis by examining data on changes in employment level by industry, combining figures for June and July 2020 with comparable figures for June/July 2019. We report these figures in Tables 1.3 and 1.4.

The first set of figures in Table 1.3 presents job loss *within* each industry, both for Ohio and the U.S. overall. The second set of figures in Table 1.4 shows the contributions, industry-by-industry, to Ohio's *overall* decline in employment relative to 2019. In the second set of figures, we incorporate the size of each industry in terms of employment prior to the crisis. This allows us to measure the relative contribution of each industry to overall job losses based on both 1) the size of the industry; and 2) the industry's job loss rate. Here again, we compare the figures for Ohio with those for the U.S. overall.[15]

TABLE 1.3
Job Losses within Industries, Ohio and U.S. Percentages
Figures are employment figures, not seasonally adjusted, from June/July 2019 to June/July 2020

Ohio: *Decline in state employment = 9.2%*		**United States:** *Decline in national employment = 12.5%*	
Leisure and hospitality	-26.5%	Leisure and hospitality	-44.3%
Mining and logging	-17.6%	Other services	-19.9%
Professional and business services	-9.8%	Mining and logging	-13.5%
Government	-8.2%	Trade, transportation, and utilities	-10.7%
Information	-7.3%	Manufacturing	-9.7%
Other services	-7.0%	Professional and business services	-9.0%
Education and health services	-6.7%	Construction	-8.9%
Construction	-6.4%	Information	-8.7%
Manufacturing	-6.3%	Education and health services	-8.4%
Trade, transportation, and utilities	-6.0%	Government	-4.8%
Financial activities	-4.6%	Financial activities	-1.7%

Sources: U.S. Labor Department.

TABLE 1.4
Share of Total Job Losses by Industry, Ohio and U.S. Percentages
Figures are employment figures, not seasonally adjusted, from June/July 2019 to June/July 2020

Ohio: *Decline in state employment = 9.2%*			**United States:** *Decline in national employment = 12.5%*		
	% of state employment	Industry job loss as % of total state employment loss		% of U.S. employment	Industry job loss as % of overall U.S. employment loss
Leisure and hospitality	10.7%	-2.8%	Leisure and hospitality	11.0%	-4.9%
Professional and business services	13.2%	-1.3%	Trade, transportation, and utilities	18.2%	-2.0%
Trade, transportation, and utilities	18.3%	-1.1%	Education and health services	16.0%	-1.3%
Education and health services	16.6%	-1.1%	Professional and business services	14.1%	-1.3%
Government	13.5%	-1.1%	Other services	3.9%	-0.8%
Manufacturing	12.6%	-0.8%	Manufacturing	8.5%	-0.8%
Other services	3.9%	-0.3%	Government	15.2%	-0.7%
Construction	4.2%	-0.3%	Construction	4.9%	-0.4%
Financial activities	5.6%	-0.3%	Information	1.9%	-0.2%
Information	1.2%	-0.1%	Financial activities	5.8%	-0.1%
Mining and logging	0.2%	0.0%	Mining and logging	0.5%	-0.1%

Sources: U.S. Labor Department.

As we see first, in Table 1.3, the employment level declines for all 11 economic sectors listed. Ohio's economic crisis is clearly widespread. At the same time, the extent of decline varies greatly by industry. The most heavily impacted industry is leisure and hospitality. Here the employment decline was nearly 27 percent between June/July 2020 relative to the 2019 level. Five other industries experienced employment declines of 7 percent or greater and all but one of the industries saw job losses of at least 6 percent relative to 2019. Overall, state employment in Ohio fell by 9.2 percent in June/July 2020 relative to 2019.

Despite Ohio's heavy job losses due to the COVID pandemic, the state's employment decline has been somewhat less acute than that for the U.S. overall. Thus, for the U.S. overall, the overall employment decline was 12.5 percent in June/July 2020 relative to June/July 2019. The leisure and hospitality job losses for the U.S. overall, at 44.3 percent, were significantly more severe than the 26.5 percent decline in Ohio. Despite these somewhat less severe employment figures for Ohio, the fact that the state's downturn has been the third worst in the U.S. as measured by food insufficiency, housing insecurity, and poverty conveys the precarious economic circumstances experienced by Ohio's population.

In Table 1.4, we see that, after taking account of the relative size of each of the industries in Ohio's economy, the leisure and hospitality industry remains as the largest drag on overall employment. Thus, job losses in leisure and hospitality account for 2.8 percentage points of the state's overall 9.2 percent level of job loss—i.e. the contraction of the leisure and hospitality industry accounts for about 30 percent of Ohio's overall job losses. Otherwise, four other sectors each account for over 1 percentage point of the state's 9.2 percent decline—professional and business services; trade, transportation and utilities; education and health services; and government.

The employment losses in education, health, and government might be among the most difficult from which to recover to the extent that they remain dependent on inflows of tax revenue. In addition, the state's leisure and hospitality industry will not return to its 2019 level of activity until the public health issues around COVID-19 have been successfully brought under control. Both of these considerations underscore the priority of the state undertaking large-scale investments in clean energy and public infrastructure in conjunction with increasing its budgets in the areas of health care and public education. Increasing state-level deficit financing may be necessary to advance these investment priorities both as a package of short-term stimulus interventions and to move Ohio onto a long-term sustainable growth path. These are the issues we will examine in Sections 2 and 3 of this study.

1.3 Conditions for Reopening Ohio's Economy

Any viable economic recovery program for the state must begin with measures that establish and sustain the highest possible standards for protecting public health.

The first confirmed cases in Ohio were reported on March 9. The state's Department of Health Director Amy Acton issued a stay-at-home order on March 23. The full state lockdown continued until May 1. The fact that Ohio has experienced somewhat fewer infections and deaths per capita from COVID than the average for the U.S. is due, at least in part, to the establishment of the strong lockdown conditions during late March and throughout April.

The state began a phased reopening on May 1, enabling hair salons and restaurants to resume operations subject to certain safety rules. Manufacturing, construction and most office activity were able to resume operations that same week. Consumer retail reopened the following week. Bars, campgrounds and gyms then reopened as of the third week of May. Gatherings of up to 300 people were permitted as of June 1. Practice for full contact sports resumed as of June 22.[16]

The state's daily infection rates began to rise again during the first week of June and continued to rise through the middle of July. Since then, the state's infection rate has been on a modestly downward trend through mid-September, even while the average level of infections and deaths remains above the rates that prevailed over the April – May lockdown months. Hospital beds and intensive care units were at 66 – 68 percent of capacity as of mid-September, which is considered "normal," and therefore sufficient to manage the state's existing caseloads for COVID and all other forms of care. However, as of mid-September, the state was still 12 percent below the target testing rate and the state's positive test rate, at between 3.5 and 4 percent, remains above the target rate of 3 percent or below. The state's death rate from COVID was trending upward in this period. Overall, the assessment of the website CovidExitStrategy.org was that, as of September 17, Ohio was "trending poorly" even while some positive developments have also emerged.[17]

The first priority for Ohio is therefore to raise its public health standards, to enable the economy to begin to return to normalcy as soon as possible. This would mean, among other things, succeeding in lowering the positive testing rate below 3 percent and maintaining the figure at that low level on a sustained basis. The state also needs to reverse the most recent upward movement of death rates. Towards that end, the state needs to expand its testing facilities and contact tracing operations and ensure that hospitals and other treatment facilities have adequate resources to handle COVID cases. Achieving these targets will become increasingly challenging as the weather turns colder and Ohioans spend more time indoors.

Expanding Medicare Coverage

The sharp increase in job losses in Ohio, as with the U.S. overall, has meant that millions of unemployed workers have lost the health care coverage they had been receiving through their employer. These workers need to be guaranteed health insurance coverage at least over the full course of the pandemic.

In May 2020, Representatives Pramila Jayapal and Joe Kennedy proposed the Medicare Crisis Program, as a measure that would provide support to families over the course of the pandemic and severe economic downturn.[18] Senator Bernie Sanders introduced a similar measure in the U.S. Senate, the Health Care Emergency Guarantee Act.[19]

The Medicare Crisis program would enable anyone who has filed for unemployment insurance due to the COVID-19 crisis to receive traditional Medicare support for themselves and their families. This will include any testing or treatments related to COVID-19 itself. In addition, under Medicare Crisis, the federal government also absorbs all cost-sharing for unemployed workers and their families, including deductibles, co-payments and any additional out-of-pocket expenses. These costs are normally paid by Medicare enrollees themselves.

Further, under the Medicare Crisis program, all ongoing Medicare enrollees—whether or not they have become unemployed due to the pandemic and economic downturn—will receive additional health insurance benefits. This will include COVID-19 testing and treatment at no costs, as well as a cap on cost sharing for all other treatments at 5 percent of income.

To date, neither this Jayapal-Kennedy proposal in the House of Representatives, nor the equivalent Sanders bill in the Senate, have been included in any version of the HEROES Act or any other overall federal stimulus proposals. Nevertheless, this proposal needs to be integral to any recovery project, for Ohio and the U.S. more generally. The reasons include the following:

1. It provides critical income support for workers and their families, especially workers who are already unemployed.
2. It will provide an overall boost to the economic recovery. Otherwise, families of unemployed workers are likely to face major new financial burdens due to their loss of health insurance.
3. Without guaranteed health coverage, people will be reluctant to get tested and treated for COVID. This will therefore prolong the ongoing spread of the virus. As such, it will also inhibit the prospects for a sustainable recovery.

Because this kind of initiative is so critical to a successful reopening and economic recovery, it is a measure that Ohio should enact on its own at the state level if it is not incorporated in any upcoming rounds of federal stimulus legislation. In Section 3, we provide a rough cost estimate of such a statewide proposal.

Workers' Rights Protections

The public health provisions described in this section must be matched by a corresponding level of rights and protections extended to all workers in Ohio during the pandemic and economic crisis. As a minimum, all workers in the state must have the right to guaranteed paid sick leave. Such an initiative should be understood as a measure that protects the health and well-being of the workers themselves but equally, the health and well-being of the overall community. Of course, workers who feel compelled to come to a public workplace even if they are experiencing COVID-like symptoms are endangering the health of the entire community.

The Ohio Department of Job and Family Services announced on July 6 that up to 20 weeks of extended benefits will be available to eligible Ohioans who exhaust both the maximum 26 weeks of regular unemployment benefits and 13 weeks of Pandemic Emergency Unemployment Compensation.[20] Governor DeWine also signed an executive order that expands the definition of good cause throughout the COVID-19 State of Emergency.[21] But much more will be needed.

In short, a viable recovery program for Ohio must include an enhanced commitment to protecting workers' rights at all levels of the state economy, starting with its most vulnerable workers.

PART 2:

CLEAN ENERGY INVESTMENTS, JOB CREATION, AND JUST TRANSITION

2.1 Ohio's Existing Clean Energy Policies

To date, the State of Ohio has had a mixed record in advancing climate change policies. Most recently, the Ohio legislature passed and Governor Mike DeWine signed House Bill 6 in 2019. The main features of this bill included surcharges for Ohio's electricity consumers to support two failing coal plants in the state owned by the Ohio Valley Electricity Corporation. The bill also includes surcharges to subsidize two nuclear power stations owned by First Energy Solutions.

This same bill reduced the state's renewable portfolio standard — i.e. the share of electricity that the state's utilities are required to produce through renewable sources, such as solar, wind or hydro power. Prior to passage of House Bill 6, the state was already operating with a very modest renewable portfolio standard, which was producing 12.5 percent of the state's electricity from renewable sources by 2027. House Bill 6 lowered the standard to 8.5 percent from renewables by 2026. The state's renewable portfolio standard would then also be terminated altogether in 2026.

House Bill 6 also lowered the energy efficiency standard for the state — i.e. the rate at which utilities need to reduce energy consumption to generate a given amount of electricity. Prior to the 2019 bill, the state's energy efficiency standard was to reduce energy consumption for generating electricity by 22 percent as of 2027 relative to 2008. Under House Bill 6, the efficiency standard was reduced to 17.5 percent by 2026. In addition, according to this measure, the state's utilities would then no longer be required to maintain an energy efficiency standard after 2026.[22]

The 2020 bill was preceded by comparable measures over the past decade. Thus, the 2014 Senate Bill 310 froze the state's renewable energy and energy efficiency standards across the board for 2014 – 2016. The 2011 Senate Bill 315 established a "comprehensive energy strategy" for Ohio whose main purpose was to facilitate the expansion of the state's fracking industry.[23] Clearly, none of these measures were aimed at supporting a clean energy transition for Ohio or achieving a net zero statewide economy by 2050.

At the same time, Ohio does also have in place a range of measures that provide important components of a framework on which to base a robust clean energy transition program for Ohio. These include the following:

1. **The Clean Energy Loan Fund.**[24] This fund is financed through recovering the costs of the state's energy efficiency programs. It provides small grants for energy efficiency and renewable energy projects.
2. **Property Assessed Clean Energy (PACE) Funding.**[25] This enables property owners in "Special Energy Improvement Districts" to take out loans to finance renewable energy and energy efficiency projects. These loans are then repaid through specially assessed taxes. This strengthens the security of the loans, which in turn reduces financing costs for borrowers.
3. **Clean Vehicle Incentives.**[26] Ohio offers a range of programs to help finance purchases of electric cars and other low- to zero-emissions vehicles in the state. The program also provides support for purchasing and installing alternative fuel, blending and distribution facilities, such as electric car charging stations.

4. **Energy Efficiency Grant Program for Manufacturers.**[27] Ohio manufacturers can receive grants from both the Federal government and the Ohio Advanced Energy Fund to reduce the costs they face in implementing energy efficiency improvements to their facilities.
5. **Home Weatherization Assistance Program.** Eligible participants include households that are at or below 200 percent of the U.S. poverty line. They can receive assistance for improving the efficiency of their homes. They also receive a free energy audit as part of the process to determine needed improvements.
6. **Net Metering.** Ohio's utilities are required to provide net metering to its customers—that is, for the customers to be able to sell to the utility the energy they generate on their own through solar panels or, in some cases, wind turbines. However, the program only applies to when total private-generated power is less than 1 percent of the providers' aggregate customer peak demand for the state. The utility is not required to purchase the privately-generated electricity once that private supply exceeds 1 percent of the utility's peak demand. The price at which the utility must purchase the privately-generated electricity is also below full retail prices.
7. **Revenue Decoupling.**[28] This enables electric utilities in Ohio to set electricity prices relative to the utilities' costs, after allowing for consumption levels to fall through raising efficiency standards.

In addition to these programs in place at the state level, Ohio's cities and municipalities have developed their own climate stabilization programs. Thus, in 2018, Cleveland adopted the goal of reducing its greenhouse gas emissions by 80 percent as of 2050, with an interim goal of a 40 percent reduction as of 2030. Similarly, Cincinnati introduced its "Green Cincinnati Plan" that includes 80 steps to achieve an 80 percent reduction in CO_2 emissions by 2050.[29]

In their various ways, all of these initiatives are supportive of moving Ohio onto a clean energy transition path. But to date, none of them operate at a large enough scale relative to the challenge of achieving a 50 percent reduction in state-level CO_2 emissions as of 2030 and to make Ohio a net zero emissions economy as of 2050. In Section 2.7, we will describe the scale of clean energy investment activity that will be necessary to successfully move Ohio onto a clean energy transition path.

At the same time, even if these measures were to operate on a much larger scale, they would still need to be supported by strong regulatory policies in the state. This should include effective renewable portfolio and energy efficiency standards. That is, the weakening or outright elimination of the renewable portfolio and energy efficiency standards enacted in 2019 through House Bill 6 will need to be reversed in order for Ohio to move onto a clean energy transition path.

All such initiatives to move Ohio onto a clean energy transition path will also have to be fully complemented by just transition policies that will support the workers and communities in Ohio that are presently dependent on the state's fossil fuel industries for their livelihoods. We will examine the features of a just transition program for Ohio in detail in Section 2.9.

2.2 Energy Sources and CO_2 Emissions for Ohio

In this section, we review the sources of energy supply and demand in Ohio, as well as the factors generating CO_2 emissions in the state. This discussion will provide necessary background for advancing a viable framework for reaching the state's emission reduction goals for 2030 and 2050.

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

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

	Buildings						
	Residential	Commercial	All buildings	Industrial	Transportation	TOTAL	% of TOTAL
1. Total	**923.8**	**705.6**	**1,629.4**	**1,205.8**	**920.7**	**3,755.9**	---
2. % of Total	**24.6**	**18.8**	**43.4**	**32.1**	**24.5**	**100.0**	
3. Natural gas[1]	442.9	296.2	739.0	442.1	31.2	1,212.3	32.3
4. Petroleum[2]	34.3	37.0	71.3	189.4	849.9	1,110.6	29.6
5. Coal	215.0	186.3	401.3	316.4	0.1	717.8	19.1
6. Nuclear	68.2	59.1	127.3	64.2	0.0	191.5	5.1
7. Bioenergy	23.7	6.6	30.3	64.6	39.4	134.3	3.6
8. Wind	5.4	4.7	10.2	5.1	0.0	15.3	0.4
9. Geothermal	2.6	0.8	3.4	0.0	0.0	3.4	0.1
10. Hydro	0.8	0.7	1.5	0.7	0.0	2.2	0.1
11. Solar	1.0	1.4	2.4	0.4	0.0	2.8	0.1
12. Net interstate flow of electricity[3]	--	--	--	--	--	365.3	9.7
13. Net electricity imports	--	--	--	--	--	0.3	0.0

Notes:
1. Includes supplemental gaseous fuels that are commingled with natural gas.
2. Petroleum includes motor gasoline, distillate fuel oil, jet fuel, HGL, residual fuel and other petroleum. Co-mingled fossil fuels are excluded.
3. Electricity use is distributed within each energy source and sector. Electricity figures include losses distributed by source and sector.
Source: https://www.eia.gov/state/?sid=OH.

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 Ohio in 2018 was 3,755.9 trillion BTUs, or approximately 3.8 Q-BTUs. This means that, roughly, 1 Q-BTU would be able to provide for Ohio, at its 2018 consumption level, slightly more than all the energy consumed for all purposes over 3 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 Ohio's economy. As we see, about 43 percent of all consumption is used to operate buildings (1,629.4 T-BTUs), both residential and commercial structures. Of the remaining 57 percent, 32 percent is used for industrial activity (1,205.8 T-BTUs) and the remaining 25 percent for transportation (920.7 T-BTUs). Nearly 10 percent of all energy consumed in Ohio is imported from other states as electricity

In rows 3 – 12 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 Ohio, providing about 32 percent of all the state's energy supply. About 61 percent of natural gas petroleum is used for buildings in Ohio, with most of the rest used in industry. Petroleum is nearly as large as an energy source in Ohio, at about 30 percent of all supply, and with 77 percent of petroleum used for transportation and most of the rest for industry. The contribution of coal is still substantial, at 19 percent of all supply, with coal being used primarily for buildings (56 percent) and industry (44 percent). Nuclear energy supplies about 5 percent of Ohio's total energy supply.

The most heavily consumed renewable energy source in Ohio is bioenergy, at 134 T-BTUs, equal to 3.6 percent of the state's energy supply. However, as we discuss below, bioenergy is not necessarily a clean renewable energy source. Within a 30-year cycle, emissions levels from wood and other plant-based raw materials are comparable to coal when burned directly, and to petroleum when converted into liquid biofuels. Bioenergy can become a low-emissions energy source. But this requires that the raw materials for producing energy are either waste products, such as waste grease or agricultural wastes such as corn stover, or cheap and rapidly growing plants such as switchgrass, and that these raw materials are refined into biofuels by relying on clean rewnable energy sources. We assume that such low-emissions bioenergy sources can develop in Ohio between 2021 – 2030.[30]

The supply of energy provided in Ohio by all clean renewable energy sources combined—i.e. wind, solar, hydro and geothermal—remains negligible as of 2018, accounting for only 0.7 percent of Ohio's total energy supply. Among the clean renewable sources, wind power is the most developed in the state, at 0.4 percent of total supply. It is clear that expanding overall energy supply in Ohio from clean renewable sources will be a formidable challenge.

Electricity Supply and Demand

To further clarify the profile of energy consumption in Ohio, we show data in Tables 2.2 and 2.3 on the uses and sources of electricity in the state.

Electricity, of course, is unique in that it is an intermediate energy source, relying on several primary sources—including natural gas, coal, and nuclear energy as its primary sources in Ohio —for its generation. It is also unique in that, as Table 2.2 shows, approximately 56 percent of all energy consumed is lost in the conversion process from the primary energy sources to electricity supply, while only 44 percent is channeled into energy that is consumed. That is why, as we see in Table 2.2, electricity production requires 1,180 T-BTUs of Ohio's total energy consumption, amounting to 31 percent of all energy consumed in the state, while, as an energy source to final consumers in the state's building, transportation and industrial sectors, electricity provides only about 522 T-BTUs, or 14 percent of the total energy supplied. One evident way to raise energy efficiency, in Ohio and elsewhere, would therefore entail reducing the percentage of energy losses through electricity use.[31]

In terms of electricity demand, we see in Table 2.3 that the most prevalent use is for the operation of buildings, accounting for about 66 percent of all electricity demand. Industrial processes utilize the remaining 34 percent of all electricity. At present, electricity is not used to a measurable extent in transportation. But the share of electricity demand for transportation would rise sharply if the use of electricity-powered vehicles were to grow significantly.

Table 2.3 also shows the primary energy sources used in Ohio to generate electricity. As we see, the largest source is still coal, at 51 percent, with natural gas at 29 percent and nuclear at 16 percent. It therefore follows, again, if the state is going to achieve dramatic reductions in generating CO_2, this will require a massive growth of clean renewable energy supply and the state's energy infrastructure will need to operate at a greatly enhanced level of energy efficiency.

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

Total energy consumed in generating electricity	1,180.4 TBTUs *(31.4% of state energy consumption)*
Electricity consumption as share of overall energy consumption	521.7 T-BTUs (*13.9% of state energy consumption)*
Energy losses as share of energy consumed in generating electricity	55.8%

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

TABLE 2.3
Ohio Electricity Consumption, 2018
Figures are T-BTUs

	Buildings					
	Residential	Commercial	All buildings	Industrial	Transportation	TOTAL
Coal	95.0	82.4	177.4	89.4	0.1	266.9 *51.2% of total*
Natural gas	53.8	46.6	100.3	50.6	0.0	150.9 *28.9% of total*
Nuclear	30.2	26.1	56.3	28.4	0.0	84.7 *16.2% of total*
Petroleum	2.9	2.5	5.4	2.7	0.0	8.1 *1.6% of total*
Wind	2.4	2.1	4.5	2.3	0.0	6.8 *1.3% of total*
Bioenergy	1.1	0.9	2.0	1.0	0.0	3.0 *0.6% of total*
Hydro	0.3	0.3	0.6	0.3	0.0	1.0 *0.2% of total*
Solar	0.2	0.1	0.3	0.1	0.0	0.4 *0.1% of total*
Geothermal	0.0	0.0	0.0	0.0	0.0	0.0 *0.0% of total*
Total	185.8	161	346.8	174.8	0.1	521.7
Share of total (in %)	36%	31%	66%	34%	0%	100%

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

2.3. What Is Clean Energy?

In this section, we consider the extent to which alternative energy sources and technologies can serve effectively to reduce CO_2 emissions in Ohio by approximately 50 percent and to transform the state into a net zero emissions economy by 2050. We begin with natural gas, which, as we have seen, is the most heavily consumed energy source in the state at present.

Natural Gas

There are large differences in the emissions levels resulting through burning oil, coal, and natural gas respectively, with natural gas generating about 40 percent fewer emissions for a given amount of energy produced than coal and 15 percent less than oil. It is therefore widely argued that natural gas can be a "bridge fuel" to a clean energy future.[32] Such claims do not withstand scrutiny. To begin with, emissions from burning natural gas are still substantial, even if they are lower than coal and petroleum. As a straightforward matter, it is not possible to get to a net zero economy through increasing reliance on CO_2-emitting natural gas energy. But it is also imperative, in calculating the full emissions impact of natural gas, that we take account of the leakage of methane gas into the atmosphere that results through extracting natural gas through fracking. Recent research finds that when more than about 5 percent of the gas extracted leaks into the atmosphere through fracking, the impact eliminates any environmental benefit from burning natural gas relative to coal. Various studies have reported a wide range of estimates as to what leakage rates have actually been in the United States, as fracking operations have grown rapidly. A recent survey paper puts that range as between 0.18 and 11.7 percent for different specific sites in North Dakota, Utah, Colorado, Louisiana, Texas, Arkansas, and Pennsylvania.

It would be reasonable to assume that if fracking expands on a large scale in the U.S., or elsewhere, it is likely that leakage rates will fall closer to the higher-end figures of 12 percent, at least until serious controls could be established. This then would greatly diminish, if not eliminate altogether, any emission-reduction benefits from a coal-to-natural gas fuel switch.[33]

Nuclear Energy

Nuclear energy is a significant part of Ohio's energy mix, totaling to 5 percent of the state's overall energy consumption which generates about 16 percent of the state's electricity supply. Nuclear energy provides the important benefit that it does not generate CO_2 emissions or air pollution of any kind while operating. At the same time, the processes for mining and refining uranium ore, making reactor fuel, and building nuclear power plants all require large amounts of energy.

But even if we put aside the emissions that result from building and operating nuclear power plants, we still need to recognize the longstanding environmental and public safety issues associated with nuclear energy. These include:

- ***Radioactive wastes.*** These wastes include uranium mill tailings, spent reactor fuel, and other wastes, which according to the U.S. Energy Information Agency (EIA) "can remain radioactive and dangerous to human health for thousands of years" (EIA 2012, p. 1).

