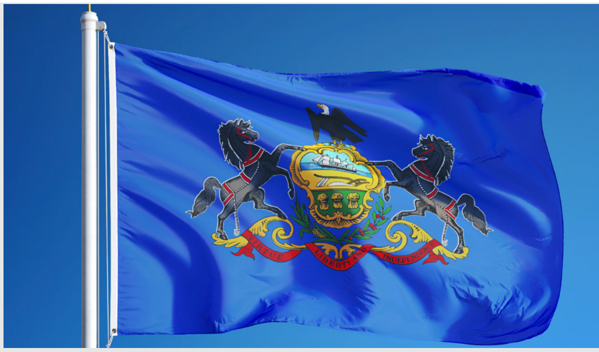
IMPACTS OF THE REIMAGINE APPALACHIA & CLEAN ENERGY TRANSITION PROGRAMS FOR PENNSYLVANIA

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 Pennsylvania, as with most everywhere else in the United States. The pandemic is likely moving into its latter phases, due to the development of multiple vaccines that have demonstrated their effectiveness. Nevertheless, as of this writing in mid-January 2021, infections and deaths from COVID are escalating, both within Pennsylvania and throughout the U.S. Correspondingly, the economic slump resulting from the pandemic continues.

This study proposes a recovery program for Pennsylvania that is capable of exerting an effective counterforce against the state's ongoing recession 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 Pennsylvania 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 Pennsylvania
2. Clean Energy Investments, Job Creation and Just Transition
3. Investment Programs for Manufacturing, Infrastructure, Land Restoration and Agriculture
4. Total Job Creation in Pennsylvania 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 Pennsylvania 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 Pennsylvania 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 Pennsylvania 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 $23 billion per year will generate roughly 162,000 jobs per year in Pennsylvania.

In Part 3, we present investment programs for Pennsylvania 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 $8.2 billion per year over 2021 – 2030, equal to about 1 percent of Pennsylvania's 2019 GDP. We estimate that the full program would generate about 81,000 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 243,000 jobs in Pennsylvania—equal to roughly 4 percent of Pennsylvania's current workforce—while providing the foundation for a long-term sustainable growth path for the state.

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 as the state's residents become vaccinated over the coming months. The state's hospitality and tourism industries have been hardest hit by the pandemic, accounting for 32 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 in the months prior to the population becoming vaccinated. All workers 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 Pennsylvania to achieve emission reduction targets consistent with the IPCC's goals are capable of producing, between 2021 – 2030, an average of about 162,000 per year in Pennsylvania—i.e., about 152,000 jobs in 2021, with these 152,000 jobs carrying over into 2022, 2023, 2024, etc., along with further job increases resulting each year as clean energy investments grow along with overall economic activity in Pennsylvania. 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. About 64,000 people are employed in Pennsylvania in fossil fuel-based industries. This includes those engaged in fracking operations to extract natural gas from the Marcellus Shale regions in the state. The total job figure also includes other oil and gas extraction operations, as well as support activities for all oil and gas projects, coal mining, and other ancillary sectors, such as fossil fuel-based power generation. Workers in the state's fossil fuel-based industries will therefore experience job losses as the state dramatically reduces consumption of these CO_2-generating energy sources. We estimate that about 1,800 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 Pennsylvania's Economic Base through Manufacturing, Infrastructure, Land Restoration and Agriculture Investments. Pennsylvania'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 $8.2 billion per year, or 1 percent of the state's GDP—in these areas. The roughly 81,000 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 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 Pennsylvania state and municipal budgets, 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 Pennsylvania onto a viable recovery path.

Starting last March with the CARES Act, the federal government has injected about $70 billion into the state's economy, equal to 8.6 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 $35 billion over the 2021 fiscal year (about 4.1 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 mid-January 2021, it is not clear how much additional support the federal government will provide through the $900 billion second stimulus program that became law in December and any additional measures that could be forthcoming, including especially the nearly $2 trillion proposal advanced in January by the Biden Administration.. As such, we recommend that the state and local governments in Pennsylvania 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 Pennsylvania are able to sell up to $12.6 billion in bonds to the Fed. Pennsylvania is also able to borrow at mostly very low rates on the open market, with yields on Pennsylvania's municipal bonds reaching as low as 0.5 percent on 1/31/21. With Pennsylvania's state and municipal governments being able to frequently borrow at such low rates, the prospects are favorable for these public entities to support large-scale programs to counteract the crisis and move Pennsylvania 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 Pennsylvania. 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 Pennsylvania without increasing emissions outside of the state.
- Creating roughly 162,000 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 Pennsylvania's GDP per year, will raise productivity and enhance well-being in the state, while also generating over 82,000 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 Pennsylvania relative to the 2018 emissions level.
    - Emissions in Pennsylvania in 2018 were at 238 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 roughly 120 million tons.[1]