- ***Storage of spent reactor fuel and power plant decommissioning.*** Spent reactor fuel assemblies are highly radioactive and must be stored in specially designed pools or specially designed storage containers. When a nuclear power plant stops operating, the decommissioning process involves safely removing the plant from service and reducing radioactivity to a level that permits other uses of the property.
- ***Political security.*** Nuclear energy can obviously be used to produce deadly weapons as well as electricity. Thus, the proliferation of nuclear energy production capacity creates dangers of this capacity being acquired by organizations — governments or otherwise — which would use that energy as instruments of war or terror.
- ***Nuclear reactor meltdowns.*** An uncontrolled nuclear reaction at a nuclear plant can result in widespread contamination of air and water with radioactivity for hundreds of miles around a reactor.

Even while recognizing these problems with nuclear energy, it is still the case that nuclear power presently supplies over five percent of global energy supply, and a comparable proportion of Ohio's overall energy supply. For decades, the prevalent view throughout the world was that these risks associated with nuclear power were relatively small and manageable, when balanced against its benefits. However, this view was upended in the aftermath of the March 2011 nuclear meltdown at the Fukushima Daiichi power plant in Japan, which resulted from the massive 9.0 Tohoku earthquake and tsunami. The full effects of the Fukushima meltdown cannot possibly be known for some time.[34] Still, these safety considerations with nuclear energy must be accorded significant weight. This is especially the case, given the high probability that the necessary tight standards for regulating nuclear power plants will become compromised if the number of such plants were to expand significantly on a global scale. As such, the most appropriate course for Ohio is to build its clean energy foundation through safer energy sources.

Bioenergy

As we saw in Table 2.1, biomass provides nearly 4 percent of Ohio's total energy supply. To date, it is the only significant source of renewable energy in the state. But, as noted above, it is critical to recognize that, unlike other renewable energy sources, burning biomass can generate significant emissions levels, depending on the raw materials used and the processes used for converting raw materials into energy. To begin with, 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), bioenergy 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 bioenergy emissions has been widely refuted in the recent research literature.[35] The main consideration here is that trees require decades to regrow and thereby to absorb CO_2. By contrast, emissions generated by burning wood enter into the atmosphere immediately on combustion. Allowing that we are operating within the emissions-reduction timeframe set out by the IPCC, this means that we have only 10 years to reduce CO_2 emissions by 45 percent and 30 years to reach net zero emissions. As such, the decades-long process through which newly planted trees absorb CO_2 will not deliver carbon neutrality within a 30-year time frame, much less a 45 percent emissions reduction within 10 years.

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

> The scientific evidence does not support the burning of wood in place of fossil fuels as a climate solution. Current science finds that burning trees for energy produces even more CO_2 than burning coal, for equal electricity produced…and the considerable accumulated carbon debt from the delay in growing a replacement forest is not made up by planting trees or woods substitution.[36]

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. Even when including the refining and energy-generating processes, these bioenergy fuel sources can become low-emissions energy sources.[37]

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 Ohio. In fact, emissions from biomass and biofuels vary widely.[38] As a rough approximation, we assume that emissions levels from bioenergy in Ohio are, at present, at a midpoint level between burning coal and petroleum. But we will also include low-emissions bioenergy as among the clean renewable energy sources that can contribute toward transforming Ohio into a net zero emissions economy.

Geoengineering

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

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

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

By contrast, afforestation is, of course, a natural and proven carbon removal technology. About 30 percent of Ohio's overall land area is presently covered by forest. Thus, forest growth in Ohio can provide a significant offset to the emissions generated through combusting fossil fuels and biomass to produce energy. Enabling Ohio's existing forested areas to grow over time can provide a significant source of carbon absorption. As such, Ohio 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 2.10, which focuses on the path for Ohio to become a net zero emissions economy.

The idea of stratospheric aerosol injections builds from the results that followed from the volcanic eruption of Mount Pinatubo in the Philippines in 1991. The eruption led to a massive injection of ash and gas, which produced sulfate particles, or aerosols, which then rose into the stratosphere. The impact was to cool the earth's average temperature by about 0.6^0C for 15 months.[39] The technologies being researched now aim to artificially replicate the impact of the Mount Pinatubo eruption through deliberately injecting sulfate particles into the stratosphere. Some researchers contend that to do so would be a cost-effective method of counteracting the warming effects of greenhouse gases.

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

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

Energy Efficiency and Clean Renewable Energy

Given these major problems with biomass, natural gas, nuclear energy and geoengineering, it follows, in advancing a program to cut emissions by 50 percent as of 2030 and to net zero emissions by 2050, that Ohio should focus instead on the most cautious clean energy transition program, i.e. investing in technologies that are well understood, already operating at large-scale, and, without question, safe. In short, we focus here on investments that can dramatically raise energy efficiency standards and equally dramatically expand the supply of clean renewable energy sources.

2.4 Prospects for Energy Efficiency

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

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

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

After taking account of the burning bonus as well as the efficiency gains available in the operations of buildings, transportation systems and industrial equipment, Prentiss concludes, with respect to the U.S. economy specifically, that economic growth could proceed at a normal rate while total energy consumption could remain constant or even decline in absolute terms. Prentiss's conclusions regarding the U.S. economy are consistent with the most recent projections for U.S. energy demand—as well as global energy demand—by the International Energy Agency (IEA 2019). The IEA assumes that the U.S. economy will grow at a 2.0 percent average annual rate between 2018 – 2040. Nevertheless, under their "Current Policies Scenario," which reflects existing policy commitments within the U.S. but nothing beyond these, the IEA assumes that U.S. energy consumption will decline by an average of -0.2 percent per year. But under its more ambitious Sustainable Development Scenario, the IEA estimates that U.S. energy demand will fall by -1.3 percent per year, even while economic growth still proceeds at a 2.0 percent average rate.[40]

Estimating Costs of Efficiency Gains

How much will it cost to achieve major gains in energy efficiency, in general and with respect to Ohio specifically? In fact, estimates as to the investment costs for achieving energy efficiency gains vary widely. For example, the 2010 study by the National Academy of Sciences estimated average costs for building, transportation and industrial efficiency improvements in the United States at $29 billion per Q-BTU of energy savings. More recent studies, focused on the U.S. building sector alone, report similar cost estimates.[41] However, a 2008 World Bank study by Taylor et al. puts average costs at $1.9 billion per Q-BTU of energy savings, based on a study of 455 projects in both industrial and developing economies, a figure that is only 7 percent of the National Academy of Sciences estimate. A 2010 study by the McKinsey consulting firm estimates costs for a wide range of non-OECD economies at $11 billion per Q-BTU of energy savings.

It is not surprising that average costs to raise energy efficiency standards should be significantly higher in industrialized economies. A high proportion of overall energy efficiency investments are labor costs, especially projects to retrofit buildings and industrial equipment. However, these wide differences in cost estimates between the various studies do not simply result from variations in labor and other input costs by regions and levels of development Thus, the World Bank estimate of $1.9 billion per Q-BTU includes efficiency investment projects in both industrialized and developing countries.

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

A conservative approach is to use the National Academy of Sciences estimate as a baseline figure, at $29 billion per Q-BTU of energy savings through efficiency investments. In addition, it would be prudent to assume that the average costs per Q-BTU of savings will have increased, given that some significant energy efficiency investments have been undertaken in Ohio over the past decade. We discuss this further below. For now, the point is that these efficiency gains were likely to have been concentrated among projects that offered relatively lower-cost energy savings opportunities. As such, we will assume here that the average costs will be $35 billion to achieve one Q-BTU of energy savings in Ohio, or $35 million per T-BTU.

Rebound Effects

Raising energy efficiency levels will generate "rebound effects"—i.e. energy consumption increases resulting from lower energy costs. But such rebound effects are likely to be modest in Ohio, 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 Ohio are close to saturation points in the use of home appliances and lighting—i.e. 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. Average rebound effects are likely to be significantly larger in developing economies.[42]

2.5 Prospects for Clean Renewable Energy

A critical factor for building a net zero economy in Ohio, and throughout the world, by 2050 is the fact that, on average, the costs of generating electricity with clean renewable energy sources are now at parity or lower than those for fossil fuel-based electricity. Table 2.4 shows the most recent figures reported by the International Renewable Energy Agency (IRENA), for 2010 and 2017, on the "levelized costs" of supplying electricity through alternative energy sources. Levelized costs takes 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, continue through to the transmission and delivery of electricity, and include the costs of energy that is lost during the electricity-generation process.

As we see in Table 2.4, the levelized costs for fossil-fuel generated electricity range between 5.0 and 17.7 cents per kilowatt hour as of 2019. The average figures for the four clean renewable sources are all within this range for fossil fuels as of 2019, with solar at 6.8 cents, onshore wind at 5.3 cents, hydro at 4.7 cents and geothermal at 7.3 cents. The costs of geothermal and hydro did not fall, and actually rose somewhat, between 2010 and 2019. However, the costs of onshore wind fell by 38 percent, from 8.6 to 5.3 cents. The most impressive result though is with solar PV, in which levelized costs fell by 82 percent from 2010 to 2019, from 37.8 cents to 6.8 cents per kilowatt hour. These average cost figures for solar and wind should continue to decline still further as advances in technology and economies of scale proceed along with the rapid global expansion of these sectors.[43]

We emphasize that these cost figures from the IRENA are simple averages. They do not show differences in costs due to regional or seasonally-specific factors.[44] In particular, solar and wind energy costs will vary significantly by region and season. Moreover, both wind and solar energy are intermittent sources—i.e. they only generate energy, respectively, when the sun is shining or the wind is blowing. These issues of energy storage will become significant as Ohio, the U.S., and global economies approach the net zero emissions goal by 2050. Over the decade 2021 – 2030, these issues will not be pressing. This is because petroleum, natural

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

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

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

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

gas, coal and nuclear power will be supplying roughly 85 percent of Ohio's total energy supply as of 2021, with that figure still maintained at over 60 percent as of 2030, even as Ohio achieves major improvements in energy efficiency. Thus, the economy's baseload energy source will continue to be fossil fuels and nuclear power through 2030 and several years beyond.

Keeping all such considerations in mind, we can still roughly conclude from these figures that, for the most part, clean renewable energy sources are rapidly emerging into a position at which they can produce electricity at comparable or lower costs than non-renewable sources and high-emissions bioenergy. As such, assuming that solar, wind, low-emissions bioenergy, geothermal, and small-scale hydro can be scaled up to meet virtually all the state's energy demand by 2050, then the costs to consumers of purchasing this energy should not be significantly different from what these consumers would have paid for non-renewable energy. Indeed, overall, the costs to consumers of purchasing electricity from clean renewable sources are likely to be *lower* than what they would be from fossil fuel sources. It is critical to also emphasize that this is *without* factoring in the environmental costs of burning oil, coal, natural gas and high-emissions bioenergy.

Costs of Expanding Renewable Capacity

With most clean renewable technologies, the largest share of overall costs in generating electricity is capital costs—i.e. the costs of producing new productive equipment, as opposed to the costs of operating and maintaining that productive equipment once it has been built and is generating energy. These capital costs are between 71 – 75 percent for solar, wind, and hydro power. They are somewhat lower, at 54 percent for geothermal power, and lower still, at 42 percent for low-emissions bioenergy. But even with bioenergy, capital costs are still the largest cost area.[45] From these figures on levelized costs, we can also estimate the capital costs of installing renewable energy capacity as a lump sum—i.e. how much investors need to spend *upfront* to put this capital equipment into place and in running order.

We produce estimates of these lump sum capital costs in Table 2.5. Specifically, these figures represent the present values of total lump-sum capital expenditures needed to produce one Q-BTU of electricity from these various clean renewable sources.[46] As we see,

TABLE 2.5
Capital Expenditure Costs for Building Renewable Electricity Productive Equipment
Present values of total lump-sum capital costs per Q-BTU of electricity

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

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

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

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

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

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

We can now work with our two rough high-end estimates of the overall costs of both raising energy efficiency standards and building new clean renewable energy capacity--$35 billion per Q-BTU ($35 million per T-BTU) for efficiency gains and $200 billion per Q-BTU ($200 million per T-BTU) for expanding renewable capacity—to generate an estimate of the total costs of achieving a 50 percent CO_2 emissions reduction in Ohio by 2030 and to reach net zero emissions by 2050.

2.6 Determinants of Ohio's CO_2 Emission Levels

Table 2.6 shows how, as of 2018, Ohio generated approximately 220 million tons of CO_2 from burning natural gas, oil and coal, and a small amount of biomass to produce energy. We also see the shares of total emissions generated by the respective sources, with petroleum at 74.7 million tons, natural gas at 64.2 million tons and coal at 68.4 million tons.

It is clear from these figures that driving down overall emissions in Ohio from about 220 to 110 million tons by 2030 will require major reductions in all emissions-generating sources. Operating within a framework in which energy efficiency is rising significantly between 2021 – 2030, we assume that the consumption of oil, natural gas, coal and high-emissions bioenergy will all fall by 40 percent as of 2030 and that coal consumption will fall by 70 percent. Thus, as we see in Table 2.6, oil falls from 1,100 to 666 T-BTUs as of 2030, natural gas falls from 1,211 to 727 T-BTUs, coal falls from 718 to 215 T-BTUs and bioenergy falls from 134 to 80 T-BTUs. Through following this scenario, total CO_2 emissions in Ohio will fall by half, from approximately 220 to 111 million tons. Columns 4 and 5 of Table 2.6 present the calculations through which we derive this result.

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

	2018 Actuals			2030 Projections	
	1) 2018 Energy consumption *(in T-BTUs)*	**2) 2018 CO_2 emissions** *(in million metric tons)*	**3) CO_2 emissions per Q-BTU** *(in millions of tons; = column 2/ (column 1/1000))*	**4) 2030 Energy consumption** *(in T-BTUs)*	**5) 2030 CO_2 emissions** *(in millions of tons; = column 3 x column 4/1000)*
Fossil Fuels					
Petroleum	1,110	74.7	67.3	666	44.8
Natural gas	1,211	64.2	53.0	727	38.5
Coal	718	68.4	95.3	215	20.5
Fossil fuel totals	3,039	207.3	---	1,608	103.8
Bioenergy	134	12.3	90— *rough approximation*	80	7.2
Totals, including bioenergy estimate	**3,173**	**219.6**	---	**1,688**	**111.0**

Notes: Assumption made for the 2030 projected scenario is that oil, natural gas and bioenergy are reduced by 40 percent and coal is reduced by 70 percent.
Source: US EIA, https://www.eia.gov/environment/emissions/state/analysis/.

GDP, Energy Intensity, and Emissions Intensity as Emissions Drivers

In order to develop an effective strategy for achieving Ohio'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 Ohio, as well as other states and the U.S. overall, into three component parts. This yields three ratios, each of which provides a simple measure of one major aspect of the climate change challenge, for Ohio, the rest of the U.S. states and elsewhere. That is, CO_2 emissions per capita can be expressed as follows:

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

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

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

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

TABLE 2.7
Determinants of Per Capita CO_2 Emissions Levels in Various States, 2017
Level of development, energy intensity and emissions intensity

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

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

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

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

By contrast, per capita income in Ohio as of 2017 was about $55,000. This is about 8 percent below the average figure for the U.S. overall, at $60,062. Ohio's ranking in 2017 was 34th in per capita income among the 50 U.S. states.

With respect to this average income level, Ohio could, hypothetically, reduce its per capita emissions figure by half as of 2030 by also cutting per capita GDP in half, to around $27,000, while maintaining its existing energy infrastructure fully intact. But this is obviously not a program for expanding well-being while also reducing emissions. To the contrary, the aim of a statewide clean energy project, again, is to achieve the 2030 emissions reduction level to no more than 111 million tons of CO_2 while the state's economy grows at a reasonable rate and job opportunities expand.

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

1. ***Energy efficiency****:* The state operates at an energy efficiency level that is about 12 percent worse than the national average, with an energy intensity ratio of 5.6 Q-BTUs per $1 trillion in GDP versus the U.S. national average of 5.0. Ohio's neighboring state of Pennsylvania is also at close to the national average of energy intensity, with a 5.1 ratio. Ohio's energy intensity ratio is significantly lower than both Texas and Kentucky, whose ratios are 8.1 and 8.3 respectively. But Ohio also utilizes energy far less efficiently than either New York, whose energy intensity ratio is 2.3, California, with a 2.8 energy intensity ratio, or Colorado, with a 4.2 ratio. New York's high efficiency level is due primarily to the intensive use in the state of both rail transit and apartment-based residential dwellings. This is not possible for Ohio to replicate. But California has achieved its high efficiency level largely through relatively high automobile efficiency standards. Colorado is not as efficient as California, but is still utilizing energy 25 percent more efficiently than Ohio. One of the main policy initiatives in Ohio should therefore be to raise energy efficiency so that it reaches a standard somewhere within the range of California and Colorado.
2. ***Clean-burning energy***: Ohio's emissions intensity ratio of 59.3 million tons per Q-BTU of energy is only modestly above the U.S. average of 57.2. As such, a program to dramatically raise the proportion of clean energy supply for Ohio can correspond closely with the project for the U.S. overall.

In addition to these factors explaining Ohio's level of per capita emissions at present, it is also important to recognize that the state has achieved some gains over time in what is termed "absolute decoupling"—i.e. achieving absolute reductions in emissions per capita levels over the recent past even while both average incomes and population in the state have grown. We can see the factors driving the absolute decoupling trend in Table 2.8. As the

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

	Total CO_2 emissions from fossil fuel and bioenergy consumption *(in million metric tons)*	Population	Per capita emissions *(in metric tons)*	GDP *(in 2018 dollars)*	Per capita GDP *(in 2018 dollars)*	Energy consump-tion *(in T-BTUs)*	Energy intensity ratio *(Q-BTUs per trillion of 2018 dollars GDP)*	Emissions intensity ratio *(CO_2 emissions in millions of tons/Q-BTU)*
1999	257.2	11.3 million	22.7	$543.6 billion	$48,100	4,276	7.8	60.6
2018	217.8	11.7 million	18.6	$675.9 billion	$57,800	3,756	5.6	58.0

Source: See Table 2.7.

table shows, per capita emissions fell between 1999 and 2018 from 22.7 to 18.6 tons, while per capita GDP rose from $48,100 to $57,800. This amounts to an average reduction in emissions per capita of about 1 percent per year while average per capita incomes rose by 0.9 percent per year. This absolute decoupling resulted through gains in both energy efficiency and in the share of renewable energy supplied within the state.

Thus, in terms of energy efficiency, we see in Table 2.8 that the state's energy intensity ratio fell from 7.8 to 5.6, a 28 percent improvement. This is equal to a 1.6 percent average improvement in the state's energy efficiency standards every year from 1999 – 2018. This gain in energy efficiency is substantial. Yet despite these efficiency gains over the past 20 years, it is still the case, as we saw in Table 2.7, that the state's current level of energy intensity remains 12 percent higher than the figure for the U.S. overall, 25 percent higher than Colorado and 50 percent higher than California. There is clearly considerable room for significantly greater efficiency gains. Ohio's emissions intensity also fell over this period, though much more modestly, from 60.6 to 58.0 in CO_2 emissions per Q-BTU of energy consumed in the state, a 0.2 percent average annual improvement.

Ohio's absolute decoupling trajectory is certainly a favorable development. At the same time, for the state to reduce emissions by 50 percent by 2030 will require a much more aggressive, absolute, decoupling trajectory. Specifically, emissions will need to fall by an average of 6.7 percent per year. We assume that this nearly 7 percent per year decline in emissions will occur while average incomes in the state will be rising, at a rate at least equal to the 0.9 percent rate that prevailed from 1999 – 2018.

To accomplish these two ends will therefore require a major mobilization to both raise energy efficiency standards and to expand the state's clean renewable energy generating capacity. These are the issues to which we now turn.

2.7 Achieving a 50 Percent Emissions Reduction by 2030

The 10-year clean energy investment initiative being proposed in this study is designed to achieve, again, two interrelated fundamental goals. The first is to bring total CO_2 emissions in Ohio down by 50 percent, to approximately 110 million tons by 2030, from its 2018 level of 220 million tons. The second is to advance this climate stabilization program while the Ohio economy grows at an adequate rate between now and 2030, so that existing jobs are protected, job opportunities expand, and average well-being rises throughout the state. In this section of the study, we describe the clean energy investment levels that will be needed to bring together these two goals.

To explore the prospects for achieving the 2030 emissions reduction goal within the context of a growing Ohio economy, we must, unavoidably, work with some assumptions as to the state's real economic growth trajectory between 2021 - 2030. Thus, we assume that the Ohio 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 is mostly faster than the 1.1 percent average annual growth rate that Ohio experienced over the recent 20-year period, i.e. 1999 - 2018. If we assume that the Ohio economy, and the U.S. economy more generally, emerge in 2021 out of its current severe slump tied to the COVID pandemic, it is reasonable to assume that the economy's growth trajectory will be at least moderately stronger than over 1999 – 2018. For one thing, the 20-year period of 1999 – 2018 includes the 2007 – 2009 Great Recession, the most severe U.S. economic downturn other than the 1930s Great Depression and the current COVID-based crisis. In addition, the aim of the full program we are proposing for Ohio in this study will be to support a healthy growth rate through the clean energy investment program, along with investments in public infrastructure, agricultural and land restoration, and a significantly improved public health system.

In Table 2.9, we first report on Ohio's real GDP as of 2018 (expressed in 2018 dollars) and the projected level in 2030, assuming the economy's average real growth rate is maintained at 1.5 percent through 2030. We see that, under this growth assumption, Ohio's real GDP will be approximately $808 billion in 2030, growing from the 2018 figure of $676 billion. Within this full time period, we are most interested in the years 2021 – 2030, over which Ohio will be achieving its 50 percent emissions reduction relative to the 2018 level.

TABLE 2.9
Ohio State GDP Levels, 2018 Actual and Projections for 2021, 2026, and 2030
Figures are in 2018 dollars

2018 GDP	$675.9 billion
Projected average growth rate through 2030	1.5%
Projected 2021 GDP	$706.8 billion
Projected 2030 GDP	$808.1 billion
Projected midpoint GDP between 2021 – 2030 (average of 2025 and 2026)	$755.8 billion

Source: BEA and authors' calculations.

Assuming again a 1.5 percent average annual growth rate, the 2021 GDP will be $707 billion. The midpoint over the 2021 – 2030 decade will be effectively January 1, 2026. Ohio's real GDP will be at $756 billion at that midpoint.

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

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

	1) 2018 actuals	2) 2030 with approximate Steady State Energy Infrastructure *(= categories grow at 1.5% average annual rate)*	3) 2030 through Clean Energy Investment Program
1) Real GDP	$676 billion	$808 billion	$808 billion
2) Energy intensity ratio *(Q-BTUs / $1 trillion of GDP)*	5.56	5.56	3.61
3) Total energy consumption *(T-BTU)*	3,756	4,492	2,917
Energy mix			
4) Non-renewables and bioenergy (T-BTUs—rows 5 - 9)	*3,365*	*4,023*	*1,880*
5) Natural gas	1,211	1,448	727
6) Petroleum	1,110	1,327	666
7) Coal	718	858	215
8) High-emissions bioenergy	134	160	80
9) Nuclear	192	230	192
10) Electricity imported from other states and countries	*366*	*434*	*217*
11) Clean renewables (T-BTUs—rows 4 - 10)	*25*	*35*	*820*
12) Solar	3	4	410
13) Wind	16	19	164
14) Low-emissions bioenergy	--	4	123
15) Geothermal	3	4	61
16) Hydro	2	3	61
Emissions			
17) Total CO_2 emissions *(million metric tons)*	220	263	111
18) Emissions Intensity Ratio *(CO_2 Emissions per state-generated Q-BTUs = row 17 / ((rows 3 – 10) x 1000)*	64.9	64.8	41.1

Note: Emissions figures exclude electricity imported from other states and countries.

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

show the actual breakdown of energy consumption and emissions as of 2018. In column 2, we then present projected figures, assuming Ohio'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 "steady state" energy infrastructure trajectory for Ohio. In this scenario, all energy sources grow at exactly the state's overall 1.5 percent annual GDP growth rate.

Thus, we see in row 2, columns 1 and 2, that Ohio's energy intensity ratio remains constant between 2018 and 2030, at 5.6 (rounded from 5.56) Q-BTUs per $1 trillion in GDP. The state's emissions intensity ratio also remains basically unchanged, at 64.8 in 2030 versus 64.9 in 2018, as shown in row 18, columns 1 and 2. Given the assumption of a stable energy infrastructure between 2018 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 2.10. That is, total CO_2 emissions increase from 220 to 263 million tons, an increase of 19.5 percent.

In column 3 of Table 2.10, we then show the impact on the energy mix and emissions levels of a clean energy program focused on bringing down CO_2 emissions to around 110 million tons by 2030. The first component of this program is energy efficiency investments. As noted in Section 2.4, we assume energy efficiency investments will span across the building, transportation and industrial sectors of the Ohio economy. Following from that prior discussion, we assume that, by 2030, Ohio is capable of reducing the economy's energy intensity ratio from the 2018 level of 5.6 (with rounding) to 3.6 Q-BTUs per $1 trillion of GDP. This would be a 36 percent gain in overall energy efficiency in the state. It would bring Ohio by 2030 to an efficiency level approximately midway between the levels which California and Colorado operated in 2017. Correspondingly, total energy consumption at the 2030 GDP level, would fall from approximately 4,500 to 2,900 T-BTUs (i.e. 4.5 to 2.9 Q-BTUs).

We then need to consider the energy mix that will be necessary to allow for 2,900 T-BTUs of consumption while still maintaining emissions at no more than about 110 million tons. As we have seen in Table 2.6, in order to bring overall CO_2 emissions in Ohio down to 111 million tons by 2030, one viable path would be for the consumption of natural gas, oil, and high-emissions bioenergy to all fall by 40 percent, while coal declines by 70 percent. As we see in column 3 of Table 2.10, this implies that natural gas is at 727 T-BTUs as of 2030, oil is at 666, coal is at 215, and high-emissions bioenergy is at 80. Ohio then continues to utilize nuclear energy at its 2018 consumption level of 192 T-BTUs. In combination then, the non-renewable energy sources along with high-emissions bioenergy would provide Ohio with a total of 1,880 T-BTUs of energy in 2030. We finally also assume that Ohio will cut its imported electricity, both from other U.S. states as well as Canada, by half relative to the 2030 steady-state scenario. This entails cutting imported electricity from 434 to 217 T-BTUs as of 2030. Relying less on imported electricity will help promote clean energy investments and job creation within the state.

This then entails that 820 T-BTUs of energy will need to be provided by clean renewable sources in order for Ohio's overall energy consumption to reach 2,917 T-BTUs in 2030.

As of 2018, all clean renewable sources—solar, wind, low-emissions bioenergy, geothermal, and hydro—combined to supply only 25 T-BTUs of energy to Ohio. Effectively then, 795 T-BTUs of *new supply* needs to be provided by wind, solar, hydro, and geothermal in order to bring Ohio's total energy supply to 2917 T-BTUs in 2030, with emissions falling by 50 percent, from 220 to 110 million tons as of 2030.

As discussed in Section 2.5, we assume, as a high-end estimate, that the average lump-sum capital expenditures needed to expand clean renewable energy supply by 1 Q-BTU will be $200 billion. This then means that, to expand the clean renewable supply in Ohio by 795 T-BTUs, will require $159 billion in new capital expenditures. Working, again, with the assumption that this is a 10-year investment program, this implies that the average level of expenditures per year to increase the supply of clean renewable energy by 795 T-BTUs in 2030 will be $15.9 billion per year.

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

- ***Efficiency.*** $ 5.5 billion per year in energy efficiency investments between 2021 – 2030, amounting to about 0.7 percent of Ohio's projected midpoint GDP between 2021 – 2030. These efficiency investments will generate 1,576 T-BTUs of energy savings relative to the steady state growth path for Ohio through 2030.
- ***Clean renewables.*** $15.9 billion per year for investments in solar, wind, low-emissions bioenergy, geothermal, and small-scale hydro power. This will amount to about 2.1 percent of Ohio's projected midpoint GDP between 2021 – 2030. It will generate an increase of 795 T-BTUs of clean renewable supply by 2030.
- ***Overall program and emissions reduction.*** Combining the efficiency and clean renewable investments, the program will therefore cost about $21.4 billion per year, or 2.8 percent of Ohio's projected midpoint GDP between 2021 – 2030. Overall, this program will generate 2,371 T-BTUs in either energy savings relative to the steady state scenario or expanding the clean renewable energy supply. The end result of this program will be that overall CO_2 emissions in Ohio in 2030 will be 111 million tons, 50 percent less than its level for 2018. Ohio will have achieved this 50 percent emissions reduction while the state's economy also will have grown at an average rate of 1.5 percent per year through 2030.

Is $21.4 Billion per Year in Clean Energy Investments Realistic for Ohio?

The short answer is "yes." To understand why, it is important to consider our estimate of Ohio's annual clean energy investment needs within the broader context of the state's overall economic trajectory. As we have already noted above, this $21.4 billion annual investment figure represents about 2.8 percent of Ohio's average GDP over 2021 – 2030, assuming that the state grows, on average, at about 1.5 percent per year over that 10-year period. In other words, our estimate of Ohio's annual clean energy investment needs for bringing CO_2 emissions down in the state by 50 percent as of 2030 implies that roughly 97 percent of all economic activity in Ohio can continue to be directly engaged in activities *other than* clean energy investments.

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

TABLE 2.11
Ohio Clean Energy Investment Program for 2021- 2030

A) Energy Efficiency Investments

1. 2030 Energy intensity ratio	3.61 Q-BTUs per $1 trillion GDP *(35% improvement over 5.56 Q-BTU per $1 trillion GDP steady state figure)*
2. Total energy consumption	2,917 T-BTUs *(= 35% reduction relative to 4,492 T-BTU steady state figure)*
3. Energy saving relative to steady state	1,576 T-BTUs *(= 4,492 – 2,917 T-BTUs)*
4. Average investment costs per Q-BTU in efficiency gains	$35 billion per Q-BTU
5. Costs of energy savings	$55.2 billion *(= $35 billion x 1.576 Q-BTUs in savings)*
6. Average annual costs over 2021 – 2030	$5.5 billion *(= $55.2 billion/10)*
7. Average annual costs of efficiency gains as % of mid-point GDP	0.7% *(= $5.5 billion/$755.8 billion*

B) Clean Renewable Energy Investments

1. Total renewable supply necessary	820 T-BTUs *(= 2,917 T-BTUs – 1,880 T-BTUs supplied by non-renewables/ bioenergy – 217 electricity imported)*
2. Expansion of renewable supply relative to 2018 level	795 T-BTUs *(= 820 – 25 T-BTUs)*
3. Average investment costs per Q-BTU for expanding renewable supply	$200 billion per Q-BTU
4. Costs of expanding renewable supply	$159.0 billion *(= 0.795 Q-BTUs x $200 billion)*
5. Average annual costs over 2021 – 2030	$15.9 billion *(= $159.0 billion/10)*
6. Average annual costs of renewable supply expansion as % of midpoint GDP	2.1% *(= $15.9 billion/$755.8 billion)*

C) Overall Clean Energy Investments: Efficiency + Clean Renewables

1. Total clean energy investments	$214.2 billion *(= $55.2 billion for energy efficiency + $159.0 billion for renewables)*
2. Average annual investments	$21.4 billion *(= $214.2 billion/10)*
3. Average annual investments as share of midpoint GDP	2.8% *(= $21.4 billion/$755.8 billion)*
4. Total energy savings or clean renewable capacity expansion	2,371 T-BTUs *(= 1,576 T-BTUs in energy saving + 795 T-BTUs in clean renewable supply expansion)*

Sources: Tables 2.9 – 2.10.

Leveraging Public Funds for Expanding Total Clean Energy Investments

What level of public funding will be needed to generate an average of $21.4 billion a year in total new clean energy investments in Ohio? To help answer that question, it will be useful to briefly review the experience with the federal Department of Energy Loan Guarantee Program, which was one part of the 2009 American Recovery and Reinvestment Act—i.e. the Obama stimulus program. This program helped underwrite about $14 billion in new clean energy investments between 2009 –2013. Even after taking full account of the large-scale and widely publicized failure of the Northern California solar company Solyndra, the default rate and corresponding financial obligations stemming from this program were modest. According to our estimates discussed in Pollin et al. (2014), total losses from the government covered by the government's loan guarantees amounted to about $300 million, i.e. equal to about 2.1 percent of the $14 billion in new loans for clean energy investments that the government guaranteed. This means that the leverage rate for the loan guarantee program was about $47 in additional clean energy investments underwritten by $1 of federal support.

If Ohio were able utilize its full set of existing policy tools, including the set of financial subsidies, tax incentives, and regulations described above to leverage at the same 47/1 rate as the 2009 federal Energy Loan Guarantee program, that would imply that the state would need to spend about only $450 million per year to deliver $21.4 billion in total clean energy investments in Ohio. Such public spending could take the form of direct public investments, loan guarantees and other forms of credit subsidies, or tax benefits. The remaining roughly $21 billion would be coming from private investors. The $450 million in public funding would amount to about 1.5 percent of the state's total budget of roughly $68 billion for fiscal year 2019 (i.e. pre-COVID).

However, for various reasons, this leverage ratio is almost certainly too high. One factor is that, to date, Ohio's existing clean energy programs that we discussed in Section 2.1 have been operating at a small scale, including the Clean Energy Loan Fund, the PACE Funding program, the Clean Vehicle Incentive program, the Energy Efficiency Grant Program, the Home Weatherization Assistance Program and the net metering program. Their existing administrative capacity is therefore not likely to be sufficient to operate a loan guarantee program at the scale of the 2009 federal program. On the other hand, the framework does exist to bring these programs to scale, to match the challenge of building a clean energy infrastructure and achieve net zero emissions by 2050.

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

For 2021 – 2022, the first years of the investment program, overall investment spending would be around $20 billion (with $21.4 billion/year being the midpoint amount over 2021 – 2030). For 2021, this would imply that the state would need to contribute about $2 billion on clean energy projects, an amount that would then be matched by $18 billion in private sector investments. The $2 billion in public investments would amount to about 3 percent of Ohio's 2019 state budget. Note that this 9/1 leveraging ratio is about one-fifth the ratio that was achieved with the federal clean energy loan guarantee program over 2009 – 13.

2.8 Clean Energy Investments and Job Creation

In Tables 2.12 and 2.13, we present our estimates as to the job creation effects of investing in energy efficiency in Ohio. Tables 2.14 and 2.15 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 annual level of investment spending we have proposed for 2022, i.e. $5.5 billion in energy efficiency and $15.9 billion in clean renewable energy.

Direct, Indirect, and Induced Job Creation

Before reviewing the actual data on job creation in Tables 2.12 – 2.15, 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 2.12 – 2.15, 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 2.12, 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 2.12 shows, direct plus indirect job creation per $1 million in spending ranges between 1.6 jobs for expanding the high efficiency automobile fleet to 11.7 jobs for public transportation expansion and upgrades.

In Table 2.13, we show the level of job creation through spending an average of $5.5 billion per year on these efficiency projects in Ohio between 2021 – 2030. We have as-

TABLE 2.12

Job Creation in Ohio through Energy Efficiency Investments

Job creation per $1 million in efficiency investments

	Direct jobs	Indirect jobs	Direct + indirect jobs total	Induced jobs	Direct, indirect + induced jobs total
Building retrofits	4.7	2.4	7.2	2.5	9.7
Industrial efficiency, including combined heat and power	2.7	1.8	4.5	3.0	7.6
Electrical grid upgrades	3.2	1.5	4.6	2.8	7.4
Public transportation expansion/upgrades, including rail	9.9	1.8	11.7	3.3	15.1
Expanding high efficiency automobile fleet	0.4	1.2	1.6	1.3	2.9

Note: Due to rounding, total employment figures do not in all cases exactly equal the sum of the category-by-category employment figures.

Sources: Authors' calculations using IMPLAN 3.0. See Appendix 1.

TABLE 2.13

Job Creation in Ohio through Energy Efficiency Investments, 2021 – 2030

Job creation through average annual spending of $5.5 billion in efficiency investments

ASSUMPTIONS FOR ENERGY EFFICIENCY INVESTMENTS

- 40% on building retrofits
- 20% on combined heat and power (CHP) and other industrial efficiency measures
- 15% on electrical grid upgrades
- 15% on public transportation expansion/upgrades
- 10% on expanding high-efficiency auto fleet
- No job creation through auto purchase subsidies

	Spending amounts	Direct jobs	Indirect jobs	Direct + in-direct jobs	Induced jobs	Direct, indirect + induced jobs
Building retrofits	$2.2 billion	10,340	5,280	15,840	5,500	21,340
Industrial efficiency, including combined heat and power	$1.1 billion	2,970	1,980	4,950	3,300	8,360
Electrical grid upgrades	$830 million	2,656	1,245	3,818	2,324	6,142
Public transportation expansion/upgrades, including rail	$830 million	8,217	1,494	9,711	2,739	12,533
Expanding high efficiency automobile fleet	$550 million	0	0	0	0	0
TOTALS	**$5.5 billion**	**24,183**	**9,999**	**34,319**	**13,863**	**48,375**

Note: Due to rounding, total employment figures do not in all cases exactly equal the sum of the category-by-category employment figures.
Sources: See Tables 2.11 and 2.12.

sumed that the overall level of funding is channeled into the various energy efficiency areas as follows: 40 percent for building retrofits, 20 percent for industrial efficiency and CHP; 15 percent respectively for electrical upgrades and public transportation expansion/upgrades; and 10 percent for expanding the fleet of high-efficiency automobiles.

Spending to bring high efficiency automobiles into operation rapidly will be an important component of the overall efficiency investment initiative. However, our assumption, as shown in Table 2.13, is that this will not be a source of new job creation. This is because producing high efficiency automobiles will basically substitute for producing lower-efficiency models. Roughly the same level of employment will be needed either way. Working with this assumption, the overall result of $5.5 billion per year in efficiency investments in Ohio will be the creation of 24,183 direct jobs and 9,999 indirect jobs, for a total of 34,319 direct plus indirect jobs created through this energy efficiency investment program. Including induced jobs adds another 13,863 jobs to the total figure. This brings the total job creation figure for efficiency investments, including induced jobs to 48,375 jobs.

Job Creation through Clean Renewable Energy Investments

In Table 2.14, we show the job creation figures for our five clean renewable energy categories—solar, onshore wind, low-emissions bioenergy, geothermal, and small-scale hydro. As we see, the extent of direct plus indirect jobs ranges from 3.5 direct plus indirect jobs per $1 million in expenditure for solar projects to 8.4 direct and indirect jobs for investing $1 million in small-scale hydro. Adding induced jobs brings the range to 6.0 jobs for solar, 6.6 for wind, 8.5 for low-emissions bioenergy, 10.8 for geothermal and 12.1 for small-scale hydro.

Based on these proportions, we see in Table 2.15 the levels of job creation in Ohio generated by spending an average of $15.9 billion per year between 2021 – 2030 in these areas of clean renewable energy. As we see in Table 2.15, we have divided total spending levels as follows: 50 percent for solar, 20 percent for wind, 15 percent for low-emissions bioenergy, and 7.5 percent respectively for geothermal and small-scale hydro.

Following from these budgetary assumptions, we see in Table 2.15 that total direct plus indirect job creation generated in Ohio by this large-scale expansion in the state's clean renewable energy supply will be 74,381 jobs. If we include induced jobs, then the total rises to 116,686 jobs.

TABLE 2.14
Job Creation in Ohio 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	1.9	1.7	3.5	2.4	6.0
Onshore wind	2.3	1.8	4.1	2.5	6.6
Low-emissions bioenergy	4.1	1.9	6.0	2.5	8.5
Geothermal	5.5	2.0	7.5	3.3	10.8
Small-scale hydro	6.6	1.8	8.4	3.7	12.1

Note: Due to rounding, total employment figures do not in all cases exactly equal the sum of the category-by-category employment figures.
Sources: Authors' calculations using IMPLAN 3.0. See Appendix 1.

TABLE 2.15
Annual Job Creation in Ohio through Clean Renewable Energy Investments, 2021 – 2030
Job creation through average annual spending of $15.9 billion in clean renewable investments

ASSUMPTIONS FOR CLEAN RENEWABLE INVESTMENTS *(percentages are rounded)*

- 50% on solar PV energy
- 20% on onshore wind energy
- 15% on low-emissions bioenergy
- 7.5% on geothermal energy
- 7.5% on small-scale hydro

	Spending amounts	Direct jobs	Indirect jobs	Direct + indirect jobs	Induced jobs	Direct, indirect + induced jobs
Solar	$8.0 billion	15,200	13,600	28,000	19,200	48,000
Onshore wind	$3.2 billion	7,360	5,760	13,120	8,000	21,120
Low-emissions bioenergy	$2.39 billion	9,799	4,541	14,340	5,975	20,315
Geothermal	$1.19 billion	6,545	2,380	8,925	3,927	12,852
Small-scale hydro	$1.19 billion	7,854	2,142	9,996	4,403	14,399
TOTALS	**$15.9 billion**	**46,758**	**28,423**	**74,381**	**41,505**	**116,686**

Note: Due to rounding, total employment figures do not in all cases exactly equal the sum of the category-by-category employment figures.
Sources: See Tables 2.11 and 2.14.

Table 2.16 brings together our job estimates for both energy efficiency and clean renewable energy through spending about $21.4 billion per year on this project in Ohio between 2021 – 2030. We show total figures for direct plus indirect jobs only, then we also show the total when induced jobs are included.

We see in row 12 of Table 2.16 that total direct and indirect job creation as of 2021 is 108,700 jobs and 165,061 jobs when we add induced jobs to the total. As we see in row 13, this level of job creation amounts to between 1.9 and 2.8 percent of the total workforce in Ohio as of 2019, the range depending on whether we include induced jobs in the total.

Indicators of Job Quality

In Table 2.17, we provide some basic measures of job quality for the jobs that will be generated through clean energy investments in Ohio. These basic indicators include: 1) average total compensation (including wages plus benefits); 2) the percentage of workers receiving health insurance coverage; 3) the percentage having retirement plans through their employers; and 4) the percentage that are union members.

We focus here on the *direct* jobs that will be created through clean energy investments in Ohio. By definition, the direct jobs are the ones that are fully integrated within the state's clean energy investment activities. As such, the characteristics associated with these directly created jobs will most fully reflect the specific range of opportunities that will result through building a clean energy economy in Ohio. The jobs created through the indirect and induced channels will be more diffuse in their characteristics. Indeed, the characteristics of the induced jobs created will simply reflect the overall characteristics of Ohio's present-day workforce.

TABLE 2.16

Annual Job Creation in Ohio through Combined Clean Energy Investment Program

Average annual figures for 2021 – 2030

Industry	Number of direct and indirect jobs created	Number of direct, indirect and induced jobs created
$5.5 billion in energy efficiency		
1) Building retrofits	15,840	21,340
2) Industrial efficiency	4,950	8,360
3) Electrical grid upgrades	3,818	6,142
4) Public transportation expansion/upgrades	9,711	12,533
5) Total energy efficiency job creation	34,319	48,375
$15.9 billion in clean renewables		
6) Solar	28,000	48,000
7) Wind	13,120	21,120
8) Low emissions bioenergy	14,340	20,315
9) Geothermal	8,925	12,852
10) Small-scale hydro	9,996	14,399
11) Total job creation from clean renewables	74,381	116,686
12) TOTALS *(= rows 5+11)*	**108,700**	**165,061**
13) TOTAL AS SHARE OF 2019 OHIO LABOR FORCE *(Labor force at 5.8 million)*	**1.9%**	**2.8%**

Sources: Tables 2.13 and 2.15.

TABLE 2.17

Indicators of Job Quality in Ohio Clean Energy Industries: Direct Jobs Only

	Energy Efficiency Investments				Clean Renewable Energy Investments				
	1. Building retrofits *(10,340 workers)*	**2. Industrial efficiency** *(2,970 workers)*	**3. Grid upgrades** *(2,656 workers)*	**4. Mass transit** *(8,217 workers)*	**5. Solar** *(15,200 workers)*	**6. Wind** *(7,360 workers)*	**7. Low-emissions bioenergy** *(9,799 workers)*	**8. Geo-thermal** *(6,545 workers)*	**9. Small-scale hydro** *(7,854 workers)*
Average total compensation	$60,600	$64,300	$67,800	$46,200	$65,700	$65,000	$55,800	$63,100	$62,300
Health insurance coverage, percentage	40.0%	44.8%	52.3%	36.9%	42.5%	42.7%	36.8%	42.4%	41.2%
Retirement plans, percentage	32.8%	35.6%	48.5%	35.0%	42.2%	38.9%	29.2%	40.2%	35.1%
Union membership, percentage	23.0%	10.0%	12.3%	18.9%	17.3%	18.2%	20.7%	18.1%	21.3%

Sources: See Appendix 2.

Starting with compensation figures, we see that the averages range between about $46,000 for workers in the mass transit sector to about $68,000 in the grid upgrade sector.

The range for workers carrying employer-based health insurance coverage is narrower, from 37 percent of workers in the mass transit and bioenergy sectors to 52 percent in grid upgrades. Thus, in only one of these clean energy sectors is more than half of the workforce provided with employer-sponsored health insurance.

The range of coverage with respect to private retirement plans is comparable to that for health insurance. The low-end figure is with bioenergy, in which about 29 percent of workers have retirement plans. The highest figure is again with grid upgrades, at nearly 49 percent. Thus, less than half of the workers in all the clean energy sectors have employer-sponsored retirement plans. Only a minority of workers in the various clean energy sectors are represented by unions, with the figures ranging between 10 – 23 percent of the respective workforces. Nevertheless, this level of union representation is substantially above the average for the U.S. private sector overall, which was 6.2 percent as of 2019.

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

More generally, these indicators of job quality will be valuable for purposes of comparison when we consider the jobs that will be lost in Ohio as a result of the contraction of fossil fuel production and consumption in the state through 2030. What is especially important to highlight now—in anticipating our discussion in Section 2.9 on workers in Ohio's fossil fuel related industries—is that, for the most part, the compensation figures in clean energy industries are lower than those for fossil fuel industry-based workers. As such, one of the aims of a clean energy investment agenda for Ohio should be to raise wages, benefits and working conditions in the newly-created clean energy investment industries.

Educational Credentials and Race/Gender Composition for Clean Energy Jobs

In Table 2.18, we present data on the educational credentials for workers in jobs that are directly tied to clean energy investment activities in Ohio as well as the race and gender composition of these workers.

Educational Credentials

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

As Table 2.18 shows, the level of educational credentials is generally similar across industries. Thus, in 8 of the 9 industries listed, between 45 – 58 percent of the workers have high school degrees or less. The one exception is industrial efficiency, in which only 31 percent of the workers have high school degrees or less, while 44 percent have Bachelor's

TABLE 2.18
Educational Credentials and Race/Gender Composition of Workers in Ohio Clean Energy Industries: Direct Jobs Only

	Energy Efficiency Investments				Clean Renewable Energy Investments				
	1. Building retrofits *(10,340 workers)*	**2. Industrial efficiency** *(2,970 workers)*	**3. Grid upgrades** *(2,656 workers)*	**4. Mass transit** *(8,217 workers)*	**5. Solar** *(15,200 workers)*	**6. Wind** *(7,360 workers)*	**7. Low-emissions bioenergy** *(9,799 workers)*	**8. Geo-thermal** *(6,545 workers)*	**9.Small-scale hydro** *(7,854 workers)*
Share with high school degree or less	57.9%	30.9%	58.0%	56.0%	45.4%	51.1%	58.4%	48.7%	55.2%
Share with some college or Associate degree	28.7%	24.7%	32.3%	28.5%	26.7%	27.1%	27.3%	26.8%	28.3%
Share with Bachelor's degree or higher	13.4%	44.4%	9.7%	15.5%	27.9%	21.8%	14.3%	24.5%	16.4%
Racial and gender composition of workforce									
Pct. non-white	14.7%	15.4%	14.2%	28.7%	18.4%	16.3%	12.4%	17.3%	14.2%
Pct. female	8.8%	29.4%	11.7%	23.1%	19.0%	14.8%	13.7%	16.5%	9.8%

Sources: See Appendix 2.

degrees or higher. Otherwise, with the other 8 industries, the share of workers with Bachelor's degrees or higher ranges between 10 – 28 percent.

If we consider this range of clean energy investment areas as a whole, it is clear that a significant share of the newly generated jobs in the various clean energy sectors will be open to workers with relatively lower educational credentials, as well as those with mid-level credentials, such as Associate degrees. This means that there will be a substantial expansion of employment opportunities for workers that more generally face difficulties finding good-quality jobs.

Race and Gender Composition

It is clear from the figures in Table 2.18 that, at present, the jobs created by clean energy investments are held predominantly by white male workers. The share of jobs held by people of color within the various clean energy sectors ranges between 12 – 29 percent. These figures are somewhat below the average for the entire U.S. workforce, in which 28 percent of people identify as non-white. However, the non-white share of the Ohio population is 17 percent. As such, the growth of Ohio's clean energy economy will certainly create increased opportunities for people of color in the state. Fortunately, as a starting point, the baseline level of employment for people of color in the clean energy industries is not disproportionately low at present.

By contrast, women are badly under-represented across all clean energy sectors. The share of female employment is between 9 – 29 percent, even while women make up 47 percent of Ohio's workforce.

Despite these disparities in the current composition of the workforce associated with clean energy investments in Ohio, especially with regard to women, the large-scale expansion of these investments will provide a major opportunity to increase opportunities for both people of color and female workers. An initiative focused on equal opportunity in the growing clean energy investment areas could be readily integrated into the broader investment project.

Prevalent Job Types with Clean Energy Investments

To provide a more concrete picture of the jobs that will be created in Ohio through investments in energy efficiency and clean renewable energy, in Tables 2.19 – 2.23, we report on the prevalent job types associated with three of the major efficiency and renewable energy activities. Table 2.19 provides data for investments in building retrofits, our largest category of energy efficiency investments. Table 2.20 focuses on industrial efficiency, including combined heat and power (CHP), and Table 2.21 on public transportation. Table 2.22 then reports these same figures for the largest category of clean renewable energy investments, solar energy. Table 2.23 shows the employment profile for the other four areas of clean renewable energy investments, i.e. wind, low-emissions bioenergy, geothermal and hydro

TABLE 2.19
Building Retrofits: Prevalent Job Types in Ohio Industry
(Job categories with 5 percent or more employment)

Job category	Percentage of direct jobs created	Representative occupations
Construction	56.4%	Plumbers; electricians; first-line supervisors
Management	21.0%	Marketing managers; general managers; chief executives
Installation and maintenance	6.7%	Maintenance workers; truck mechanics; heating installers

Sources: See Appendix 2.

TABLE 2.20
Industrial Efficiency, including Combined Heat and Power: Prevalent Job Types in Ohio Industry
(Job categories with 5 percent or more employment)

Job category	Percentage of direct jobs created	Representative occupations
Management	21.6%	Operations managers; sales managers; construction managers
Construction	20.7%	Pipelayers; carpenters; construction laborers
Business operation specialists	20.1%	Purchasing agents; human resource workers; management analysts
Office and administrative support	8.5%	Shipping clerks; order fillers; secretaries

Sources: See Appendix 2.

TABLE 2.21
Public Transportation: Prevalent Job Types in Ohio Industry
(Job categories with 5 percent or more employment)

Job category	Percentage of direct jobs created	Representative occupations
Transportation and material movers	47.5%	First-line supervisors; transportation attendants; bus drivers
Construction	20.7%	Pipefitters; electricians; construction laborers
Management	10.1%	Purchasing managers; general managers; construction managers
Installation and maintenance	8.1%	Telecommunications line installers; telecommunications equipment repairers; diesel engine specialists

Sources: See Appendix 2.