Major Areas of Clean Energy Investments

- ***Energy Efficiency.*** Dramatically improving energy efficiency standards in Pennsylvania'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 Pennsylvania's economy.
- ***Total Investment Expenditures.*** The level of investment needed to achieve Pennsylvania's energy goals will average roughly $22.6 billion per year between 2021 – 2030.
    - This estimate assumes that Pennsylvania's economic growth proceeds at an average rate of 1.5 percent per year.
    - Clean energy investments will need to equal about 2.5 percent of Pennsylvania's annual GDP.
    - The average annual clean energy investment level of 2.5 percent of GDP means that more than 97 percent of Pennsylvania'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 enables 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 Pennsylvania 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 $22.6 billion per year in clean energy projects in Pennsylvania over 2021 – 2030 will generate an average of about 162,000 jobs per year in the state.
- More specifically, we estimate that about 152,000 jobs will be generated in 2021, with these 152,000 jobs carrying over into 2022, 2023, 2024, etc., along with further job increases resulting each year as clean energy investments grow along with overall economic activity in Pennsylvania.
- 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 $70,000 – $80,000 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 78 percent of all energy that is either consumed in Pennsylvania or exported to other states as electricity 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 percent for the state to reduce CO_2 emissions by 50 percent as of 2030.
- Nuclear power generates nearly 20 percent of all energy that is either consumed in Pennsylvania or exported as electricity. We assume that nuclear power generation will remain at its current level in the state through 2050. That is, the existing nuclear power facilities will remain in operation but no new facilities will be built.
- About 64,000 workers in Pennsylvania are presently employed in the state's fossil fuel-based and bioenergy industries, including fracking operations to extract natural gas from the Marcellus Shale deposits.

- We estimate that total job displacements will average 1,800 per year.
  - This is after allowing that an average of about 1,000 workers per year will voluntarily retire.
- A just transition program for these roughly 1,800 workers per year presently employed in Pennsylvania'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 $115,000 per worker. Overall costs will amount to about $210 million per year over the duration of the just transition program.

Achieving Net Zero Emissions by 2050

- Pennsylvania can become a zero emissions economy by 2050 through continuing its clean energy investment program.
- Pennsylvania 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 1.9 percent of state GDP per year over 2031 – 2050.
- Average job creation through these clean energy investments will average about 111,000 jobs per year.
- Just Transition support for displaced workers over 2031 – 2050 will amount to an average of about $210 million per year. We estimate this amount will less than 0.01 percent of Pennsylvania's average GDP between 2031 – 2050.

Investments in Manufacturing, Infrastructure, Land Restoration and Agriculture

- In 2018, the American Society of Civil Engineers (ASCE) gave an overall grade of C- to Pennsylvania's public infrastructure.
- 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 $8.2 billion per year, equal to 1 percent of Pennsylvania'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 $ 8.2 billion per year in these areas would generate about 81,000 jobs per year within Pennsylvania.

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

- Our annual average job estimates for 2021 – 2030 include:
  - 162,000 jobs per year through $22.6 billion in spending on energy efficiency and clean renewable energy.
  - 33,000 jobs per year through investing $4.1 billion in manufacturing and public infrastructure.
  - 48,000 jobs per year through investing $4.1 billion in land restoration and agriculture.
- The total employment creation through clean energy, manufacturing/infrastructure and land restoration/agriculture will total to about 243,000 jobs.
- Net job creation will average about 3.9 percent of Pennsylvania's workforce as of 2019.