TABLE 2.22
Solar: Prevalent Job Types in Ohio Industry
(Job categories with 5 percent or more employment)

Job category	Percentage of direct jobs created	Representative occupations
Construction	41.2%	Pipelayers; carpenters; construction laborers
Management	18.0%	Operations managers; industrial production managers; chief executives
Life, physical and social science	9.7%	Chemical technicians; materials scientists; physical science technicians
Office and administrative support	6.3%	Receptionists; office clerks; first-line supervisors
Architecture and engineering	5.8%	Computer hardware engineers; civil engineers; engineering technicians
Installation and maintenance	5.1%	Telecommunications line repairers; truck mechanics; heating mechanics

Sources: See Appendix 2.

power. In all cases, we report on the job categories in which we estimate that 5 percent or more of the new jobs will be created through clean energy investments.

It is difficult to summarize the detailed data on job categories presented in these tables. But it will be useful to underscore a few key patterns. First, a high proportion of jobs will be created in the construction industry through all of the clean energy investment activities. Of course, this is true with the 56 percent of jobs created through building retrofit investments. But we also find that 41 percent of jobs in the solar sector will be in construction, along with 46 percent of jobs in other areas of renewable energy investments and 21 percent in other areas of energy efficiency investments. The specific types of construction industry jobs will vary widely, given the different types of construction projects that will be pursued. Thus, investments in building retrofits as well as the other areas of efficiency investments

TABLE 2.23
Wind/Low Emissions Bioenergy/Geothermal/ Small Scale Hydro: Prevalent Job Types in Ohio Industry
(Job categories with 5 percent or more employment)

Job category	Percentage of direct jobs created	Representative occupations
Construction	46.4%	Steamfitters; electricians; construction laborers
Management	21.8%	Operations managers; agricultural managers; construction managers
Installation and maintenance	5.8%	Telecommunications line installers; heating mechanics; air conditioner installers
Office and administrative support	5.3%	Information clerks; general office clerks, administrative assistants

Sources: See Appendix 2.

will create large numbers of jobs for laborers, carpenters, and electricians. This pattern of job creation holds as well with renewable-energy based construction work.

Jobs in management also constitute a large share of overall job creation across all categories, accounting for between 10 – 22 percent of total jobs created in the various specific clean energy investment categories. Beyond this, what emerges generally from Tables 2.19-2.23 is that clean energy investments will generate a wide range of new employment opportunities. This broad range of new opportunities will be available for workers in Ohio that will have been displaced by the contraction of the state's fossil fuel industry activities, as well as more broadly throughout the state's labor force.

Requirements for Generating Good-Quality Jobs

What is clear from the evidence we have reviewed is that: 1) large-scale job creation will certainly result in Ohio through clean energy investments in the range of $21 billion per year, or 2.8 percent of average state GDP over 2021 – 2030; but that 2) these jobs will not necessarily be good jobs. As we have seen, average compensation varies fairly widely in the various clean energy sectors, from roughly $46,000 for workers in the mass transit sector to about $68,000 in the grid upgrade sector. These average compensation figures are, for the most part, below the average compensation level for U.S. workers overall, which is about $65,000. They are also below the averages in most of the clean energy sectors nationally. For example, the average compensation figure for clean renewable energy in the U.S. overall is $83,000. Workers employed in the clean vehicles industry in the U.S. also earn $83,000 on average.[47] In addition, as we will review below, the compensation figures in the current clean energy sectors remain below those for workers in Ohio's fossil-fuel based industries. The clean energy economy should be able to provide employment quality levels of at least those of the current fossil fuel-based industries.

A $15.00 minimum wage standard would be an important way to improve the quality of these newly created jobs. Currently, the federal minimum wage is $7.25 and Ohio's state minimum wage is $8.55.[48] Wage rates this low do not afford a small family a decent living standard, even with a full-time year-round worker. The official poverty line, as established by the U.S. Census, is $20,578 for a family of three (including one child) and $25,926 for a family of four (including two children).[49] A worker employed full-time year-round at Ohio's minimum of $8.55 would make under $18,000. A $15.00 minimum wage would enable a small family, with one full time worker, to earn $31,200, wages sufficient to avoid living at a level of severe economic privation. We estimate that about 16 percent of the jobs directly produced by clean energy investments pay less than $15.00 per hour. In order to raise the wage rates of these jobs to a $15.00 minimum wage would increase the overall clean energy investment levels by only a modest amount, less than 0.5 percent.[50]

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

This becomes clear in comparing the respective experiences in the solar installation sectors in California and Arizona. The California sector operates within a framework of relatively strong unions and labor laws while these are both relatively weak in Arizona. A 2014 study by University of Utah economist Peter Phillips describes how these distinct institutional settings play out within the respective state-level solar installation labor markets. Phillips writes:

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

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

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

The problems described by Appel with poor workforce standards and insufficient training pipelines in the California energy efficiency sector are also being reported by employers in the sector from their distinct perspectives. In Tables 2.24 and 2.25 below, we report on the results of a 2018 survey conducted by the U.S. Labor Department, in which, among other questions, employers in clean energy sectors were asked whether they faced difficulties in hiring new workers. We show the survey results in the three largest areas of clean energy employment to date in the U.S.—i.e. energy efficiency, in which 2018 employment was at 2.3 million; solar electricity, with 242,343 people employed; and wind electricity, with 111,166 people employed. We show the results for each clean energy sector broken out according to sub-sectors, including construction; professional/business services; manufacturing; wholesale trade, distribution and transport; utilities; and other services.

In the energy efficiency sector, the largest source of employment by far is in construction, with 1.3 million out of the total employment of 2.3 million—i.e. 56 percent of total energy efficiency employment. We see in Table 2.24 that fully 84 percent of employers reported difficulties in hiring workers, with 52 percent finding it "very difficult" to hire qualified workers.

The results are only moderately lower in the other sub-sectors within energy efficiency. Thus, manufacturing firms reported the lowest level of hiring difficulties, at 72 percent. As we see in Tables 2.24 B and C, as well as in the summary Table 2.25, these patterns are similar in the solar and wind electricity sectors and sub-sectors as well.

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

The study's conclusion from these survey results is that "The need for technical training

TABLE 2.24
Firms that Reported Hiring Difficulties in Solar, Wind, and Energy Efficiency Sectors

A) Energy Efficiency; 2018 Employment = 2.3 million

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

B) Solar Electric Power; 2018 Employment 242,343

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

C) Wind Electric Power; 2018 Employment 111,166

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

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

TABLE 2.25
Summary Figures: All Firms Reporting Hiring Difficulties in Energy Efficiency, Solar Electricity, and Wind Electricity Sectors

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

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

and certifications was also frequently cited, implying the need for expanded investments in workforce training and closer coordination between employers and the workforce training system," (2019, p. 6).

It is clear therefore that high-quality and accessible workforce training programs need to be included as an important component of Ohio's overall clean energy transition project. In Section 2.9, on just transition policies, we discuss initiatives throughout the U.S. These discussions will provide a basis for considering approaches to expanding high-quality programs throughout the state as its clean energy investment projects grow. We also discuss briefly in Section 2.9 the types of affirmative action policies that will be needed in Ohio, and elsewhere, so that women and people of color will have equal opportunities to move into the expanding clean energy economy.

Which Clean Energy Projects are "Shovel-Ready?"

Given the current recession conditions, it will be a challenge to move roughly $20 billion into the state's investment spending stream within the first months of this program. Some activities will inevitably face delays. It is therefore important to take seriously issues around how best to time the launch of various components of the overall project. The point is to ensure that we maximize both their short-term stimulus benefits in addition to their longer-term impacts.

This means that we need to identify the subgroup of green investment projects that can realistically roll into action at scale within a matter of months. One good example would be to undertake energy efficiency retrofits of all public and commercial buildings. This would entail improving insulation, sealing window frames and doors, switching over all lightbulbs to LEDs, and replacing aging heating and air conditioning systems with efficient ones, preferably, where possible, with heat pumps. Ohio's construction industry has been permitted to operate since early May within a framework of COVID-focused public health and safety guidelines. However, it not clear that the public health guidelines have been followed scrupulously to date. Moving forward, it will be critical that they will be followed, so that important projects, such as short-term retrofits of public buildings, can proceed without interruptions and workers being exposed to excessive health risks. [51]

As we see in Table 2.12, the energy efficiency investment program will generate about 10 jobs per $1 million in expenditures within Ohio. Thus, $2.2 billion in annual energy efficiency investments included in the Table 2.13 calculations will generate about 21,000 jobs quickly within the state, for secretaries, truck drivers, and accountants as well as for construction workers. It is also capable of delivering immediate energy savings of about 30 percent and comparable levels of reduced emissions. Front-loading these projects with larger budgetary outlays will also increase job creation proportionally.

Building off this initial set of truly shovel-ready projects, a full clean energy investment project, at a spending level of about 2.8 percent of the state's GDP every year until 2030, can then be phased in as quickly as possible. The ramping up of the rest of the clean energy investment program will provide a strong overall boost to the economy in moving out of recession and into recovery.

2.9 Just Transition for Fossil Fuel-Based Industry Workers

As we have shown above, in order for Ohio to bring total CO_2 emissions down from its 2018 level of 220 million tons to no more than about 110 million tons by 2030, we have developed a 10-year program for reducing the consumption of natural gas, oil, and high-emissions bioenergy by 40 percent as of 2030, and to reduce coal consumption by 70 percent. As we have seen, natural gas, oil and coal provided 81 percent of Ohio's overall energy supply in 2018, and high-emissions bioenergy contributed another 4 percent. That is, these are the predominant sources of energy supply in Ohio at present.

The issue on which we focus in this section is what the impact will be on workers in industries in Ohio that are dependent on statewide consumers continuing to purchase fossil fuels and bioenergy. We assume that, through 2030, production activity and employment in these industries will also decline at approximately the same rates as energy consumption in the states—i.e. natural gas, oil and bioenergy by 40 percent, and coal by 70 percent.[52] In particular, we develop here a just transition program for the workers in these fossil fuel and bioenergy related sectors who will face displacement as a result of the statewide contraction in the consumption of CO_2-producing energy sources.

Our primary focus in this section is on the *direct* jobs that will be lost in Ohio through the contraction of the state's fossil fuel-based and bioenergy industries. Our reasoning for focusing on the contraction of direct jobs is the same as we discussed above with respect to the job quality issues regarding clean energy investments in the state. That is, the direct jobs that will be lost in Ohio through the cuts in CO_2-generating energy sources are the jobs that are, at present, most closely associated with the state's fossil fuel-based and bioenergy 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 Ohio 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 Ohio'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 Ohio who experience unemployment. We return to this issue below, after we first review here job figures and policies to support a just transition as they apply to the direct jobs that will be lost.

Measuring Direct Employment Levels

In Table 2.26, we show employment levels for the 14 fossil-fuel and ancillary industries in Ohio as of 2018.[53] As we see, there are, as of 2018, there are 49,302 people employed in the fossil fuel and ancillary industries in Ohio. Of these, 17,060 (35 percent) are employed in oil and gas extraction, 7,146 (15 percent) work in oil and gas support activities, and 6,496 are in

TABLE 2.26
Number of Workers in Ohio Employed in Fossil Fuel-Based Industries, 2018

Industry	2018 Employment levels	Industry share of total fossil fuel-based employment
Oil and gas extraction	17,060	34.6%
Support activities for oil/gas	7,146	14.5%
Natural gas distribution	6,496	13.2%
Wholesale-petroleum and petroleum products	3,649	7.4%
Fossil fuel electric power generation	3,340	6.8%
Drilling oil and gas wells	2,516	5.1%
Pipeline transport	2,286	4.6%
Petroleum refining	2,186	4.4%
Pipeline construction	1,430	2.9%
Support activities for coal	1,237	2.5%
Coal mining	1,234	2.5%
All other petroleum and coal products manufacturing	391	0.8%
Mining machinery and equipment manufacturing	194	0.4%
Oil and gas field machinery and equipment manufacturing	136	0.3%
Total	***49,302***	***100%***
TOTAL FOSSIL FUEL-BASED EMPLOYMENT AS SHARE OF OHIO STATE EMPLOYMENT *(Ohio 2018 employment = 5.5 million)*	**0.90%**	

Sources: IMPLAN, 3.0, U.S. Department of Labor. See Appendix 2.

natural gas distribution (13 percent). Thus, these three sectors—extraction, support activities and natural gas distribution together account for over 60 percent of total employment in all of Ohio's fossil fuel-based industries.

Characteristics of Fossil Fuel-Based Industry Jobs

Table 2.27 provides basic figures on the characteristics of the direct jobs in Ohio for workers in fossil-fuel based sectors. We first see that, on average, these are relatively high-paying jobs. The average overall compensation is $100,400, 34 percent more than the $66,000 average pay level for solar industry workers, who, on average, are among the highest paid in Ohio's clean energy sector.

In terms of private health insurance coverage, the fossil fuel industries are, for the most part, providing coverage for their workers, with 66 percent of workers receiving employer-based insurance. This level of health insurance coverage is consistently much higher than is generally the case with the industries that would expand as a result of clean energy invest-

TABLE 2.27
Characteristics of Workers Employed in Ohio's Fossil Fuel-Based Industries

Average total compensation	$100,400
Health insurance coverage	66.2%
Retirement benefits	58.0%
Union membership coverage	11.9%
Educational credentials	
Share with high school degree or less	47.8%
Share with some college or Associate degree	18.9%
Share with Bachelor's degree or higher	33.3%
Racial and gender composition of workforce	
Pct. non-white workers	10.5%
Pct. female workers	17.8%

Source: See Appendix 2.

ments. As we saw in Table 2.17, the extent of health insurance coverage in the clean energy industries ranges between 37 – 52 percent.

Union membership is at about 12 percent. This is lower than the various clean energy industries, but still much higher than the figure for the overall U.S. economy of 6.2 percent.

Table 2.27 also reports figures on educational credential levels for workers in each of the industries, as well the percentages of workers who are women and people of color. With respect to educational credentials, the overall level of attainment is relatively high, with about 33 percent having Bachelor's degree or higher, and another 19 percent have some college or Associate degree. The remaining roughly 48 percent have high school degrees only or less. Women account for only 18 percent of the workforce, and people of color account for 11 percent.

In Table 2.28, we gain further detailed information on workforce and employment conditions for workers in Ohio's fossil fuel-based industries. We show the most prevalent job categories and the representative occupations in each job category.

The key finding that emerges from these tables is that the fossil fuel industries in Ohio provide a wide range of employment opportunities for the nearly 50,000 workers currently employed in these industries. As we see, the largest share of jobs, at 22 percent of the total, is in management. But other job categories—including construction, transportation, production, office support, extraction, architecture and engineering, and computer/math specialists—each account for roughly 7 percent or more of the total.

Overall, from the data presented in Table 2.28, we see that there are a large number of jobs, probably a majority, that match up well with new types of employment that will be generated through clean energy investments in Ohio, as well as expanded investments in public infrastructure. But that will not be the case with *all occupations* in which workers are now employed in Ohio's fossil fuel-based activities. As such, any just transition program to support displaced workers in Ohio's fossil fuel related industries will need to be focused on the specific background and skills of each of the impacted workers. We now turn to estimating the magnitude of this problem as Ohio transitions out of CO_2-generating energy sources.

TABLES 2.28
Prevalent Job Types in Ohio's Fossil Fuel-Based Industries
(Job categories with 5 percent or more employment)

Job category	Percentage of direct jobs lost	Representative occupations
Management	22.3%	Construction managers; marketing managers; financial managers
Construction	12.4%	Construction laborers; electricians; first-line supervisors
Transportation and material movers	10.5%	Excavating machine operators; pumping station operators; freight movers
Production	9.3%	Assemblers and fabricators; crushing, grinding, polishing, mixing and blending workers; inspectors
Office and administrative support	8.2%	Customer service representatives; billing clerks; administrative assistants
Extraction	8.1%	Explosive workers; earth drillers; mining machine operators
Installation and maintenance	7.8%	Riggers; maintenance and repair workers; heavy vehicle service technicians
Architecture and engineering	7.4%	Chemical engineers; mining and geological engineers; petroleum engineers
Computer and math specialists	6.7%	Operations research analysts; mathematical science occupations; computer systems analysts

Source: See Appendix 2.

Features of a Just Transition Program

We present here a Just Transition program for workers who face job losses through direct channels from the 40 percent contraction of the state's natural gas and oil industry, and a 70 percent contraction in the coal industry. The program has three major elements. These are:

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

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

To translate these general principles of a Just Transition into specific policies, and to estimate the costs of providing these policies, we now examine a basic policy package. We present the provisions of this policy package in Table 2.29.

As we see in Table 2.29, the detailed policy package includes five components. These are:

TABLE 2.29
Policy Package for Displaced Workers in Ohio's Fossil Fuel-Based Industries

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

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

Steady versus Episodic Industry Contraction

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

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

The costs of a 10-year just transition will be much lower if the transition is able to proceed smoothly rather than through a series of episodes. One reason is that, under a smooth transition, the proportion of workers who will retire voluntarily in any given year will be substantially greater than if several large businesses were to shut down abruptly and lay off their full work force at a given point in time. Another factor is that it will be easier to find new jobs for displaced workers if the pool of displaced workers at any given time is smaller.

We proceed here by assuming that Ohio will successfully implement a relatively smooth contraction of its fossil fuel sectors.[54] As we will see, a smooth transition should be realistic as long as the state's policymakers remain focused on that goal.

Estimating Attrition by Retirement and Job Displacement Rates

In Table 2.30, we show figures on annual employment reductions in Ohio's fossil-fuel based industries over 2021 – 30 that would result from a smooth 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 40 percent contraction in oil and gas, and 70 percent contraction in coal. As described above, the just transition program will provide support for all displaced workers through a re-employment guarantee along with wage insurance, retraining, and relocation support.

All forms of just transition support will also be fully available to those workers 65 and over who choose to continue working. We therefore need to estimate how many workers 65 and older are likely to choose to remain employed. For the fossil fuel sector taken as a whole, we approximate that about 20 percent of workers who are 65 and over choose to continue on their jobs.[55] 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

TABLE 2.30
Attrition by Retirement and Job Displacement for Ohio's Fossil Fuel-Based Industry Workers

	Fossil fuel workers
1) Total workforce as of 2018	49,302
2) Job losses over 10-year transition, 2021-2030	21,152
3) Average annual job loss over 10-year production decline *(= row 2/10)*	2,115
4) Number of workers reaching 65 over 2021-2030 *(=row 1 x % of workers 54 and over in 2019)*	13,805 *(28% of all workers)*
5) Number of workers per year reaching 65 during 10-year transition period *(=row 4/10)*	1,381
6) Number of workers per year retiring voluntarily	1,105 *(80% of 65+ workers)*
7) Number of workers requiring re-employment *(= row 3 – row 6)*	1,010

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

2021 – 2030. Specifically, we incorporate into our calculations in Table 2.30 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 2.30. As we see in column 2 of Table 2.30, there were, as of the most recent 2018 figures, 49,302 workers in Ohio employed in all fossil fuel-based industries. We assume that all the oil and natural gas-based industries will contract by 40 percent and all the coal-based industries by 70 percent. As we see in row 2 of the table, this means that total employment in these sectors will fall by 21,152 as of 2030, which means that there will be another 28,150 jobs retained. If we then assume that the contraction in these industries proceed at a steady rate between 2021 – 2030, this means that 2,115 jobs in these industries will be lost each year, as we see in row 3 (i.e. 21,152 job losses in total/10 years of industry contraction = 2,115 job losses per year).

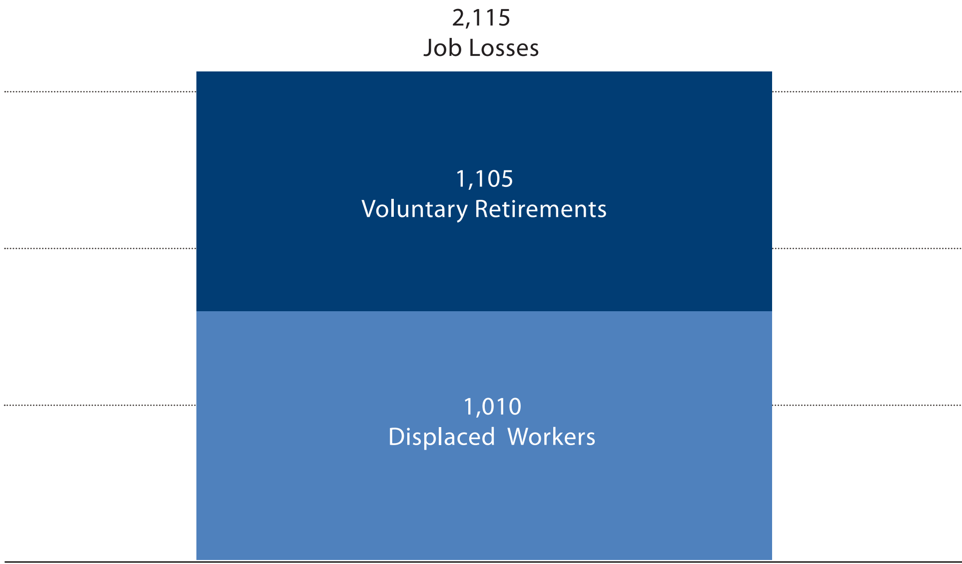
We see in row 4 that, of the workers presently employed in these sectors in Ohio, 13,805, or 28 percent, will be between 55 – 65 over 2021 – 2030. If all these workers were to voluntarily retire at a steady rate over 2021 – 2030, this would mean that 1,381 workers will move into retirement every year over the 10-year period. However, we are assuming that only 80 percent of these workers will retire once they reach 65. That is, as we see in row 6, we estimate that 1,105 workers employed in these sectors will retire voluntarily every year between 2021 – 2030. Given that total job losses each year will average 2,115 over the 2021 – 2030 period, that in turn means that the total number of workers currently employed in Ohio's fossil fuel-based sectors that will require re-employment will be 1,010 per year. We show this figure in row 7 of Table 2.30.

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 1,105 workers per year moving into voluntary retirement; and 2) Providing all the forms of re-employment support, including the re-employment guarantee, for the 1,010 workers per year facing displacement. Of course, these figures are not meant to be understood as precise estimates, but rather to provide broadly accurate magnitudes. Among other factors beyond what these figures themselves show, we again have to recognize that the pattern of contraction is not likely to be as smooth as is being assumed in our calculations.

Nevertheless, precise details aside, it is the overall finding that these results firmly establish that is most central: that the number of workers in Ohio who are likely to experience job displacement through the state's transitioning away from CO_2-generating energy sources will be small—indeed, the number of workers facing displacement should be in the range of 1,000 per year. Given that there are nearly 50,000 people employed presently in Ohio's fossil fuel-based industries, we acknowledge that it may appear implausible that there should be only about 1,000 workers per year who would be displaced through a program to cut consumption from CO_2-generating energy sources by 50 percent as of 2030. But as we saw in Table 2.30, this finding is not due to any kind of unreasonable assumptions or incomprehensible mathematical manipulations.

In Figure 1, we illustrate the main results of our calculations in Table 2.30.

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



Source: See Table 2.30.

Cost Estimates for a Just Transition Program

Pension Guarantees for Retiring Workers

What becomes clear from the evidence on the steady rate of contraction for Ohio's fossil fuel related industries is that guaranteeing workers' pension funds must be a centerpiece of the state's overall just transition program. This is especially important, given that the fossil fuel-based enterprises will likely face major financial challenges as a result of experiencing sharp contractions between 2021 – 2030. Under these circumstances, these firms may not consider their pension fund commitments to be a top financial priority. Despite this, guaranteeing workers' pensions as a first-tier financial obligation for employers can be established through regulatory policies. For example, the State of Ohio could work in coordination with federal regulators, at the Pension Benefit Guarantee Corporation (PBGC) to place liens on company assets when pension funds are underfunded. Through such measures, the pension funds for most of the affected workers can be protected through regulatory intervention alone, without the government having to provide financial infusions to sustain the funds.[56]

Guaranteed Re-employment

New employment opportunities will certainly open up in the expanding clean energy sectors, with approximately 110,000 new direct plus indirect jobs created per year in Ohio through clean energy investments at the level of $21 billion per year (see Table 2.16).[57] The new state clean energy projects are likely to be financed at least partially through public-sector funding. Given such public sector funding, the state could require job preference provisions for the displaced workers. Again, our estimate of the number of displaced workers that will need re-employment is about 1,000 in total. It will not be difficult for the state to set aside 1,000 guaranteed jobs for these displaced workers, or, for that matter, even, say, 10,000 jobs, as needed for this purpose. As we will discuss in the next section of this study, an additional 54,000 direct and indirect jobs should be created through an additional $7 billion per year invested in manufacturing and public infrastructure investment in Ohio, as well as agriculture and land restoration. Here again, the state could easily set aside approximately 1,000 jobs per year on average for displaced workers from the state's fossil fuel-based sectors.

Income Support through Wage Insurance

Though it will not be difficult to find new employment opportunities for the 1,000 fossil fuel-based workers that will be displaced annually on average, 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. As we have seen, the average compensation for fossil fuel-based workers in Ohio at present is about $100,000. This compares with the average compensation in the clean energy areas, ranging, as we saw in Table 2.17, between about $46,000 - $68,000 per year in the various specific 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 initial 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.

The data in Table 2.31 presents a framework for calculating a rough estimate as to what the costs would be for such a compensation insurance program. In row 1, the table shows the figures we have seen in Table 2.30 on the number of displaced workers in the fossil-fuel based sectors—i.e. 1,010 workers per year. Row 2 then shows their average compensation level of $100,400. In row 3, we show the mean compensation level for all of Ohio's clean energy sectors, as reported in Table 2.17, which is $60,600. From this difference in average compensation levels, we then calculate that the annual cost of compensation insurance for 1,010 workers will be about $120 million.

Retraining Support

As we have seen above (Tables 2.18-2.23), the range of new jobs that are being generated through clean energy investments vary widely in terms of their formal educational credentials as well as special skill requirements. Some of the jobs will require skills closely aligned with those that the displaced workers used in their former fossil fuel-based industry jobs. These include a high percentage of construction-related jobs for efficiency investments as well as most management, administrative and transportation-related positions throughout the clean energy industries. In other cases, new skills will have to be acquired to be effective at the clean energy industry jobs. For example, installing solar panels is quite distinct from laying oil and gas pipelines. This is why a just transition program must include a provision

TABLE 2.31
Estimating Costs of 100 Percent Compensation Insurance for Displaced Workers in Ohio's Fossil-Fuel Based Sectors

1. Number of fossil fuel-based displaced workers per year requiring re-employment	1,010
2. Average compensation for displaced workers	$100,400
3. Average compensation for clean energy sector jobs	$60,600
4. Average compensation difference between fossil fuel-based and clean energy jobs *(= row 2 – row 3)*	$39,800
5. Annual cost of compensation insurance for 1,010 workers *(= row 4 x row 1)*	$40.2 million
6. Total cost of compensation insurance for 3 years *(= row 5 x 3)*	$120.6 million

Source: See Tables 2.17, 2.27, and 2.30.

for retraining for the displaced fossil fuel-based industry workers. The just transition program will also need to serve as a job placement clearinghouse for all displaced workers.

There will be two components of this job retraining program for displaced workers. The first will be to finance the actual training programs themselves. We can estimate this with reference to the overall costs of providing community college education. An upper-end figure for annual non-housing costs for community college in Ohio is around $5,000.[58] We then also allow an additional $2,500 per year per worker to cover other expenses during their training program, such as purchases of textbooks and equipment. We assume that workers would require the equivalent of two full years of training, which they would most likely spread out on a part-time basis, as they move into their guaranteed jobs. By this measure, the average costs of the training program for 1,010 workers would be about $14 million per year.

Relocation Support

Some of the displaced workers will need to be relocated to begin their new jobs. For the purposes of our discussion, we assume that one-half of the 1,010 displaced workers per year will need relocation allowances, at an average of $75,000 per displaced worker.[59] That would bring the annual relocation budget to about $38 million for 505 workers each year.

Overall Costs for Supporting Displaced Workers

In Table 2.32, we show estimates of the full costs of providing this set of wage insurance, retraining and relocation support for 1,010 workers per year. As Table 2.32 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 2021, the first cohort of 1,010 displaced workers will receive support through the just transition program, including wage insurance, retraining and relocation sup-

TABLE 2.32
Total and Annual Average Costs for Just Transition Support for Displaced Fossil Fuel-Based Workers in Ohio, 2021 – 2030

Year	Income support *(3 years of support for 1,010 workers)*	Retraining support *(2 years of support for 1,010 workers)*	Relocation support *(1 year of support for 505 workers)*	Total *(cols. 1+2+3)*
2021	$40.2 million (1 cohort)	$7.6 million (1 cohort)	$38.0 million	$85.7 million
2022	$80.4 million (2 cohorts)	$15.2 million (2 cohorts)	$38.0 million	$133.5 million
2023	$120.6 million (3 cohorts)	$15.2 million (2 cohorts)	$38.0 million	$173.7 million
2024	$120.6 million (3 cohorts)	$15.2 million (2 cohorts)	$38.0 million	$173.7 million
2025	$120.6 million (3 cohorts)	$15.2 million (2 cohorts)	$38.0 million	$173.7 million
2026	$120.6 million (3 cohorts)	$15.2 million (2 cohorts)	$38.0 million	$173.7 million
2027	$120.6 million (3 cohorts)	$15.2 million (2 cohorts)	$38.0 million	$173.7 million
2028	$120.6 million (3 cohorts)	$15.2 million (2 cohorts)	$38.0 million	$173.7 million
2029	$120.6 million (3 cohorts)	$15.2 million (2 cohorts)	$38.0 million	$173.7 million
2030	$120.6 million (3 cohorts)	$15.2 million (2 cohorts)	$38.0 million	$173.7 million
2031	$80.4 million (2 cohorts)	$7.6 million (1 cohort)		$88.0 million
2032	$40.2 million (1 cohort)			$40.2 million
Total	**$1.2 billion**	**$151.8 million**	**$380 million**	**$1.7 billion**
Average annual costs	**$100.5 million** *(12 years of support)*	**$13.8 million** *(11 years of support)*	**$38.0 million** *(10 years of support)*	**$144.8 million**

Source: Tables 2.29 – 2..31.

port, as needed. As we can see in column 4, these full costs will amount to $85.7 million in 2021. Costs increase in 2022, since we now have two cohorts of displaced workers receiving income and retraining support, as well as one cohort receiving relocation support. Thus, total costs in 2022 rise to $133.5 million. In 2023, there are now three cohorts of displaced workers receiving income support, along with 2 cohorts receiving retraining support and, again, one cohort receiving relocation support. This totals to $173.7 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 $88 million, then to $40.2 million.

In total, just transition benefits provided to 1,010 displaced workers per year in Ohio will total to $1.7 billion, or an average of $144.8 million per year over 12 years, in total costs and about $170,000 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 Ohio 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 Ohio even as the fossil fuel-based industries themselves contract.

2.10 Transition Programs for Fossil Fuel Industry Dependent Communities

As we have seen, the total amount of employment in the fossil fuel and ancillary industries in Ohio is relatively low, at about 49,000 jobs. This amounts to about 0.9 percent of total statewide employment. As such, only a relatively small number of communities in the state will experience job losses that will significantly affect the overall level of economic activity in these respective communities. The losses experienced in these relatively hard-hit communities will also be partially offset by the job guarantee and wage insurance features of our proposed just transition program. Nevertheless, some communities will experience negative impacts of the fossil fuel industry contraction to a disproportionate extent.

In Table 2.33, we present estimates on the counties in Ohio in which, between 2021 – 2030, employment losses would amount to 2 percent or more of total private sector employment through the contraction of the state's fossil fuel industries to the extent we have described earlier—i.e. a 40 percent contraction of oil and gas and a 70 percent contraction of coal. These figures provide a useful reference for assessing which areas in the state will be most negatively impacted by the statewide contraction. Correspondingly, from these figures, we can also identify which areas in the state will be most in need of community transition support.

As Table 2.33 shows, there 8 counties in Ohio which will experience private sector employment losses of 2 percent or more between 2021 – 2030 from the state's fossil fuel industry contraction, at the contraction rates we have assumed. Monroe County will experience the most severe proportional employment losses, equal to about 14 percent of private sector employment in the county. At present, coal and oil/gas are the two largest employ-

TABLE 2.33
Ohio Counties with More than 2 Percent Private Sector Employment Loss through Statewide Fossil Fuel Sector Contraction, 2021 – 2030

County	Total fossil fuel jobs lost through 2021 – 2030 contraction	Job loss as pct. of county private-sector employment
Monroe County, Ohio	273	14.1%
Harrison County, Ohio	208	6.8%
Noble County, Ohio	88	4.3%
Belmont County, Ohio	768	4.0%
Carroll County, Ohio	181	3.5%
Vinton County, Ohio	52	3.1%
Guernsey County, Ohio	378	2.9%
Perry County, Ohio	96	2.0%

Source: U.S. Department of Labor's Quarterly Census of Employment and Wages
Note: Overall county employment figures are from 2018.

ers in the county, so it follows that the county will be hard hit as these industries are phased down.[60] Total employment losses as of 2030 would amount to 273 jobs, out of a total of 1,936 private-sector jobs in the county.[61]

Harrison County will be the next most severely impacted by the state's fossil fuel industry contraction. Total job losses in Harrison County will total to 208 jobs, equal to 6.8 percent of the county's overall private sector job pool of about 3,060 jobs. The other six most impacted counties—Noble, Belmont, Carrol, Vinton, Guernsey, and Perry counties—will experience job losses in the range of about 2 – 4 percent.

Total job losses in these eight counties will amount to 2,044 jobs, equal to a bit less than 10 percent of the 21,152 overall jobs that will be lost in Ohio between 2021 – 2030 through a 40 percent cut in the state's oil and gas industries and a 70 percent cut in coal. As such, the broad picture that emerges from these figures is that, for the most part, job losses in Ohio will be widely distributed throughout the state.

At the same time, we need to emphasize that our community impact estimates are overall average figures, derived from our working assumptions of a statewide fossil fuel industry contraction of, again, 40 percent for oil and gas and 70 percent for coal. In reality, there will be instances in which, for example, a coal mine in a community shuts down entirely and abruptly—i.e. a 100 percent shutdown within a few months' time span, as opposed to a gradual phase-out over the full 2021 – 2030 decade. Adams County experienced such a shutdown when AES Ohio Generation closed its J.M Stuart and Killen coal-fired power plants in 2018. An extensive 2019 study by Jolley, Khalaf, Michaud, and Sandler documented the local impact of these shutdowns, including 370 direct jobs at the two plants but also the equivalent of about 760 additional full-time jobs in other industries. They also estimate that local government tax revenue fell by $8.5 million due to the shutdown, and that more than 70 percent of that revenue would have gone to schools and children's services.[62]

This overall result suggests that a community transition program for Ohio should include two features. It should, first, focus on supporting the areas, such as Adams, Monroe and Harrison Counties, which have already experienced, or will experience over the course of the next decade, disproportionate employment losses through the statewide fossil fuel industry contraction. At the same time, support for new investment activity should also be broadly distributed throughout the state to minimize the negative impacts of the relatively widely disbursed employment losses in other parts of the state.

It is critical to recognize here that the decline of Ohio's fossil fuel industry will be occurring in conjunction with the rapid expansion of its clean energy economy, along with parallel investment programs that we will discuss in detail below in the areas of manufacturing, public infrastructure, land restoration and agriculture. This should provide a strong supportive foundation for advancing effective community transition policies, in ways similar to what we have already discussed in terms of providing job opportunities for younger displaced fossil fuel industry workers.[63]

Within this broader clean energy investment program, policies can be designed so that regions and communities that are heavily dependent on fossil fuel industries will receive disproportionate support to advance regionally appropriate clean energy projects. Previous federal programs can serve as useful models on how to leverage this wave of clean energy investments to also support fossil-fuel dependent communities facing transition. There are both positive and negative lessons on which to build.

Reclamation

Reclamation of abandoned coal mines as well as oil and gas production sites is one major category of community reinvestment that should be pursued as the fossil fuel industry contracts. Moreover, the federal government already has extensive experience financing and managing reclamation projects, beginning with the passage of the Abandoned Mine Land (AML) program in 1977, as one part of the broader Surface Mine Control and Reclamation Act. The program has been funded through fees charged to U.S. mining companies, with the fees having been set as a percentage of market prices for coal. In the early years of the program, the fees amounted to about 1.6 percent of the average price of a ton of surface coal and 0.7 percent of underground coal. However, the fee rates have declined sharply over time, to less than half their initial value as of 2013. Since its inception, the program has generated around $9 billion in total fees.

As of the most recent Department of Interior figures, the program had reclaimed over $5.9 billion worth of damaged sites spanning roughly 800,000 acres.[64] However, a 2015 study by Dixon and Bilbrey estimates that at least an additional $9.4 billion will be needed to remediate the approximately 6 million acres of land and waters that remain damaged through mining and abandonment. In 2016, the Obama administration had proposed a Power Plus Plan through which $1 billion from the existing pool of AML funds would be disbursed, with about 1/3 of these funds targeted for the Central Appalachian states. These funds would have represented significant support. At the same time, this $1 billion budget would still have represented only about 10 percent of the nearly $10 billion Dixon and Bilbrey estimate will be needed to adequately remediate the roughly 6 million acres that remain damaged.

In any case, the Obama program was never enacted once Donald Trump assumed the presidency in January 2017.[65] But the reclamation of the abandoned coal mines still needs to be accomplished. Otherwise, the damaged 6 million acres will continue to face severe problems, including, as Dixon and Bilbrey write, "landslides, the collapse of exposed highwalls, mine fires, subsidence caused by the deterioration of underground mines, water problems caused by abandoned mine pollution, and more." Dixon and Bilbrey further argue that "these problems continue to markedly impede local economic development and threaten the livelihoods of citizens," (2015, p. 13).

There are no comparable federal reclamation projects for abandoned oil and gas extraction production sites. However, in June 2020, the U.S. Congress began considering legislation to plug so-called orphaned oil and gas wells.[66] Orphaned wells are abandoned oil and gas wells for which no viable responsible party can be located. Idle oil and gas wells emit pollutants into the air, including hydrogen sulfide and organic compounds that contribute to ground-level ozone.

The one-time owners of these wells earn revenues during the wells' productive lives. They then frequently file bankruptcy to shield assets from creditors and then "orphan" the wells. At that point, the costs and responsibility to decommission and plug the wells becomes a matter of public policy intervention.

The policy measure that was introduced into the House of Representatives in June 2020 was included in the $1.5 trillion Moving Forward Act.[67] This bill included $2 billion to support well-plugging programs. But this budgetary figure assumes that there are only about 57,000 orphaned wells around the country and that the average clean-up cost would be $24,000. By contrast, in 2018, the U.S. Environmental Protection Agency estimated the number of orphaned onshore wells to be between 2.3 and 3 million—that is, more than 30 times the number of wells estimated in the House bill.[68] The total number of orphaned wells has been increasing due to the recent global oil price collapse, and will increase further, of course, as the clean energy transition proceeds.[69] Moreover, a recent report on the costs of plugging orphaned wells in Ohio specifically put this figure at $110,000, more than 4 times the amount included in the House bill. In short, plugging orphaned oil and gas wells should be recognized as a major reclamation project. It can also generate thousands of long-term jobs for former oil and gas field workers.

At the same time, while recognizing the imperative of reclamation projects, it is also important to not overstate their potential as an engine of long-run community development. For one thing, beyond the clean-up work itself, even when such projects are substantial, one cannot expect that a broader set of community-based development projects will inevitably emerge as spillover effects tied to the reclamation projects. In addition, reclamation projects are generally highly capital intensive. As such, on their own, they are not likely to produce large numbers of new job opportunities for workers laid off through declining fossil fuel production. It is therefore critical to also examine experiences and prospects for repurposing beyond reclamation in the current fossil fuel-dependent communities.

Repurposing

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

The conditions faced by the nuclear power-dependent communities and the aims of the repurposing program for them have useful parallels with the challenges that will be faced by many fossil fuel-dependent communities. To begin with, for security reasons, the nuclear facilities were located in rural areas. Most fossil fuel extraction sites are also in rural areas, as determined by the location of the fossil fuel deposits. As a result, in most cases, with both the nuclear weapons facilities and the fossil fuel production sites, the surrounding communities and economies became heavily dependent on these single activities. Finally, both with the nuclear and fossil fuel-dependent communities, the opportunities are limited to directly repurpose much of the physical infrastructure in place, since that infrastructure was built to meet the specific needs of each of the industries.[70]

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

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

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

The experience in Piketon, Ohio provides a good case study of how this program has operated in one community. Piketon had been the home of a plant producing weapons-grade uranium that closed in 2001. The workers in the plant were represented by the Oil Chemical and Atomic Workers union (OCAW—which merged in 1999 with the United Steel Workers). The union leadership was active in planning the plant's repurposing project. The closure could have been economically devastating for the region, but the federal government provided funding to clean up the 3,000-acre complex. The clean-up operation began in 2002 and is scheduled to take 40 years to complete.[71] Currently 1,900 workers are employed decontaminating the site at a cost of $300-$400 million a year. The contractor hired to clean up the site employs union workers and the president of the USW local union is enthusiastic about the long-term prospects for the project and the site (Hendren 2015).

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

To address this problem directly, community assistance initiatives could encourage the formation of new clean energy businesses in the affected areas. One example of a successful diversification program was the repurposing of a nuclear test site in Nevada to what is now a solar proving ground. More than 25 miles of the former nuclear site are now used to demonstrate concentrated solar power technologies and help bring them to commercialization.[72]

There are also important cases of successful repurposing projects in other countries. Most prominent has been the experience in Germany's Ruhr Valley, which has been the traditional home for its coal, steel and chemical industries. Since the 1990s, the region has advanced industrial policies to develop new clean energy industries.[73] As one important example of this repurposing project in the Ruhr region, RAG AG, a German coal-mining firm, is in the process of converting its Prosper-Haniel coal mine into a 200 megawatt pumped-storage hydroelectric reservoir that acts like a giant battery. The capacity is enough to power more than 400,000 homes in North-Rhine Westphalia.[74] In addition to hydroelectric power storage, the company is also erecting wind turbines on the top of tall waste heaps and installing solar panels on the slopes. Other firms in the region have branched into producing wind and water turbines. This regional transition project has succeeded through mobilizing the support of the large coal, steel and chemical companies and their suppliers, along with universities, trade unions and government support at all levels.

It is not realistic to expect that transitional programs will, in all cases, lead to developing new economic bases that support a region's previous level of population and community income. In some cases, the role of community assistance will be to enable communities, moving forward, to shrink to a size that a new economic base can support. As we have seen in some cases with repurposing nuclear waste sites and in the experiences in Germany's Ruhr Valley, one central challenge for Ohio will be to effectively integrate transition programs with the coming wave of public and private investments in energy efficiency and clean renewable energy that we have described above. These clean energy investments will also combine with programs to support manufacturing development, public infrastructure, land restoration and agriculture that we describe in Part 3. As we will summarize in Part 4, our estimate is that, in combination, these investments will generate roughly 240,000 jobs in Ohio.

2.11 Achieving a Zero Emissions Economy by 2050

If Ohio is able to bring overall CO_2 emissions in the state down to 110 million tons by 2030—a 50 percent decline relative to the 2018 level of 220 million tons—it should also be able to establish a zero emissions economy by 2050.

In fact, bringing Ohio in alignment with a global climate stabilization project will not require fossil fuel energy consumption in the state, and thereby CO_2 emissions, to fall precisely to zero. This is because perhaps as much as 5 – 10 million tons of CO_2 emissions can be absorbed through afforestation and the expansion of organic agricultural practices within Ohio itself. These are projects that will be supported through the investment program we will describe below in the areas of land restoration and agriculture. Nevertheless, as a means of simplifying the analysis here, we assume that the goal will be for Ohio to reach zero emissions within the state by 2050. The global climate stabilization project would then be further strengthened as afforestation and the expansion of organic farming in the state contribute toward absorbing the accumulated stock of CO_2 in the atmosphere.

Ohio should be able to establish a zero emissions energy infrastructure 2050 basically through continuing the clean energy investment project that would have proceeded from 2021 – 2030. Moreover, on an annual basis, the scale of the investments in energy efficiency and clean renewable energy between 2031 – 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 2.11, our estimate of the clean energy investment costs for bringing emissions down to 110 million tons by 2030 was about 2.8 percent of Ohio's GDP per year between 2021 - 2030. 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 about 1.8 percent of Ohio's average GDP. The impact of the smaller investment project on job opportunities throughout the state are therefore likely to also be more modest than during 2021 – 2030, though still strongly in the positive direction.

We do not attempt to develop here a full assessment as to the technical requirements for achieving a zero emissions economy in Ohio by 2050. However, many researchers, focused on a range of different regions and countries, have concluded that conversion to an economy relying on clean renewable sources to meet 100 percent of energy demand is technically feasible within a few decades or less. One important study reaching this conclusion is by the Harvard University physicist Mara Prentiss. Prentiss concludes in her 2015 book, *Energy Revolution: The Physics and the Promise of Efficient Technology,* that "Electricity generated by renewable energy can easily provide 100 percent of the average energy consumption of the United States during those next 50 years, virtually eliminating the negative environmental consequences associated with fossil fuel consumption," (2015, p. 304).[75]

Within a framework that recognizes the technical feasibility of bringing CO_2 emissions to zero by 2050, our focus here is to assess the economic trajectory of how this goal can be accomplished while the state's economy and job opportunities continue to grow. Of course, considering how such a trajectory is likely to proceed entails making a series of assumptions about the economy's long-term growth path. This exercise necessarily becomes increasingly speculative the further out one moves in time. To keep our discussion as realistic as possible, we rely on a small number of assumptions that are credible within the body of knowledge that is available to us at present.

The assumptions on which we will rely are as follows:

1. *Economic growth.* We assume that average economic growth in Ohio proceeds at the same rate as we have assumed for 2021 – 2030, i.e. at 1.5 percent per year.
2. *Energy efficiency.* We have already assumed that Ohio will have achieved major gains in energy efficiency between 2021 – 2030, specifically that the state's energy intensity ratio will have fallen from 5.6 to 3.6 Q-BTUs per $1 trillion of GDP—a 36 percent improvement. We assume that further efficiency gains are possible through continued investments, and that the costs of achieving these efficiency gains will remain at $35 billion per Q-BTU, the same cost figure for our 2021 – 2030 scenario. We make this assumption of stable overall costs, based on two ideas: 1) technological improvements will occur in raising efficiency standards; but 2) the "low-hanging fruit" possibilities for efficiency gains will have dissipated. We assume that these two factors will roughly counteract each other.
3. *Clean renewable energy.* Technological advances in generating, storing and transmitting renewable energy will certainly occur between 2031 – 2050, especially given that these industries will have scaled up dramatically over 2021 – 2030. But to proceed cautiously, we assume only a modest rate of average technological improvement for renewables overall—that the average costs of creating 1 Q-BTU of renewable capacity falls at an average rate of 1 percent per year between 2031 – 2050. This means, specifically, that average costs for expanding renewable energy supply will fall from the 2030 level of $200 billion per Q-BTU to an average of $182 billion over 2031 – 2050.
4. *Job creation.* We assume that labor productivity in all clean energy investment activity improves at an average annual rate of 1 percent per year. These gains in productivity will proceed concurrent with the 1.5 percent average annual GDP growth rate. As such, the net increase in employment will be 0.5 percent per year.

Working from these assumptions on 1) economic growth; 2) the costs of achieving energy efficiency gains and an expanded clean renewable energy supply; and 3) labor productivity, we then develop projections as to how Ohio could become a zero emissions economy by 2050. We present these results in Tables 2.34 – 2.39.

In Table 2.34, we show Ohio'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 $808 billion. This figure is itself a projection, of course, which we derived through assuming that Ohio's GDP would grow at an average annual rate of 1.5 percent between 2018 – 2030, starting from the 2018 actual GDP level of $676 billion. Based on these assumptions, as we see in Table 2.34, Ohio's GDP will be $1.1 trillion in 2050. We then calculate the midpoint GDP level between 2031 – 2050 under this scenario. As we see, this midpoint figure is $962 billion.

In Table 2.35, we then estimate the investment costs necessary to bring Ohio's energy intensity ratio down from the 2030 figure of 3.6 to 2.2 Q-BTUs of energy/$1 trillion in GDP. We had projected in Table 2.10 that Ohio would be at the 3.6 intensity ratio by 2030 under the clean energy investment program we outlined for 2021 – 2030. Table 2.35 shows that to arrive at a 2.2 energy intensity ratio by 2050 will require $56 billion in new energy efficiency investments between 2031 – 2050 under the 1.5 percent growth scenario. Con-

TABLE 2.34
Ohio Average Economic Growth Projection for 2031 – 2050
Assumption is 1.5% average GDP growth

Projected 2030 GDP level *From Table 2.9*	$808.1 billion
Projected 2031 GDP level	$820.2 billion
Projected 2050 GDP level	$1.1 trillion
Midpoint GDP level for investment spending estimates *(= (2031 GDP + 2050 GDP)/2)*	$962.1 billion

Source: See Table 2.9; authors' calculations.

TABLE 2.35
Energy Efficiency Investments Needed to Bring Ohio Energy Intensity Ratio to 2.2 by 2050
Energy Intensity Ratio = Q-BTUs of energy/GDP in trillions of dollars
Assumption is 1.5% average GDP growth

1) 2050 GDP assumption *From Table 2.34*	$1.1 trillion
2) Total 2050 energy consumption at 3.6 energy intensity ratio *(=3.6 x $1.1 trillion)*	4.0 Q-BTUs
3) Total energy consumption at 2.2 energy intensity ratio *(=2.2 x $1.1 trillion)*	2.4 Q-BTUs
4) Gains in energy efficiency through 2031 – 2050 efficiency investments *(= rows 2 – 3)*	1.6 Q-BTUs
5) Costs of achieving energy efficiency gains *(= row 4 x $35 billion)*	$56 billion
6) Costs per year over 20-year investment cycle *(=row 5/20)*	$2.8 billion

Sources: Tables 2.11, 2.34, and authors' projections

sidered on an annual basis, these total costs amount to an average of $2.8 million per year under the 1.5 percent growth scenario.

In Table 2.36, we perform a comparable set of calculations for clean renewable energy investments between 2031 – 2050. We begin these calculations with the assumption of a 2.2 energy intensity ratio for 2050. This then entails that, in 2050, overall energy consumption in Ohio will be at 2.4 Q-BTUs. This total level of energy demand will then need to be supplied by clean renewable energy sources. As of 2030, clean renewable energy supply will be at 0.82 Q-BTUs. This means that the net expansion of clean renewables by 2050 will need to be 1.58 Q-BTUs. As we see in rows 4 – 7 of Table 2.36, achieving this higher level of productive capacity in clean renewables will require a level of investment averaging $14.4 billion per year.

In Table 2.37, we then summarize these results for achieving zero emissions in Ohio as of 2050. As we see, we estimate these overall costs to be $344 billion, which averages to

TABLE 2.36
Clean Renewable Energy Investments Needed to Reach Zero Emissions by 2050

1) 2050 Energy consumption level with 2.2 energy intensity ratio *From Table 2.35*	2.4 Q-BTUs
2) Total clean renewable energy supply required *(= 100% clean energy supply)*	2.4 Q-BTUs
3) Clean renewable energy supply as of 2030 *From Table 2.11*	0.82 Q-BTUs
4) Renewable energy expansion needed by 2050 *(= rows 2-3)*	1.58 Q-BTUs
5) Midpoint cost per Q-BTU of expanding clean renewable supply *Assumes average costs decline at 1% per year relative to 2030*	$182 billion
6) Total costs of reaching 2.4 Q-BTUs in renewable supply *(= rows 4 x 5)*	$288 billion
7) Average annual costs over 20-year investment cycle *(= row 6/20)*	$14.4 billion

Sources: Tables 2.11, 2.35, and authors' projections

TABLE 2.37
Overall Estimated Costs of Achieving Zero Emissions in Ohio by 2050

1) Total energy efficiency investment costs *From Table 2.35*	$56 billion
2) Total renewable energy investment costs *From Table 2.36*	$288 billion
3) Total clean energy investment costs *(= rows 1 + 2)*	$344 billion
4) Average annual costs per year for 20-year investment cycle *(= row 3/20)*	$17.2 billion
5) Average annual costs per year as percentage of midpoint GDP *(= row 4/Table 2.34 figure)*	1.8%

Sources: See Tables 2.34, 2.35, and 2.36.

$17.2 billion per year over 2031 – 2050. As a share of Ohio's projected midpoint GDP over 2031 – 2050, these annual cost figures would amount to 1.8 percent of GDP. As mentioned above, these figures are significantly below the cost level we have estimated for the initial 2021 – 2030 investment period that would be necessary to bring Ohio's CO_2 emissions down to 110 million tons by 2030. We estimated those costs to amount to about 2.8 percent of the state's average GDP between 2021 - 2030.

Employment Creation through 2031 – 2050 Investment Project

In Table 2.38, we provide rough estimates as to the level of employment creation that would be generated by the clean energy investment levels necessary to bring Ohio's CO_2 emissions

TABLE 2.38
Average Annual Ohio Employment Creation through Clean Energy Investments, 2031 – 2050

1) Estimated annual average job creation through 2021 – 2030 clean energy investments (rounded) *From Table 2.16*	165,000 jobs
2) Approximate average annual investment spending 2031 – 50 as pct. of 2021 – 30 spending *From Tables 2.11 and 2.37*	80.4%
3) Average annual employment creation 2031 – 2050 with fixed productivity *(= row 1 x row 2)*	133,000 jobs
4) Average annual employment creation 2031 – 2050 with 1% labor productivity growth *(= row 3 x 0.91, midpoint productivity relative to 2030)*	121,000

Sources: See Tables 2.11, 2.16, and 2.37.

down to zero by 2050. We have estimated these employment figures based on two assumptions: 1) the overall clean energy investment spending levels for 2031 – 50 as a proportion of the 2021 – 2030 spending level; and 2) our assumption of a 1 percent average annual increase in labor productivity in these clean energy investment projects, while clean energy investments increase at the same rate as GDP growth, i.e. at 1.5 percent per year.

We saw in Table 2.16 that, for over 2021 – 2030, our estimate of total employment—direct, indirect and induced employment—generated through clean energy investments at $21.4 billion per year would be about 165,000 jobs. This rounded figure of 165,000 jobs is repeated in row 1 of Table 2.38. In row 2, we then calculate average annual clean energy investment spending for 2031 – 2050 as a share of average spending over 2021 – 2030. That figure is 80.4 percent. From this figure, we then generate an estimate of 121,000 jobs being created on average within the 2031 – 2050 labor force, after assuming that labor productivity grows by 1 percent per year between 2031 – 2050.

Just Transition Program

In Table 2.39, we provide estimates for the just transition program for 2031 – 2050. The figures we present in Table 2.39 are derived from the material we have developed for the 2021 –2030 period in Section 2.9 of this paper, including in Tables 2.29 and 2.30.

With the 2021 – 2030 analysis, we reported in Table 2.26 that a total of 49,302 workers were employed in Ohio as of 2018 at jobs in the state's fossil fuel-based industries. In Table 2.30, we provide the estimate that by 2030, a total of 21,152 of these jobs, equal to 43 percent of the jobs, will be lost. This results from our assumption that oil and natural gas consumption will decline by 40 percent and coal will fall by 70 percent as of 2030. These cuts in consumption will then correspond to equivalent cuts in production activity and employment levels. This result also implies that, as of 2030, 28,150 jobs will remain in these industries across Ohio (49,302 – 21,152 = 28,150).

Starting from the goal that Ohio is going to achieve zero emissions by 2050, this means that all 28,150 jobs will be phased out between 2031 – 2050. This amounts to 1,408 jobs lost

TABLE 2.39
Costs of Just Transition Program for Displaced Workersin Fossil Fuel Sectors: 2031 – 2050 Scenario

1) Projected number of workers employed in fossil fuel industries in 2030	28,152
2) Employment contraction, 2031 – 2050 *(100% contraction)*	28,152
3) Average employment contraction per year *(= row 2/20)*	1,408
4) Projected number of workers reaching retirement between 2031 – 2050 *(workers 45 years and over in 2031; assume 50%)*	14,076
5) Average annual attrition through voluntary retirement *(= row 4 x 80%/20)*	563
6) Average number of workers displaced annually, 2031 – 2050 *(= row 3 – row 5)*	845
7) Average annual costs of 100% just transition: compensation insurance, retraining and relocation support *(= row 6 x $145,000 per worker)*	$123 million
8) Average annual costs of just transition as share of average 2031 – 2050 GDP *(= row 7/$962.1 billion)*	0.01%

Sources: Projections based on figures from Tables 2.30 and 2.32.

per year as an annual average figure over this 20-year period. Working from the age profile of workers in the industry, we estimate that 563 workers per year will voluntarily retire over this same period. This then means that an average of 845 workers per year in Ohio's fossil fuel-based industries will face displacement.

From the figures we report in Table 2.32, we assume that the total costs per worker of the just transition program—including compensation insurance, retraining, and relocation support—will be $145,000 per worker. Thus, the average annual costs of just transition support for 845 Ohio workers will be $123 million. As we note in row 8 of Table 2.39, this figure amounts to about 0.01 percent of Ohio's average GDP between 2031 – 2050 of $962 billion. In short, covering the full costs of just transition for all of Ohio's displaced fossil fuel-based industry workers comes to a trivial figure relative to the overall level of economic activity in the state.

PART 3:
INVESTMENT PROGRAMS FOR MANUFACTURING, INFRASTRUCTURE, LAND RESTORATION, AND AGRICULTURE

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

The overall level of investment we propose is one percent of Ohio's current GDP level of approximately $700 billion. We propose dividing the full set of funding equally between the two broad categories, i.e. investments in manufacturing/public infrastructure and land restoration/agriculture respectively. Both of these broad investment areas would receive $3.5 billion per year in support.

The specific projects on which we focus, and the budget amounts we propose to allocate, are as follows:

Manufacturing and Public Infrastructure--$3.5 billion per year

1. Broadband development: $1 billion/year
2. Water/wastewater/inland waterways upgrades: $1 billion/year
3. Manufacturing R&D: $500 million/year
4. Bioplastics R&D: $500 million/year
5. Dams/Levees upgrades: $300 million/year
6. Repairing existing gas distribution pipelines: $200 million/year.

Land Restoration and Agriculture--$3.5 billion per year

1 Regenerative agriculture: $1.5 billion/year
2. Farmland conservation: $1 billion/year
3. Plugging orphaned oil and gas wells: $500 million/year
4. Land restoration: $500 million/year

These proposed funding areas and budget allocations reflect the priorities developed by a range of organizations working to promote the revival of the U.S. manufacturing and agricultural sectors in conjunction with advancing a viable clean energy transition project. We refer specifically to three sets of initiatives which have offered constructive proposals in these areas:

- The THRIVE Agenda introduced into the U.S. Congress in September 2020;
- The 2017 and 2019 assessments of the American Society of Civil Engineers as to the conditions of Ohio's public infrastructure; and
- The Reimagine Appalachia program in support of a "Civilian Conservation Corps 2.0 and Regenerative Agriculture and Agro-Forestry."

THRIVE—the agenda to "Transform, Heal and Renew by Investing in a Vibrant Economy."
This is a resolution introduced into the U.S. Congress on September 10, 2020 by Senate Minority Leader Chuck Schumer, Elizabeth Warren and other members of Congress, with initial endorsements from 85 congresspeople.[76]

In the area of "Creating Millions of Good, Safe Jobs with Access to Unions," the THRIVE Agenda includes the following as priorities[77]:

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

***American Society of Civil Engineers (ASCE) evaluations on Ohio's public infrastructure*.** In 2019, the ASCE provided a detailed study, focused on the quality of the public infrastructure for Northeastern Ohio. The overall assessment of this study was that the public infrastructure in Northeastern Ohio is "in poor to fair condition and mostly below standard, with many elements approaching the end of their service life." The ASCE gave the region's infrastructure an overall D+ grade. The 2017 report was for the overall state. This report is not as detailed as the 2019 version for Northeastern Ohio only. But its summary analysis for the state's overall infrastructure at that time is consistent with the 2019 detailed study. For example, the 2017 report estimated that the state would need to invest an average of roughly $1 billion per year for 20 years to bring up to standard the state's drinking water and wastewater infrastructure. It also estimated that 412 of the state's 1,420 dams are in "high hazard" conditions.[78]

Civilian Conservation Corps 2.0 and Regenerative Agriculture and Agro-Forestry. A forthcoming paper by Patricia DeMarco and Sara Nicholas develops an agenda for Reimagine Appalachia that recommends four mutually reinforcing policies[79]:

1. Expand federal farm bill support for local food and fiber production through regenerative agriculture and agro-forestry practices that ensure fresh, nutritious food to Appalachian residents, reduce energy use and pollution, and create more local wealth that is then reinvested in local communities.
2. Revitalize and update the 1930s-era Civilian Conservation Corps into a modern-day employment creation, job training and conservation program employing hundreds of thousands now without jobs in our region, including diverse and low-income workers and returning citizens.
3. Provide financial incentives for landowners to adopt carbon-absorbing practices (e.g., planting trees and using no-till methods and cover crops), raising incomes while leaving their land healthier for future generations.

4. Establish a Rural Cooperatives and Network (Rural CAN) Administration within the U.S. Department of Agriculture that provides resources and technical assistance for co-operatives and wealth creation networks anchored by local agriculture, agro-forestry, and value-added products made with locally grown materials.

To be clear here, the specific investment areas on which we focus in this section are meant to be illustrative of the types of spending priorities and the level of spending commitments that are consistent with the THRIVE, ASCE, and Reimagine Appalachia policy proposals as well as other related proposals. We have introduced specific project areas and budget figures to enable us to generate estimates of the employment impacts of advancing significant investment programs in the broad priority areas set out by THRIVE, ASCE and Reimagine Appalachia. Our proposals are not meant to serve as detailed plans for action.

Job Creation through Manufacturing and Public Infrastructure Investments

In Table 3.1, we show the job creation figures for our six manufacturing and public infrastructure investment areas: broadband; water/wastewater/inland waterways; manufacturing R&D; bioplastics R&D; dams/levees; and repairing leaky gas distribution pipelines. As we see, the extent of direct plus indirect jobs ranges from 2.3 direct plus indirect jobs per $1 million in expenditure for repairing gas distribution pipelines to 10.1 direct and indirect jobs for upgrading the state's dams and levees. Adding induced jobs brings the range to 4.2 jobs per $1 million for repairing gas distribution pipelines to 14.1 for dams/levees.

Based on these proportions, we see in Table 3.2 the levels of job creation in Ohio generated by spending an average of $3.5 billion per year between 2021 – 2030 in these areas of manufacturing and public infrastructure investments at the levels we have assigned to each

TABLES 3.1
Job Creation in Ohio through Manufacturing and Infrastructure Investments
Job creation per $1 million in manufacturing and infrastructure investments

	Direct jobs	Indirect jobs	Direct+ indirect jobs	Induced jobs	Direct, indirect+ induced jobs
Broadband	1.9	1.9	3.8	1.8	5.7
Water/wastewater/inland waterways	5.3	1.9	7.2	3.0	10.2
Manufacturing R&D	3.3	2.7	6.0	3.0	9.0
Bioplastics R&D	3.3	2.7	6.0	3.0	9.0
Dams/levees	8.0	2.2	10.1	4.0	14.1
Gas distribution pipelines—repairing leaks	1.0	1.3	2.3	1.9	4.2

Note: Due to rounding, total employment figures do not in all cases exactly equal the sum of the category-by-category employment figures.
Sources: Authors' calculations using IMPLAN 3.0. See Appendix 1.

TABLES 3.2
Manufacturing and Public Infrastructure Investments for Ohio, 2021 – 2030
Overall Program at $3.5 billion per year
0.5 percent of 2019 Ohio GDP (= $698.5 billion)

	Budget	Direct jobs	Indirect jobs	Direct+ indirect jobs	Induced jobs	Direct, indirect+ induced jobs
Broadband	$1 billion	1,900	1,900	3,800	1,800	5,700
Water/wastewater/ inland waterways	$1 billion	5,300	1,900	7,200	3,000	10,200
Manufacturing R&D	$500 million	1,650	1,350	3,000	1,500	4,500
Bioplastics R&D	$500 million	1,650	1,350	3,000	1,500	4,500
Dams/levees	$300 million	2,400	660	3,030	1,200	4,230
Gas distribution pipe-lines—repairing leaks	$200 million	200	260	460	380	840
TOTALS	**$3.5 billion**	13,100	7,420	20,490	9,380	29,970

Note: Due to rounding, total employment figures do not in all cases exactly equal the sum of the category-by-category employment figures.
Source: Table 3.1.

area: $1 billion each for broadband and water infrastructure; $500 million each for R&D both for manufacturing in general and bioplastics specifically; $300 million for dams/levees and $200 million for repairing gas distribution pipelines.

Following from these budgetary assumptions, we see in Table 3.2 that total direct plus indirect job creation generated in Ohio by these investments will be 20,490 direct plus indirect jobs and just under 30,000 jobs total if we include induced jobs.

Job Creation through Land Restoration and Agriculture

In Table 3.3, we show the job creation figures for our four investment areas in this category: regenerative agriculture; farmland conservation; plugging orphaned oil and gas wells; and general land restoration. For these projects, we see that direct and indirect jobs ranges between 2.5 per $1 million in expenditure for plugging orphaned wells, 7.9 for land restoration, 9.7 for farmland conservation, and 12.7 for regenerative agriculture. Adding induced jobs brings the range to 4.3 per $1 million for plugging orphaned wells to 14.5 for regenerative agriculture.

Based on these proportions, we see in Table 3.4 the levels of job creation in Ohio generated by spending an average of $3.5 billion per year between 2021 – 2030 in these areas of land restoration and agriculture at the levels we have assigned to each area: $1.5 billion for regenerative agriculture; $1 billion for farmland conservation; and $500 million each for plugging orphaned wells and general land restoration.

TABLES 3.3
Job Creation in Ohio through Land Restoration and Agriculture Investments
Job creation per $1 million in investments

	Direct jobs	Indirect jobs	Direct+ indirect jobs	Induced jobs	Direct, indirect+ induced jobs
Regenerative agriculture	10.3	2.5	12.7	1.8	14.5
Farmland conservation	7.4	2.3	9.7	3.6	13.3
Plugging orphaned oil and gas wells	1.1	1.3	2.5	1.9	4.3
Land restoration	6.0	1.9	7.9	3.3	11.3

Note: Due to rounding, total employment figures do not in all cases exactly equal the sum of the category-by-category employment figures.
Sources: Authors' calculations using IMPLAN 3.0. See Appendix 1.

TABLES 3.4
Land Restoration and Agriculture Investment Program for Ohio, 2021
Overall Program at $3.5 billion per year
0.5 percent of 2019 Ohio GDP (= $698.5 billion)

	Budget	Direct jobs	Indirect jobs	Direct+ indirect jobs	induced Jobs	Direct, indirect+ Induced jobs
Regenerative agriculture	$1.5 billion	15,450	3,750	19,050	2,700	21,750
Farmland conservation	$1.0 billion	7,400	2,300	9,700	3,600	13,300
Plugging orphaned oil and gas wells	$500 million	550	650	1,250	950	2,150
Land restoration	$500 million	3,000	950	3,950	1,650	5,650
TOTALS	**$3.5 billion**	26,400	7,650	33,950	8,900	42,850

Note: Due to rounding, total employment figures do not in all cases exactly equal the sum of the category-by-category employment figures.
Source: Table 3.3.

Following from these budgetary assumptions, we see in Table 3.5 that total direct plus indirect job creation generated in Ohio by these investments will be 33,950 direct plus indirect jobs and 42,850 jobs total if we include induced jobs.

Indicators of Job Quality

In Table 3.6, we provide some basic measures of job quality for the jobs that will be generated through both the manufacturing/infrastructure and the land restoration/agriculture investment projects in Ohio. As with our discussion on clean energy investment jobs, the

TABLE 3.5

Annual Job Creation in Ohio through Combined Manufacturing/Infrastructure and Land Restoration/Agriculture Investment Programs

Estimates are annual averages for 2021 – 2030

Industry	Number of direct and indirect jobs created	Number of direct, indirect and induced jobs created
$3.5 billion in manufacturing development and public infrastructure		
1) Broadband	3,800	5,700
2) Water/wastewater/inland waterways	7,200	10,200
3) Manufacturing R&D	3,000	4,500
4) Bioplastics R&D	3,000	4,500
5) Dams/levees	3,030	4,230
6) Gas distribution pipelines-repairing leaks	460	840
7) Total job creation from manufacturing development and public infrastructure *(= rows 1 – 6)*	20,490	29,970
$3.5 billion in land restoration and agriculture		
8) Regenerative agriculture	19,050	21,750
9) Farmland conservation	9,700	13,300
10) Plugging orphaned oil and gas wells	1,250	2,150
11) Land restoration	3,950	5,650
12) Total job creation from land restoration/ agriculture *(= rows 8 – 12)*	33,950	42,850
13) Total for all investment areas *(= rows 7 + 12)*	54,440	72,820
13) TOTAL AS SHARE OF 2019 OHIO LABOR FORCE *(Labor force at 5.8 million)*	**0.9%**	**1.3%**

Sources: See Tables 3.2 and 3.4.

basic indicators again are: 1) average total compensation (including wages plus benefits); 2) the percentage of workers receiving health insurance coverage; 3) the percentage having retirement plans through their employers; and 4) the percentage that are union members. In addition, as before, we focus here only on the *direct* jobs that will be created through clean energy investments in Ohio.

Starting with compensation figures, we see that the averages for manufacturing/infrastructure are mostly within the range of the clean energy jobs with the exception of the gas pipeline repair work. That is, the average compensation for pipeline repair is very high, at $142,000, but for the other activities, the range is between about $61,000 – $72,000. Average compensation is then lower in the areas of land restoration/agriculture, ranging between a low figure in regenerative agriculture of $40,000, with farmland conservation and regen-

TABLE 3.6
Job Quality Indicators for Ohio's Manufacturing/Infrastructure and Land Restoration/ Agriculture Investments
Direct Jobs Only

	Manufacturing/Infrastructure Investments					
	1. Broad-band *(1,900 workers)*	2. Water/ wastewater *(5,300 workers)*	3. Manufac-turing R&D *(1,650 workers)*	4. Bio-plastic R&D *(1,650 workers)*	5. Dams/ levees *(2,400 workers)*	6. Gas pipe-line repairs *(200 workers)*
Average total compensation	$64,500	$60,800	$72,200	$72,200	$61,600	$142,300
Health insurance coverage, percentage	51.3%	44.5%	46.4%	46.4%	43.1%	81.2%*
Retirement plans, percentage	43.6%	34.9%	67.6%	67.6%	37.0%	80.7%*
Union membership, percentage	24.6%	14.2%	4.9%	4.9%	17.9%	11.8%

	Land Restoration/Agriculture Investments			
	7. Regen-erative ag. *(15,450 workers)*	8. Farmland conserv. *(7,400 workers)*	9. Plug orphaned wells *(550 workers)*	10. Land restoration *(3,000 workers)*
Average total compensation	$40,300	$52,700	$73,800	$57,100
Health insurance coverage, percentage	28.3%	36.8%	51.4%	39.8%
Retirement plans, percentage	22.7%	41.1%	42.4%	37.5%
Union membership, percentage	6.3%	6.8%	6.7%	5.6%

Notes: *Due to small sample sizes, the figures for the sector "Gas Pipeline Repairs" are estimated from the East North Central Division region (Illinois, Indiana, Michigan, Ohio, and Wisconsin) rather than the state of Ohio alone.

Sources: See Appendix 2.

erative agriculture at $53,000 – $57,000, and with plugging orphaned wells higher at about $74,000. It is important to note here that, with the exception of workers repairing gas pipelines, these average compensation figures are all well below the $100,000 average compensation level paid to fossil fuel industry workers.

The figures for workers receiving health insurance from their employers are also broadly similar to those for clean energy, in that for virtually all the investment areas, no more than half of the workers receive employer-based coverage. Again, the one exception here is the gas pipeline repair workers, in which over 80 percent of workers have employer-based coverage.

The range of coverage is wider with respect to private retirement plans. The low-end figure is with regenerative agriculture, in which only 23 percent of workers are provided with an employer-based pension. With most of the other activities, the share receiving employer-sponsored pensions is fewer than half of all workers. But here we do also see three exceptions—manufacturing and bioplastics R&D, where 68 percent of workers are covered with pensions, and again, the gas pipeline repair workers, in which over 80 percent have employer-based pensions.

Unionization rates vary still more widely by the various specific activities. With manufacturing and bioplastics R&D, fewer than 5 percent of workers are union members. With all of the activities under land restoration/agriculture, fewer than 7 percent are union members—a figure that is low, but still slightly above the 6.2 percent average for the overall U.S. private sector. But in the areas of gas pipeline repairs, water management, dams/levees and broadband, unionization rates are significantly higher, at 12, 14, 18 and 25 percent respectively.

Overall, as indicated by our four measures, we see in Table 3.6 that job quality standards in Ohio for workers in the areas of manufacturing and infrastructure are broadly comparable to those in the various clean energy activities. But job quality is generally lower for Ohio workers employed in the areas of land restoration and agriculture. As such, the measures that should be employed for clean energy investments to raise job quality, including support for unionization as well as accessible and effective job training programs, will be equally important, if not more so, for advancing the quality of employment as well as the number of jobs available in the areas of manufacturing/infrastructure and land restoration/agriculture.

Implementing a $15 minimum wage standard for these jobs would also be important. Of the direct jobs created by manufacturing/infrastructure spending, 14 percent pay less than $15.00 per hour. The figure for agriculture/land restoration investments is significantly higher: over one-third—36 percent—of direct jobs created by such spending pay wage rates below $15.00 per hour. Raising the pay rates of these jobs would entail a modest one percent increase in investment spending.[80]

Educational Credentials and Race/Gender Composition

In Table 3.7, we present data on the educational credentials for workers in jobs that are directly employed in the areas of manufacturing/infrastructure and land restoration/agriculture in Ohio as well as the race and gender composition of these workers.

Educational Credentials

With respect to educational credentials, as previously, we categorize all workers according to three educational credential groupings: 1) shares with high school degrees or less; 2) shares with some college or Associate degrees; and 3) shares with Bachelor's degrees or higher.

As Table 3.7 shows, there are large disparities in educational attainment levels based on the specific projects we are considering. Not surprisingly, in the two areas of manufacturing and bioplastics R&D, educational attainment levels are high, with over 70 percent of workers holding Bachelor's degrees of higher. By contrast, with most of the other activities, at least 40 percent of the workers have lower attainment levels, with high school degrees or less. In considering this range of investment areas as a whole, what emerges is that large proportions of the newly generated jobs will be open to workers at all educational attainment levels. In particular, as with the clean energy investments, we again see with these manufacturing/infrastructure and land restoration/agriculture investment programs that there will be a substantial expansion of employment opportunities for workers that more generally face difficulties finding good-quality jobs.

TABLE 3.7
Educational Credentials and Race/Gender Composition for Ohio's Manufacturing/ Infrastructure and Land Restoration/Agriculture Investments
Direct Jobs Only

	Manufacturing/Infrastructure Investments					
	1. Broad-band (1,900 workers)	2. Water/ wastewater (5,300 workers)	3. Manufac-turing R&D (1,650 workers)	4. Bio-plastic R&D (1,650 workers)	5. Dams/ levees (2,400 workers)	6. Gas pipe-line repairs (200 workers)
Share with high school degree or less	50.0%	53.1%	8.6%	8.6%	52.9%	47.9%
Share with some college or Associate degree	32.1%	28.7%	20.1%	20.1%	27.3%	20.8%
Share with Bachelor's degree or higher	17.9%	18.2%	71.3%	71.3%	19.7%	31.3%
Racial and gender composition of workforce						
Pct. non-white	16.3%	14.4%	30.2%	30.2%	14.2%	14.5%
Pct. female	12.7%	14.8%	49.3%	49.3%	13.0%	18.7%

	Land Restoration/Agriculture Investments			
	7. Regen-erative ag. (15,450 workers)	8. Farmland conserv. (7,400 workers)	9. Plug or-phaned wells (550 workers)	10. Land restoration (3,000 workers)
Share with high school degree or less	54.2%	29.6%	41.3%	42.1%
Share with some college or Associate degree	25.8%	24.2%	25.7%	26.2%
Share with Bachelor's degree or higher	20.1%	46.2%	33.1%	31.7%
Racial and gender composition of workforce				
Pct. non-white	11.3%	18.6%	17.6%	18.1%
Pct. female	35.0%	51.3%	41.8%	40.5%

Sources: See Appendix 2.

Race and Gender Composition

The representation of female workers and people of color also varies sharply according to the specific project areas. In manufacturing and bioplastics R&D, we see that half of all jobs are held by women and 30 percent are held by people of color. These figures roughly reflect the composition of Ohio's population as a whole. The representation of women is also at roughly 50 percent in farmland conservation, but is lower otherwise, with low figures in the areas of broadband and dams/levees at 13 percent, water management at 15 percent and repairing gas pipelines at 19 percent. Outside of the two R&D activities, the share of jobs held by people of color ranges between 11 – 19 percent. With the exception of regenera-tive agriculture, these figures are generally in line with the share of Ohio's population that are people of color, which is 17 percent. Thus, as is the case with Ohio's clean energy economy, the investments in manufacturing/infrastructure and land restoration/agriculture will certainly create increased opportunities for people of color in the state. But, fortunately, as a starting point, the baseline level of employment for people of color in these investment areas is not presently disproportionately low.

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

Table 3.8 reports on the prevalent job types associated with investments in manufacturing/infrastructure and Table 3.9 provides comparable figures for land restoration/agriculture. As previously, in all cases, we report on the job categories in which we estimate that 5 percent or more of the new jobs will be created through these investment areas.

It is clear from these tables that job opportunities will expand in a wide range of areas. In the manufacturing/infrastructure areas, nearly 30 percent of all employment in manufacturing/infrastructure will be in the construction industry, including jobs for pipelayers, electricians, and supervisors. The R&D investment areas will of course create employment for chemical, life science and engineering technicians. Jobs will also expand for truck mechanics, water treatment plant operators, and freight movers, as well as receptionists and bookkeeping clerks. With land restoration/agriculture, the largest expansion of employment will be for

TABLES 3.8
Manufacturing Development and Infrastructure: Prevalent Job Types in Ohio Industry
(Job categories with 5 percent or more employment)

Job category	Percentage of direct jobs created	Representative occupations
Construction	28.0%	Pipelayers; electricians; first-line supervisors
Management	16.9%	Industrial production managers; chief executives; operations managers
Life, physical and social science	10.4%	Chemical technicians; chemists; life science technicians
Office and administrative support	8.3%	Receptionists; bookkeeping clerks; secretaries
Architecture and engineering	6.8%	Electrical engineers; civil engineers; engineering technicians
Installation and maintenance	5.9%	Truck mechanics; telecommunications equipment installers; general maintenance workers
Production	5.4%	Inspectors; welding workers; water treatment plant operators
Transportation and material moving	5.1%	Excavating machine operators; crane operators; freight movers

Source: See Appendix 2.

farmers, farm managers, and agricultural workers. These will be in addition to the expansion of jobs in the areas of office support and transportation.

As with the clean energy investments, what emerges generally from Tables 3.6 – 3.9 is that investments in manufacturing/infrastructure and land restoration/agriculture will certainly generate a wide range of new employment opportunities. We again also note that this broad range of new opportunities will be available for workers in Ohio that will have been displaced by the contraction of the state's fossil fuel industry activities.

TABLES 3.9

Agriculture and Land Restoration: Prevalent Job Types in Ohio Industry

(Job categories with 5 percent or more employment)

Job category	Percentage of direct jobs created	Representative occupations
Management	30.8%	Operations managers; property managers; farmers
Farming, fishing, and forestry	10.5%	Agricultural products sorters; first-line supervisors; agricultural workers
Office and administrative support	8.4%	Customer service representatives; administrative assistants; accounting clerks
Transportation and material moving	6.5%	Recyclable material collectors; industrial truck operators; packers
Sales	5.8%	Wholesale sales representatives; real estate brokers; cashiers

Source: See Appendix 2.

PART 4:

TOTAL JOB CREATION IN OHIO THROUGH COMBINED INVESTMENTS

We include this brief Part 4 in order to bring together and highlight our estimates of the overall employment impacts of the full set of investment programs we have presented in Parts 2 and 3. These include:

- Investments in energy efficiency and clean renewable energy, targeted at bringing down CO_2 emissions in Ohio by 50 percent as of 2030.
- Investments in manufacturing and public infrastructure that will raise productivity throughout the state and also advance new areas of industrial opportunity, such as in bioplastics.
- Investments in land restoration and agriculture that will create new opportunities for family farms, recreation and ecotourism, while also reducing energy use and pollution.

As we have shown in Parts 2 and 3, we have scaled these investment projects at an average of $28.4 billion per year over 2021 – 2030, equal to about 3.8 percent of Ohio's projected average GDP for 2021 – 2030. The proposed budget allocations include $21.4 billion per year for clean energy, including $15.9 billion in clean renewable energy and $5.5 billion in energy efficiency. This is the figure that we have estimated will be needed to achieve a 50 percent reduction in Ohio's CO_2 emissions by 2030. We have also budgeted $3.5 billion per year respectively for manufacturing/public infrastructure and land restoration/agriculture.

We summarize the impact of these investment projects in Table 4.1. As the table shows, we estimate that these projects, in combination, will generate nearly 165,000 direct and indirect jobs per year in Ohio, amounting to about 2.8 percent of Ohio's labor force as of 2019.

TABLE 4.1
Annual Job Creation in Ohio through Combined Investment Programs
- Clean Energy
- Manufacturing/Infrastructure
- Land Restoration/Agriculture

Estimates are annual averages for 2021 – 2030
Overall Investments at $28.4 billion/year; 3.8% of Ohio GDP

	Number of direct and indirect jobs created	Number of direct, indirect and induced jobs created
1) $15.9 billion/year in clean renewable energy	74,381	116,686
2) $5.5 billion/year in energy efficiency	34,319	48,375
3) $3.5 billion/year in manufacturing/public infrastructure	20,490	29,970
4) $3.5 billion/year in land restoration/agriculture	33,950	42,850
5) Total for all investment areas *(= rows 1 - 4)*	163,140	237,881
13) TOTAL AS SHARE OF 2019 OHIO LABOR FORCE *(labor force at 5.8 million)*	**2.8%**	**4.1%**

Sources: See Tables 2.16 and 3.5.

When we include induced job creation (i.e. "multiplier effects"), total job creation rises to nearly 240,000 jobs, equal to about 4.1 percent of Ohio's 2019 labor force.

As a simple exercise to illustrate the potential impact of this level of job creation in Ohio, let us assume that these investments are undertaken in the state, and all else about the state's economy were to remain equal. Under such an "all else equal" assumption, this level of job creation would result, for example, in the state's unemployment rate falling from, say, 8 percent to 4 percent. A reduction in Ohio's unemployment rate at this scale would, of course deliver a major expansion in job opportunities throughout the state. It would also provide a foundation for a corresponding improvement in average living conditions.

PART 5:
FINANCING A FAIR AND SUSTAINABLE RECOVERY

The state and municipal-level governments in Ohio, along with their equivalents throughout the country, face the real possibility that they could experience massive revenue shortfalls.

For the 2020 fiscal year that recently ended (July 2019 – June 2020), the state's tax revenue fell by around $1.1 billion, a decline of about 4.6 percent relative to the state's estimate in the FY 2020 budget and amounting to 3 percent of the $35 billion general revenue fund budget.81 A revenue decline of at least this level is not surprising, given that about 60 percent of the state's revenue comes from income and sales taxes.82 Once the pandemic and lockdown conditions began in mid-March, it followed that incomes and business sales would fall sharply along with the spike in unemployment that we reported in Part 1.

In May, Gov. DeWine announced $775 million in spending cuts to cover the budget shortfall. The cuts include a $300 million reduction in K-12 public-school funding, $210 million from Medicaid spending and $110 million from college and university funding. All state government agencies will see their budgets cut, totaling $100 million, except for the state Department of Corrections, which operates state prisons. Through these cuts, and carrying over a $500 million cash balance resulting from an increased federal share of Medicaid costs, the state balanced the budget for FY 2020 without tapping the state's $2.7 billion Budget Stabilization Fund, known as the Rainy Day Fund.[83] The state is projecting a shortfall in FY 2021, however, of an additional $2.3 billion.[84] Governor DeWine has indicated that he expects public sector layoffs in the coming year, and that the state will drain the Rainy Day Fund through the course of the recovery.[85] Additionally, a refinancing of Ohio Public Facilities Commission debt will save Ohio nearly $364 million in payments to cover 15 percent of the projected shortfall in the new fiscal year.[86]

Overall then, the state government's primary response thus far to the pandemic and economic collapse has been to slash public spending in the vital areas of education and health care. The Cleveland Fed presented three alternative scenarios: a "V-shaped" recovery where the declines in tax base are half-way reversed in 2020:Q3, and they completely reverse by 2020:Q4, a "slow" scenario where declines are reversed over four quarters, and a "second wave" assuming another complete shutdown in 2020:Q4. Under the Cleveland Fed's "V-Shape" recovery scenario, state revenue would fall by 2.7 percent in FY 2021, or roughly $1.3 billion. A revenue decline of this amount would be manageable, given the state's option of drawing on its $2.7 billion Rainy Day Fund. But under the Cleveland Fed's "second wave" scenario, state revenue would fall by 14.7 percent, or about $7.1 billion. This amount is nearly 3 times larger than the state's Rainy Day Fund.[87]

The situation becomes still more serious when we incorporate the prospects for major revenue shortfalls at the level of Ohio's municipal governments as well. A report by the Cleveland Fed finds local governments lost $1.6 billion in revenues (3.8 percent of total local government revenues) in FY 2020, and risk losing up to another $1.9 billion (4.4 percent of revenues) in FY 2021 under a second wave scenario.[88] A recent report by the National Association of Counties expects counties in particular — which rely heavily on charges, fees, and income and sales tax revenues — to face a 21 percent budgetary shock nationwide through FY 2021, between lost revenues and increased expenses.[89]

In Ohio, the main local government institutions are municipalities, townships, counties and schools. By and large, schools depend on property taxes, counties on sales tax and many cities and villages rely on the income tax.[90] A Brookings Institute study found that four of the top five U.S. cities likely to be hurt most financially by the coronavirus pandemic are in Ohio: Columbus, Cincinnati, Toledo and Cleveland, with Akron coming in at number 13.

Cities in Ohio rely heavily on a flat income tax, which is immediately and significantly sensitive to changes in employment. In Columbus, for example, 76 percent of the general fund comes from income taxes, and 16 percent of regional employment is in highly vulnerable industries.[91] With the Coronavirus Aid, Relief and Economic Security (CARES) Act, which became law in March 2020, Congress provided Ohio's state and local governments $4.5 billion. However, these funds could only be allocated to cover new costs related to COVID-19. They could not be used for basic services, and therefore provided no help with budget shortfalls.

Considering these prospects for Ohio, it is imperative that the public entities at all levels undertake serious consideration of some unconventional financing possibilities, including bond sales to the Federal Reserve as well as additional borrowing on the open market. This would be in addition to obtaining increased economic stimulus and recovery funding from the U.S. Treasury. Recognizing the range of possibilities around all of these options will be the most effective approach toward preventing the worst-case scenario for Ohio ensuing over 2021.

Federal Government Support

In the federal CARES Act and related measures, the U.S. government did provide large-scale support to state and local governments and other entities through various specific channels. We summarize the total federal funding injection into Ohio's economy in Table 5.1.

As we see, the general relief funding authorized to the Ohio state government was $3.75 billion, equating to about 0.5 percent of the state's 2019 GDP.[92] In addition, $780 million was available for eligible units of local governments, like Columbus City or Cuyahoga County.[93] An additional estimated $2.2 billion is authorized for specific beneficiaries by their function, such as airports, transport authorities or financial aid to students.[94] Total support amounted to $6.7 billion, equal to 1 percent of Ohio's 2019 GDP.

In terms of support for Ohio's businesses, the main source of support was provided through the Paycheck Protection Program. This distributed $22.5 billion, equal to 3.2 percent of state GDP, by the end of August. Support for individuals through the CARES Act through supplemental unemployment insurance, the separate cash assistance fund and — from August onwards — the Lost Wages Assistance program was an estimated at $16.5 billion as of 9/9, another 2.4 percent of Ohio's GDP.[95]

The federal government's level of support beginning in March, via the CARES Act and related measures, thus totaled to $45.8 billion, or 6.6 percent of Ohio's 2019 GDP. At the same time, these headline figures may overstate the actual level of support they bring so far. This is primarily because, through mid-August, the state and local governments had expended only $547 million, or 12 percent, of their $4.5 billion relief fund.[96]

This is the context in which the U.S. House of Representatives passed the HEROES Act on May 15. This measure would have provided additional funding support for Ohio and other states. But it was opposed by the Republican-controlled U.S. Senate and President Trump. Estimates as to how much Ohio would have received under the HEROES Act ranged between about $16.9 and $20.4 billion.[97] This amount on top of the figures already received would have gone a long way towards providing sufficient funding to the state as the pandemic-induced recession has continued.

TABLE 5.1
Federal COVID-19 Related Funding to Ohio, March – September 2020

Industry	Funding level	Funding as share of Ohio 2019 GDP
Assistance to Public Entities		
Funding to state government	$3.7 billion	0.5%
Funding to local government	$0.8 billion	0.1%
Funding to other public entities*	$2.2 billion	0.3%
Total assistance to public entities	**$6.7 billion**	**1.0%**
Assistance to Businesses		
Paycheck Protection Program (through 8/8)	$18.5 billion	2.6%
Economic Injury Disaster Loans (through 8/24)	$4.0 billion	0.6%
Total assistance to businesses	**$22.5 billion**	**3.2%**
Assistance to Individuals		
Unemployment insurance benefits for all standard employees ** (through 9/9)	$4.4 billion	0.6%
Unemployment insurance benefits for freelancers, self-employed and gig workers	$1.9 billion	0.3%
Cash assistance	$10.2 billion	1.5%
Total assistance to individuals	**$16.5 billion**	**2.4%**
TOTAL ASSISTANCE	**$45.8 billion**	**6.6%**

Source: Noted in text.
Notes: Individual budget figures may not equal to totals due to rounding.
* Includes certain funds going directly to private entities, e.g. emergency student financial aid..
** Includes Pandemic Emergency Unemployment Compensation and Lost Wages Assistance disbursed during the week of 9/14/20.

State-Level Funding Prospects

Given the uncertain situation, Ohio needs to develop its own contingency plans for alternative funding to support a strong recovery. In considering this, it is critical to recognize that, by statute, the state does have the legal authority as well as the capacity to issue bonds to support certain types of capital projects which have been enabled by constitutional amendments approved by voters.[98] According to these amendments, capital projects can be funded in the areas of highways, local infrastructure, coal development, natural resources and parks, higher education, common schools, conservation, and research and development.[99] Given these areas, capital projects could include public sector-led clean energy investments to, for example, raise energy efficiency standards in public buildings through retrofitting projects. Ohio's bond issuance was limited by a 1999 amendment to the constitution that stipulated total annual debt service (repayment of principal and interest on bonds) may not exceed 5 percent of the state's current revenue in any future year of repayment.[100] As of April 30, 2020 the Ohio government calculated that with outstanding debt the highest payment would be $1.3 billion in 2021, or 3.75 percent of the FY2020 budget.[101] Of course, with the revenue shortfall from the current crisis, the 5 percent limit could quickly become a constraint, as the overall budget figure will be contracting. However, the same constitutional amendment also provides for the possibility to overrule this limit with a three-fifth majority in both houses of the Ohio legislature.[102]

In addition, the state can expand the range of investment projects that can be financed through borrowing, by issuing "human capital" bonds, to cover expenditures on keeping up health and education services during this pandemic. Focusing on state-level funding in the area of educational financing, the University of Massachusetts Amherst economist Gerald Epstein (2020) has developed a proposal in detail as to how "human capital bonds" could be introduced.[103] Epstein writes:

> Most states' balanced budget requirements only apply to the budgets for current spending. These states have separate capital budgets for longer-term investments, such as in new schools, new buildings on college campuses, new roads, etc., that are designed for borrowing. So, one way around the balanced budget problem is to identify this emergency education spending as a type of capital spending and put it under the capital budget. This would entail denoting the borrowing instruments as investments in *human capital*, using parlance long established in the economics profession. The bonds could be called, for example, *human capital bonds* and they could be issued under states' capital budgets (2020, p. 3).

As Epstein (2020) further explains, the Federal Reserve currently operates a program to purchase bonds from state and municipal governments, what the Fed has termed its "Municipal Liquidity Facility." Under its current operating procedures, the Fed has the capacity under this facility to purchase up to a total of $500 billion in state and municipal bonds.[104] Under this program, the state government and municipalities in Ohio are able to sell up to $10.7 billion in bonds to the Fed.[105] In the current state of extreme economic uncertainty, this Fed program is one major viable funding option that cannot be ruled out. Indeed, if the Fed's bond purchasing capacity were to increase in response to the ongoing severe recession, Ohio's ability to increase its borrowing through this program could then rise correspondingly. Such funding support, again, could also be supplemented by bond sales on the open market that Ohio has regularly been doing in the past.

What Are Ohio's Funding Needs?

As we have discussed, there is a great deal of uncertainty regarding the trajectory of the Ohio economy over the next year. This is equally true for the U.S. and global economies. It is therefore not possible to know what funding amounts would be sufficient to move Ohio onto a viable recovery path. Broadly speaking, we do nevertheless know that large-scale funding will be needed, at the least, to support short-term interventions in the areas of public health, unemployment insurance, and cash assistance, as well as the longer-term investment projects in health and education, and the areas on which we have focused in Parts 2 and 3, i.e. clean energy, manufacturing, public infrastructure, land restoration and agriculture.

In Table 5.2, we provide some rough estimates of funding requirements over both the very short-term of the next three months as well as within a longer-term framework of the first year of multi-year projects in the areas we have discussed above in this study—public health, unemployment insurance and cash assistance, as well as investments in clean energy, manufacturing, public infrastructure, land restoration and agriculture. The budget amounts listed in Table 5.2 are all based on the various financing considerations that we have presented in the earlier sections.

Our proposal does not consider additional support to businesses through extending the Paycheck Protection Program or any alternative targeted program for bolstering small businesses. Such support focused on small businesses will continue to be warranted both as long as the severe recession is ongoing and the support funds can be equitably allocated to their intended recipients—i.e. truly small business operations in need.[106]

Thus, starting with the 3-month time period, Table 9 first lists $10 billion in one-time cash assistance, at the level provided in March under the CARES Act. It then proposes $4.8 billion in supplemental unemployment insurance, which is equivalent to level of unemployment insurance support Ohio received over the first three months of the CARES Act.

The $1.8 billion allocated for the Medicare Crisis program, as listed in Table 5.2, would also be over a 3-month period. This figure is based on the estimate Pollin, Wicks-Lim and

TABLE 5.2
Proposed Budgets for Ohio Public Health, Short-Term Stimulus, and Long-Term Investment and Recovery Programs

Industry	Budget level	Time frame for spending
State Government Support		
Cash assistance	$10 billion	3 months—reassess in January
Supplemental unemployment insurance	$4.8 billion	3 months—reassess in January
Medicare crisis health insurance	$1.8 billion	3 months—reassess in January
Supplemental public health/safety interventions	$1.5 billion	1 year
Clean energyinvestments—public funds	$2.0 billion	1 year
Manufacturing/public infrastructure investments	$3.5 billion	1 year
Land restoration/agriculture investments	$3.5 billion	
Total state-level support	**$27.1 billion**	**Combined 3 months and 1 year**
Municipal Government Support	**$1.9 billion**	**1 year**
TOTAL STATE PLUS MUNICIPAL GOVERNMENT SUPPORT	**$29.0 billion**	**Combined 3 months and one year**
TOTAL SUPPORT AS SHARE OF OHIO PROJECTED 2021 GDP *(= $706.8 billion)*	**4.1%**	

Source: Funding levels described in text..

Arno generated of the overall funding level for this proposed program on a national basis. Our estimate of the overall funding requirements for this program is $106 billion, assuming that, on average over the next three months, 15 million people would be receiving unemployment benefits throughout the U.S.[107] The corresponding Ohio figure for residents receiving unemployment insurance would be about 250,000 people, based on the figures for initial and continued unemployment claims as of the end of September.

Moving into the longer-term budgetary allocations listed in Table 5.2, the $1.5 billion for supplemental public health/safety interventions represents a roughly 10 percent increase in the state's Health and Human Services funding level over the $15.1 billion included in the 2021 fiscal year's budget. We roughly estimate this as being the amount of additional financial support necessary in Ohio over the next year to provide sufficient adequate public health interventions to control the COVID pandemic at a level roughly equivalent to countries such as Australia, Japan or South Korea. As we have reviewed in Part 1, management of the pandemic in these three countries, as well as others, has been dramatically more effective than that in Ohio or the U.S. generally. If, as anticipated, a vaccine becomes available over the course of 2021, this level of additional public health funding will still be needed to ensure safe and rapid distribution.

These public health investments will also generate major increases in employment for health care workers. As we saw in Table 1.3, employment in Ohio's health care and education service sector declined by nearly 7 percent in June/July 2020 relative to 2019. This is at precisely the time at which the state was focused intensively on controlling the spread and mitigate the impact of COVID-19. Jobs in public health need to be restored and expanded in Ohio to sustain a safe reopening of the economy.

The $2 billion in public funding for clean energy investments (with $18 billion in private investments) is the amount that we derived in Part 2, consistent with achieving a 50 percent reduction in CO_2 emissions in Ohio by 2030. The $3.5 billion each for manufacturing/public infrastructure and land restoration/agriculture are the budget allocations we discussed in Part 3.

Finally, Table 5.2 includes $1.9 billion in overall support for municipal entities throughout the state. This is the figure we presented above, based on the projection by the Cleveland Federal Reserve municipal-government revenue losses over the coming 12 months.

As we see, adding everything up, we estimate the total level of additional public funding needs for Ohio in the areas of public health, unemployment insurance, cash assistance, public infrastructure and clean energy as being $29.0 billion. This is equal to about 4.1 percent of Ohio's 2019 GDP. It is obviously a large sum. The figure would of course be higher still if it included assistance to businesses in the state. If businesses in Ohio were to receive further support through the Paycheck Protection Program or an alternative at the 2.6 percent of state GDP figure provided through the CARES Act, the total for a new round of funding would rise to about 6.6 percent of Ohio's GDP, or $46 billion. This level of support, including now for business assistance, would be exactly in line with the $46 billion provided through the CARES Act, which, as we saw in Table 5.1.

Where to Find the Funds?

The U.S. House version of the HEROES Act, which passed the U.S. House of Representatives in May, would have been funded at $3 trillion, or about 14 percent of U.S. GDP. If Ohio were to have received its equal share of funding from the HEROES Act or its equivalent, at 14 percent of state GDP, that would amount to $98 billion—i.e. more than double the level of support we are proposing through the combined programs for public health, unemployment insurance, cash assistance, clean energy and public infrastructure, plus additional funding to small businesses.

In addition to the CARES Act and a possible new round of stimulus funding, interventions undertaken by the Federal Reserve during the COVID crisis are projected to reach between $5 and $8 trillion, or up to 40 percent of U.S. GDP.[108] These interventions operate through bond purchases from both private and public entities, including state and municipal governments, as well as direct loans to private businesses and Wall Street firms.

Overall then, more than sufficient support should be available to finance a robust second round of stimulus injections into the Ohio economy, assuming that some version of the HEROES Act, or a broadly similar measure, becomes law, almost certainly after the November 3 U.S. election. This support from the U.S. Treasury could then be bolstered through the Federal Reserve purchasing of state and municipal bonds from Ohio at highly concessionary interest rates. At present, bonds issued by the state and municipalities in Ohio are already being marketed at very low rates. As of 10/8/20, yields on Ohio municipal bonds ranged between 0.6 – 0.7.[109] These rates could remain at this level or decline even further to the extent that the Federal Reserve engages in an active program to purchase Ohio's public sector bonds. With Ohio's state and municipal governments being able to borrow at such low rates, the prospects will remain highly favorable for these public entities to support the large-scale funding programs that will likely be needed to counteract the economic crisis.

Appendix 1
Employment Estimating Methodology

The employment estimates for Ohio were developed using an input-output model. Here we used IMPLAN v3, an input-output model which uses data from the U.S. Department of Commerce as well as other public sources. The data set used for the estimates in this report is the 2018 Ohio data. An input-output model traces linkages between all industries in the economy as well as institutional sources of final demand (such as households and government). A full discussion of the strengths and weaknesses of input-output (I-O) models and their application to estimating employment in the energy sector can be found in Appendix 4 of Pollin et al. (2014).

One important point to note here is that I-O models to date do not identify renewable energy industries such as wind, solar, or geothermal, or energy efficiency industries such as building retrofits, industrial efficiency, or grid upgrades.[110] However, all of the components that make up each of these industries are contained in existing industries within the models. For example, the hardware, glass production, and installation industries that are all activities within "solar" are each an existing industry in the I-O model. By identifying the relevant industries and assigning weights to each, we can create "synthetic" industries that represent each of the renewable energy and energy efficiency industries within the model. Below we show the industries and weights used in this study. A full discussion of the methodology for creating synthetic industries can be found in Garrett-Peltier (2017).

The energy industries and weight of each component industry are shown in Table A1.1, below.

Scaling Manufacturing Activity

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

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

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

Energy Industries	Composition and Weights of Industries within the I-O Model
Building Retrofits	50% maintenance and repair construction of residential structures, 50% maintenance and repair construction of non-residential structures.
Industrial efficiency with CHP	20% environmental and technical consulting services, 10% repair construction of non-residential structures, 5% air purification and ventilation equipment manufacturing, 5% heating equipment manufacturing, 5% A/C, refrigeration, and warm air heating equipment manufacturing, 10% all other industrial machinery manufacturing, 25% turbine and turbine generator set units manufacturing, 7.5% power boiler and heat exchanger, 2.5% electricity and signal testing instruments, 10.0% architectural and engineering services.
Grid upgrades	25% construction of new power and communication structures, 25% mechanical power transmission equipment manufacturing, 25% commercial and industrial machinery and equipment repair and maintenance, 25% other electronic component manufacturing.
Public transport/ rail	30% construction of other new non-residential structures, 21% motor vehicle body and parts manufacturing, 6% railroad rolling stock manufacturing, 43% transit and ground passenger transportation.
Expanding electric vehicles	30% automobile manufacturing, 20% light truck manufacturing, 25% storage battery manufacturing, 5% motor vehicle electrical and electronic, 10% other motor vehicle parts, 2% motor vehicle stamping, 8% motor vehicle body.
Wind (onshore)	26% construction of new power and communication structures, 12% plastic and resin manufacturing, 12% fabricated structural metal manufacturing, 37% turbine and turbine generator manufacturing, 3% mechanical power transmission equipment manufacturing, 3% electronic connector manufacturing, 7% miscellaneous professional, scientific, and engineering services .
Solar PV	30% construction of new power and communication structures, 17.5% hardware manufacturing, 17.5% mechanical power transmission equipment manufacturing, 17.5% capacitor, resistor, coil, transformer, and other inductor manufacturing, 17.5% miscellaneous professional, scientific, and engineering services.
Geothermal	15% drilling wells, 35% construction of new non-residential structures, 10% pump and pumping equipment manufacturing, 10% power boiler and heat exchanger, 30% scientific research and development services.
Low-emissions bioenergy	15% grain farming, 10% sugarcane and sugar beet farming, 15% industrial process variable instruments, 20% construction of non residential structure, 10% construction of new commercial structure,10% wet corn milling, 5% sugarcane refining, 15% power boiler and heat exchanger .
Small scale hydro	50% construction of new nonresidential structures, 10% concrete pipe manufacturing, 10% architectural and engineering services, 15% turbine and turbine generator, 5% mechanical power transmission equipment manufacturing, 5% motor and generator manufacturing, 5% copper rolling.

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

Manufacturing Development	Composition and Weights of Industries within the I-O Model
Broadband	10% Cable subscription programming, 25% construction of new power structure, 20% wired telecommunication services, 20% wireless telecommunication services, 10% fiber optic cable manufacturing, 15% misc. electrical equipment.
Water and wastewater infrastructure	30% water and sewage, 25% construction of other new non-residential structure, 10% plastic pipe, 5% concrete pipe, 5% iron and steel pipe, 5% fabricated pipe, 10% other support services, 10% waste management.
Manufacturing research and development; bioplastics research and development	100% Scientific Research and Development Services.
Dams/levees	15% architectural and engineering services, 10% other support services, 50% construction of new nonresidential structures, 15% concrete block and brick manufacturing, 5% iron and steel pipe manufacturing, 5% fabricated pipe manufacturing.
Repairing leaks in gas pipelines	60% Natural Gas Distribution; 40% Pipeline transportation.
Regenerative agriculture	15% grain farming, 10% fruit farming, 5% greenhouse production, 20% all other crop, 20% animal production, 10% beef cattle ranching, 5% labor and civic organization, 15% construction of new commercial structures.
Farmland conservation	60% museums, zoos, parks, 10% social advocacy organization, 30% environmental consulting services.
Plugging orphan wells	30% Natural Gas distribution, 40% pipeline transportation, 30% support activities for oil and gas operations.
Land restoration	30% environmental consulting services, 10% museums, zoos, parks, 50% waste management, 10% landscape and horticultural services.

TABLE A1.2
Employment Multipliers per $1 Million in Unconstrained and Constrained Cases (for the clean, renewable energy sector)

	Direct, indirect, and induced jobs per $1 million	
	If all sectors expanded 100 percent	Constrained: all sectors expand at existing domestic content
Wind (onshore)	8.6	6.6
Solar PV	9.4	6.0
Geothermal	12.5	10.8
Small-scale hydro	12.5	12.1

Appendix 2
Estimating Job Characteristics for Clean Energy and Fossil Fuel Industry Jobs

Characteristics of Jobs Created by Clean Energy Investments

Our strategy for identifying the types of jobs that would be added to the economy due to an investment in one of the energy efficiency and clean energy sectors involves two steps.

The first step is to calculate, for each specific investment program, the level of employment generated in each of 526 industries through our input-output model (IMPLAN) as explained in Appendix 1.

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

Our information about the workers currently employed in the industrial mix of jobs created by an investment comes from the Current Population Survey (CPS). The CPS is a household survey administered by the U.S. Census Bureau, on behalf of the Bureau of Labor Statistics of the U.S. Labor Department. The basic monthly survey of the CPS collects information from about 60,000 households every month on a wide range of topics including basic demographic characteristics, educational attainment, and employment status. Among a subset of its monthly sample—referred to as the outgoing rotation group (ORG)—respondents are asked more detailed employment-related questions, including about their wages and union status. The CPS' survey in March includes a supplement, referred to as the Annual Social and Economic survey (ASEC) that asks additional questions, particularly about income, poverty status, and job-related health insurance and retirement benefits. We pool data from 2015-2019 for our analyses.[111]

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

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

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

where S is a scalar equal to the number of direct jobs produced overall by the level of investment being considered. For example, say Ohio's investment in solar power of $8 billion would generate 15,000 direct jobs, then S is equal to 15,000.

Some of the 526 IMPLAN industries had to be aggregated to match the industry variable in the CPS, which has 242 categories, and vice versa. For example, among IMPLAN's 526 sectors, there are 13 construction sectors while the CPS has only one construction industry. In the end, 194 industry sectors are common to both IMPLAN and the CPS.

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

Note that because the CPS ASEC—which asks about job-related retirement and health benefits—is only administered in March, the sample sizes for the variables in the supplement are substantially smaller than for the basic monthly or ORG data files of the CPS. Due to this feature of the ASEC survey, the sample sizes for some health and retirement benefits measures were too small for an Ohio-only analysis, despite pooling five years of data (2015-2019). As a result, we estimated these job features using data from the entire East North Central region. This region includes which includes Ohio, as well as, Illinois, Indiana, Michigan, and Wisconsin.

Characteristics of Jobs in Fossil Fuel Related Industries

We use the same basic methodology for identifying fossil fuel related jobs and worker characteristics. The only difference here is that IMPLAN's I-O models have well-defined sectors for fossil fuel related activities, i.e., we do not have to create "synthetic" industries. These sectors are listed in Table A1.1.

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

Definition of Jobs in IMPLAN

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

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

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

Endnotes

1 https://reimagineappalachia.org.

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

3 https://coronavirus.ohio.gov/wps/portal/gov/covid-19/dashboards/long-term-care-facilities/mortality.

4 https://coronavirus.ohio.gov/wps/portal/gov/covid-19/dashboards/long-term-care-facilities/cases.

5 https://www.usatoday.com/story/news/nation/2020/04/13/ohio-health-care-workers-test-positive-covid-19-alarming-rate/2981253001/.

6 https://covidtracking.com/race/dashboard.

7 https://calmatters.org/california-divide/2020/05/poor-los-angeles-are-infected-and-dying-at-twice-the-rate/.

8 https://www.usatoday.com/in-depth/graphics/2020/06/30/maps-covid-19-rich-and-poor-neighborhoods-show-big-disparities/3257615001/.

9 https://www.umass.edu/lrrc/sites/default/files/Western%20Mass%20Essential%20Worker%20Survey%20-%20May%202020.pdf.

10 https://www.bls.gov/news.release/flex2.t01.htm.

11 https://www.usatoday.com/story/news/health/2020/04/22/how-coronavirus-impacts-certain-races-income-brackets-neighborhoods/3004136001/.

12 https://ohiostatehousenews.com/2020/07/ohio-ranks-third-in-nation-as-financially-hurting-the-most-from-covid-economy/.

13 https://www.clevelandfed.org/en/newsroom-and-events/publications/cfed-district-data-briefs/cfddb-20200629-updated-estimates-of-revenue-losses-from-pandemic-mitigation.aspx.

14 https://www.statenews.org/post/budget-director-says-effects-pandemic-ohios-economy-could-last-years.

15 Formally, the figures reported in Table 1.4 are derived by multiplying the industry-specific employment loss figures shown in Table 1.3 by the percent of overall employment—in Ohio and the U.S. overall—as shown in the "industry job loss as % of total state employment loss" columns in Table 1.4.

16 https://www.wlwt.com/article/timeline-additional-ohio-businesses-get-the-green-light-to-re-open/32478922#.

17 https://www.covidexitstrategy.org/.

18 https://jayapal.house.gov/2020/05/01/as-uninsured-rate-skyrockets-jayapal-kennedy-lead-32-colleagues-in-introducing-legislation-to-guarantee-health-coverage-during-covid-19-pandemic/.

19 https://www.sanders.senate.gov/newsroom/press-releases/sanders-jayapal-unveil-emergency-legislation-to-provide-health-care-for-all-during-pandemic-.

20 https://www.bizjournals.com/cincinnati/news/2020/07/06/coronavirus-notebook-restaurants-open-outdoors.html.

21 https://governor.ohio.gov/wps/portal/gov/governor/media/news-and-media/covid19-update-06182020.

22 Informative reports on the features of this bill and the politics surrounding it include: https://www.cleveland.com/news/g66l-2019/05/ce7f1b02ee6954/nuclear-bailout-bill-shows-how-big-money-can-be-put-to-work-in-the-ohio-statehouse.html; and https://www.vox.com/energy-and-environment/2019/7/27/8910804/ohio-gop-nuclear-coal-plants-renewables-efficiency-hb6. Some of the wide-ranging expressions of opposition to this bill are here: http://blogs.edf.org/energyexchange/files/2019/05/HB6_Testimony.pdf.

23 References on the 2014 and 2011 measures include: https://www.nrdc.org/experts/samantha-williams/ohio-wraps-its-sb-310-energy-mandates-committee-facts-dont-lie-efficiency; http://oilandgas.ohiodnr.gov/laws-regulations/senate-bill-315#REG; https://www.dispatch.com/assets/pdf/archive/SB_315_Energy_FINAL.pdf; https://energynews.us/2013/07/09/midwest/dd-ohios-waste-heat-potential-remains-largely-untapped/.

24 https://www.c2es.org/document/public-benefit-funds/.

25 https://www.c2es.org/document/property-assessed-clean-energy-pace-programs/.

26 https://www.c2es.org/document/us-state-clean-vehicle-policies-and-incentives/.

27 https://development.ohio.gov/summary_07energyefficiencyprogram.htm.

28 https://www.c2es.org/document/decoupling-policies/.

29 https://www.adaptationclearinghouse.org/resources/cleveland-climate-action-plan-2018-update.html; https://www.adaptationclearinghouse.org/resources/green-cincinnati-plan.html.

30 See Pollin et al. (2014) for a review of the literature on high-emissions versus low-emissions bioenergy sources.

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

32 https://www.yaleclimateconnections.org/2016/07/pros-and-cons-the-promise-and-pitfalls-of-natural-gas/.

33 See, e.g. Alvarez et al. (2012); Room (2014); Howarth (2015); and Peischl (2015).

34 https://www.who.int/ionizing_radiation/a_e/fukushima/faqs-fukushima/en/.

35 See, for example, https://iopscience.iop.org/article/10.1088/1748-9326/aaac88/meta; https://science.sciencemag.org/content/359/6382/1328.full; https://iopscience.iop.org/article/10.1088/1748-9326/aaa512/meta.

36 https://www.documentcloud.org/documents/6889670-Scientist-Letter-to-Congress-8May20.html. Among the research findings cited in this letter is that by Sterman et al. (2018), who concludes that "Although bioenergy from wood can lower long-run CO_2 concentrations compared to fossil fuels, its first impact is an increase in CO_2, worsening global warming over the critical period through 2100 even if the wood offsets coal, the most carbon-intensive fossil fuel. Declaring that biofuels are carbon neutral as the EU and others have done, erroneously assumes forest regrowth quickly and fully offsets the emissions from biofuel production and combustion. The neutrality assumption is not valid because it ignores the transient, but decades to centuries long, increase in CO_2 caused by biofuels," (2018), p. 8, https://iopscience.iop.org/article/10.1088/1748-9326/aaa512/pdf.

37 See Pollin et al. (2014), pp. 113 – 117 for a more detailed review of the literature on high- versus- low-emissions bioenergy sources.

38 https://www.pfpi.net/wp-content/uploads/2011/04/PFPI-biomass-carbon-accounting-overview_April.pdf.

39 https://earthobservatory.nasa.gov/images/1510/global-effects-of-mount-pinatubo.

40 These IEA projections are on pp. 686, 687, and 753 of its 2019 *World Energy Outlook*.

41 These more recent studies include Molina (2014), Ackerman et al. (2016) and Rosenow and Bayer (2016).

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

43 These cost figures are comparable with those reported for the U.S. economy exclusively through the U.S. Energy Information Agency (EIA). See the EIA's annual publication, "Levelized Costs and Levelized Avoided Cost of New Generation Resources," in the *Annual Energy Outlook*. The 2020 edition is here: https://www.eia.gov/outlooks/aeo/electricity_generation.php.

44 Such detailed figures are also available at https://www.irena.org/publications/2020/Jun/Renewable-Power-Costs-in-2019.

45 These figures are from the EIA, "Levelized Costs," https://www.eia.gov/outlooks/aeo/electricity_generation.php.

46 The full methodology for generating these costs is presented in Pollin et al. (2014) pp. 136-37.

47 See Pollin, Wicks-Lim and Chakraborty (2020).

48 For example, Executive Order 13658 requires many federal contractors and their subcontracts to pay a $10.60 minimum wage rate—a rate that exceeds the current federal minimum wage as well as Ohio's state minimum wage. See: https://www.federalregister.gov/documents/2014/02/20/2014-03805/establishing-a-minimum-wage-for-contractors.

49 See: https://www.census.gov/data/tables/time-series/demo/income-poverty/historical-poverty-thresholds.html.

50 We estimate the overall increase in clean energy spending to raise all workers to at least $15.00 by doing the following. Using micro-data from the Labor Department's Current Population Survey (2015-2019), we estimate that 16 percent of workers in direct, clean energy jobs would earn less than $15.00 per hour, or 11,351 direct jobs (70,941 direct jobs x 16 percent). These workers earn, on average, $11.60 and work 36 hours weekly. We then assume these workers work 50 weeks over the year. Therefore, raising these workers' wages by $3.40 per hour to $15.00 would sum to just under $70 million ($3.40/hr. x 36 hrs./wk. x 50 wks. x 11,351 direct jobs = $69.5 million). $69.5 million is equal to 0.3 percent of the annual clean energy investment figure of $21.4 billion.

51 https://www.cleveland.com/business/2020/03/construction-in-ohio-deemed-essential-but-coronavirus-prompts-rising-worker-absenteeism-anxiety.html.

52 We emphasize that this assumption of a 40 percent decline in production and employment in Ohio's natural gas, oil, and bioenergy industries by 2030, and a 70 percent decline for the coal industry is only a *rough approximation*—though we believe it is the most reasonable such approximation. There are reasons to assume that production and employment in the affected industries will decline by less than the full fall in consumption. It is possible that Ohio's fossil fuel and bioenergy related businesses will find it profitable to maintain a disproportionately large workforce even while overall demand declines because doing so maintains their operations at the most effective level. By contrast, it could also follow with some firms that the decline in demand for their products will encourage them to lay off workers by a more than proportional extent—i.e. to reorganize production with a higher level of capital intensity. Some firms could also shut down altogether due to the steady decline in demand (Pollin and Callaci (2018) discuss this latter prospect more fully). Given this range of possibilities—some of which are counteracting—on balance, we conclude, again, that the most reasonable working assumption for our purposes is that the decline in production and employment in Ohio's fossil fuel and bioenergy related industries will be commensurate with the decline in statewide consumption.

53 We do not report in this section the comparable figures for Ohio's various bioenergy sectors, since the employment levels are quite small and the relevant data are not consistently reliable. We do have reliable figures on the state's biomass electricity sector. This sector provides 3 percent of Ohio's total electricity supply. But it employs only 132 workers as of 2018, according to the 2020 IMPLAN database. There are not comparably reliable employment data in IMPLAN for the state's other bioenergy-related activities, even though these other bioenergy activities—fuel ethanol, biodiesel and co-products—provide Ohio with somewhat more energy than biomass electricity (i.e. 57 T-BTUs for biomass electricity versus 77 T-BTUs for the other sectors). For the purposes of our policy analysis, we assume that the forms of just transition policy support provided for fossil fuel-based industry workers will also be available to workers facing displacement through the contraction of Ohio's bioenergy industry activities.

54 We also assume that the high-emissions bioenergy sector will contract at the same rate as oil and natural gas. We focus on the oil, natural gas, and coal contractions here because they are of much greater significance in Ohio. Employment in Ohio's bioenergy sector is modest, and is not clearly reported in the government statistical sources.

55 According to data published by the U.S. Labor Department, 20 percent of 65+ year-olds remain in the workforce. See: https://www.bls.gov/cps/cpsaat03.htm.

56 See more detailed discussions on these pension fund policies in, for example, Pollin et al. (2019).

57 An additional 50,000 – 60,000 jobs will also likely be generated through "induced" job creation channels.

58 https://www.communitycollegereview.com/tuition-stats/ohio#:~:text=For%20Ohio%20community%20colleges%2C%20the,is%20approximately%20%2413%2C841%20per%20year.

59 According to the 2020 article in Moneyzine "Job Relocation Expenses," these expenses for an average family range between $25,000 and $75,000 (https://www.money-zine.com/career-development/finding-a-job/job-relocation-expenses/). The costs include: selling and buying a home, including closing costs; moving furniture and other personal belongings; and renting a temporary home or apartment while house-hunting for a more permanent residence. For our calculations, we assume the upper-end figure of $75,000.

60 https://www.monroecountyohio.com/departments/job_and_family_services/workforce.php.

61 The total private sector employment figures are as of the 2018 county and industry-specific employment figures from the U.S. Labor Department's Quarterly Census of Employment and Wages.

62 Jolley, G. Jason, Christelle Khalaf, Gilbert Michaud, and Austin M. Sandler (2019) "The Economic, Fiscal and Workforce Impacts of Coal-Fired Power Plant Closures in Appalachian Ohio," *Regional Science Policy and*

Practice, https://rsaiconnect.onlinelibrary.wiley.com/doi/epdf/10.1111/rsp3.12191. See also the recent news story by Kathiann M. Kowalshi , "In Ohio's Coal Country, Pandemic Pushes Unemployment Rate from Bad to Worse," *Energy News Network*, 5/20/20, https://energynews.us/2020/05/20/midwest/in-ohios-coal-country-pandemic-pushes-unemployment-rate-from-bad-to-worse/#:~:text=Ohio's%20coal%20mining%20counties%20have,to%2012.2%25%20in%20Monroe%20County.

63 The Reclaiming Appalachia Coalition proposed a similar regional redevelopment program, focusing on three areas for new investments to offset the losses of the fossil fuel industry: solid waste, recycling, and sustainable management materials; technology; and recreation and ecotourism: https://reclaimingappalachia.org/new-2019-report-a-new-horizon/.

64 https://www.osmre.gov/programs/aml.shtm.

65 https://www.politico.com/magazine/story/2017/03/the-obama-administration-idea-to-save-coal-country-214885.

66 https://energynews.us/2020/06/23/national/support-grows-for-taxpayer-funded-oil-well-cleanup-as-an-economic-stimulus/. To be more precise, the term "orphan well" is a legal term that can be used for regulatory purposes by relevant federal or state-level regulators. Related terms are "marginal," "inactive" and "idle" wells. Biven (forthcoming 2020) reviews these issues in detail.

67 https://www.jdsupra.com/legalnews/the-moving-america-forward-act-if-66813/.

68 https://www.epa.gov/ghgemissions/inventory-us-greenhouse-gas-emissions-and-sinks-1990-2016.

69 https://www.nola.com/news/business/article_313d8dd2-7a9d-11ea-b4a4-e7675d1484f7.html#:~:text=Mark%20Schleifstein,-Author%20email&text=The%20Louisiana%20agency%20overseeing%20oil,the%20Louisiana%20Legislative%20Auditor's%20Office.; https://coloradosun.com/2020/05/12/fracking-oil-price-colorado-abandoned-wells/.

70 With respect to repurposing the infrastructure around the nuclear sites, Lowrie et al. write that "much of federal investment leaves behind little usable on-site infrastructure to provide long-term economic benefits to a region. For instance, there are odd-shaped buildings, unusable waste management systems, and roads and railroads with inefficient locations. It is hard to convert resources for arms production to civilian uses because the technologies are significantly different and the workers skills are unique," (1999, pp. 120 – 121).

71 In May 2016 Congress legislated to maintain funding for the site: http://www.portman.senate.gov/public/index.cfm/press-releases?ID=84DB38D2-5B4C-434F-BC68-B14E60DFA440.

72 U.S. Department of Energy, "U.S. Departments of Energy and Interior Announce Site for Solar Energy Demonstration Projects in the Nevada Desert," Press release, 7/8/10, http://energy.gov/ articles/us-departments-energy-and-interior-announce-site-solar-energy-demonstration-projects-nevada.

73 The general descriptions in this paragraph is based on Galgoczi (2015) and Dohmen and Schmid (2011).

74 See, for example, Chow (2017).

75 Prentiss does, however, recognize that, beyond providing the average level of energy demanded at any given time is the challenge of meeting the specific energy demand needs, given that wind and solar power both are intermittent energy sources. Thus, she explains that technological advances will also be necessary to achieve an energy infrastructure that relies on renewable energy for 100 percent of supply. She writes that "The question of whether renewable energy could provide all of the actual instantaneous energy needs of the United States is an open question that depends on how fluctuating renewable energy sources can be harnessed to provide power on demand. A revolutionary advance in large-scale energy storage would greatly ease the transition to a 100 percent renewable- energy economy; however, a combination of increases in energy efficiency due to widespread adoption of existing technologies and 'smart grid' that pool energy supply and demand over large geographical areas may allow a renewable energy economy to flourish even without large-scale energy storage," (2015, p. 2). Prentiss reiterates that basic conclusion in a more recent 2019 article, "The Technical Path to Zero Carbon," in which she concludes that through a range of approaches, including battery storage and straightforward improvements in energy transmission systems, "science and technology are not preventing us from achieving a 100 percent U.S. renewable energy economy." A broadly similar assessment as to the potential for renewable energy to supply 100 percent of energy needs for India was developed by Prof. S.P. Sukhatme in his 2013 paper, "Can India's Future Needs of Electricity be Met by Renewable Energy Sources?"

76 https://www.commondreams.org/newswire/2020/09/10/thrive-agenda-creates-millions-new-jobs-while-addressing-intersecting-crises.

77 https://static1.squarespace.com/static/5f53b5996b708446acb296c5/t/5f596f847cd04225906 7e795/1599696773913/THRIVE+resolution+CLEAN.pdf.

78 https://www.infrastructurereportcard.org/state-item/ohio/.

79 Patricia DeMarco and Sara Nicholas (2020) "Heal our Land and our People—Civilian Conservation Corps 2.0 and Regenerative Agriculture and Agro-Forestry," Reimagine Appalachia forthcoming.

80 We estimate the overall increase in manufacturing/infrastructure and land restoration/agriculture investment spending to raise all workers to at least $15.00 by doing the following. Using micro-data from the Labor Department's Current Population Survey (2015-2019), we estimate that 14 percent of workers in the direct, manufacturing/infrastructure energy jobs would earn less than $15.00 per hour, or 1,834 direct jobs (13,100 direct jobs x 14 percent). These workers earn, on average, $11.80 and work 38 hours weekly. We then assume these workers work 50 weeks over the year. Therefore, raising these workers' wages by $3.20 per hour to $15.00 would sum to just under $11 million ($3.20/hr. x 38 hrs./wk. x 50 wks. x 1,834 direct jobs = $11 million). The analogous figures for direct, land restoration/agriculture jobs are: 36 percent of workers earn less than $15.00 per hour, or 9,504 direct jobs (26,400 direct jobs x 36 percent). These workers earn, on average, $10.90 and work 34 hours weekly. We then assume these workers work 50 weeks over the year. Therefore, raising these workers' wages by $4.10 per hour to $15.00 would sum to just over $66 million ($4.10/hr. x 34 hrs./wk. x 50 wks. x 9,504 direct jobs = $66 million). A total of $77 million is equal to one percent of the annual $7 billion investment spending in manufacturing/infrastructure and land restoration/agriculture.

81 https://checkbook.ohio.gov/State/Expanded/StateBudgetByFunction.aspx, https://www.mahoningmatters.com/regional-news/ohio-ends-2020-fiscal-year-with-general-tax-revenue-down-11-billion-2562990 .

82 https://archives.obm.ohio.gov/Files/Budget_and_Planning/Monthly_Financial_Report/2020-07_mfr-final.pdf .

83 https://www.dispatch.com/news/20200608/ohio-says-new-budget-hole-covered-as-coronavirus-undercuts-ohio-tax-take?template=ampart, https://obm.ohio.gov/wps/portal/gov/obm/areas-of-interest/budget-and-planning/budget-stabilization-fund/ .

84 https://archives.obm.ohio.gov/Files/Budget_and_Planning/Monthly_Financial_Report/2020-06_mfr.pdf .

85 https://www.dispatch.com/news/20200708/dewine-expects-to-drain-ohiorsquos-rainy-day-fund-to-balance-budget, https://www.dispatch.com/news/20200701/bad-year-in-books-worse-one-awaits-ohiorsquos-virus-slammed-state-budget .

86 https://www.dispatch.com/news/20200701/bad-year-in-books-worse-one-awaits-ohiorsquos-virus-slammed-state-budget .

87 https://www.clevelandfed.org/en/newsroom-and-events/publications/cfed-district-data-briefs/cfddb-20200629-updated-estimates-of-revenue-losses-from-pandemic-mitigation.aspx ; In the past, Ohio has recovered more slowly from recessions than the nation. https://www.epi.org/blog/ohios-economy-no-longer-fully-recovers-after-recessions/.

88 https://www.clevelandfed.org/en/newsroom-and-events/publications/cfed-district-data-briefs/cfddb-20200629-updated-estimates-of-revenue-losses-from-pandemic-mitigation.aspx .

89 https://www.naco.org/sites/default/files/documents/NACo_COVID-19_Fiscal_Impact_Analysis_0.pdf .

90 https://www.policymattersohio.org/research-policy/quality-ohio/revenue-budget/budget-policy/congress-must-support-states-communities .

91 https://www.brookings.edu/blog/the-avenue/2020/03/31/when-will-your-city-feel-the-fiscal-impact-of-covid-19/ .

92 https://home.treasury.gov/policy-issues/cares/state-and-local-governments .

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111 We use the CPS data files provided by IPUMS-CPS: "Integrated Public Use Microdata Series, Current Population Survey: Version 7.0, Minneapolis, MN: IPUMS, 2020," published by Sarah Flood, Miriam King, Renae Rodgers, Steven Ruggles and J. Robert Warren. https://doi.org/10.18128/D030.V7.0.

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