PART 1:

PANDEMIC, ECONOMIC COLLAPSE, AND CONDITIONS FOR RECOVERY

1.1 The Pandemic in Pennsylvania

The State of Pennsylvania, like the rest of the United States, has experienced an historically unprecedented public health and economic crisis since the COVID-19 pandemic emerged full force in mid-March. Moreover, beginning in October 2020, Pennsylvania, along with much of the rest of the country, experienced a severe spike in its COVID-19 infection rate. Thus, as of October 1, there were a reported 1,055 new cases of COVID infections in Pennsylvania. As of December 13, the state's new infection rate had increased tenfold, to 10,574. As of January 13, 2021, the new infection rate had fallen somewhat relative to the December peak, to 7,181 cases. But this rate of new infections in Pennsylvania remains nearly seven times higher than the rate in early October.[2]

At the same time, as of this writing in January 2021, the pandemic has almost certainly moved into its latter phases. This is due to the development of multiple vaccines that have demonstrated their effectiveness in inoculating people against COVID-19 infections. As such, the most significant question at this point is how efficiently the vaccination program can be administered in Pennsylvania and throughout the U.S, so that the population of Pennsylvania and the U.S overall achieves 'herd immunity'—i.e., the point at which roughly 85 – 95 percent of the population has become immune to infection by COVID. The pace at which the state's population reaches herd immunity will, in turn, determine how quickly the state's economy can recover from the COVID-induced recession.

As of January 7, roughly 200,000 Pennsylvanians have received the first of two doses of a COVID vaccine. This amounts to only about 1.5 percent of the state's population.. These first vaccines have been provided to health care workers in the state along with long-term care residents and staffers. The second priority cohorts will include people over 75, along with first responders, corrections officers, food and agricultural workers and grocery store employees. The program will next become available to people over 65 and younger people with serious health conditions. After these groups have been inoculated, the program will open to the lower-risk cohorts of the population. According to the most recent projections by Pennsylvania Health Secretary Rachel Levine, Pennsylvania should achieve herd immunity by late Spring 2021.[3]

Still, the distribution of vaccines is primarily under the control of the federal government, not the state government. The newly installed Biden administration has pledged to accelerate the distribution of vaccines relative to what occurred under the Trump administration. If the Biden administration is successful in its efforts, it therefore becomes possible that Pennsylvania can achieve herd immunity earlier in the Spring.

For the purposes of this study, the critical economic challenge at present, as of January 2021, is for Pennsylvania to develop a framework for achieving a rapid and equitable short-term recovery program, and to accomplish this through measures that also put the state onto a long-term path of sustainable growth. It will be critical to review the experience in the state since March 2020 during the COVID-induced recession in order to develop such effective policy measures. We therefore now turn to reviewing the state's economic experiences during the COVID recession.

1.2 Pennsylvania's Economic Collapse

Statewide Job Losses

As with the U.S. economy overall, the Pennsylvania economy experienced an unprecedented collapse resulting from the COVID pandemic. As one clear measure of this, we show in Table 1.1 figures on job losses in Pennsylvania from the onset of the pandemic in mid-March until the first week of January 2021. Specifically, we report on initial unemployment insurance claims by workers in Pennsylvania from 3/21/20 until 1/2/21. As Table 1.1 shows, this figure for number of people in the state who lost their jobs and filed to receive unemployment insurance over this period totals to nearly 2.6 million. This figure amounts to 39.2 percent of Pennsylvania's workforce as of February 2020. That is, over the roughly eight-month period beginning with the onset of the pandemic, nearly 40 percent of all workers in Pennsylvania experienced job loss and filed for unemployment insurance.

For comparison, we show in the second column of Table 1.1 the figures over the same time period in 2019, from the third week of March until the beginning of 2020. As we see, in this comparable time period a year ago, total initial unemployment claims over this nine-month period totaled to 578,057, equal to 9.0 percent of Pennsylvania's workforce at that time. In other words, job losses over mid-March 2020 until the beginning of 2021 jumped over 4-fold relative to 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 pattern for Pennsylvania matches closely with those for the overall U.S. economy, even while the overall U.S. experience was moderately worse than that for Pennsylvania. With the overall U.S. economy, job losses between 3/21/20 to 1/2/21 were at 44.8 percent of the labor force then, while over the same time period a year ago, that figure amounted to 5.6 percent of the U.S. labor force.

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

Initial Unemployment Insurance Claims:
Weekly Figures Covering 3/21/20 – 1/2/21 and 3/23/19 – 1/4/20

	3/21/20 –1/2/21 Figures	3/23/19 –1/4/20 Figures
Figures for Pennsylvania		
1. Number of people filing initial unemployment insurance claims	2,572,092	578,057
2. Number of claims as share of February labor force	39.2% *(share of 2/20 labor force)*	9.0% *(share of 2/19 labor force)*
Figures for U.S.		
3. Number of people filing initial unemployment insurance claims	73,797,000	9,103,000
4. Number of claims as share of February labor force	44.8% *(share of 2/20 labor force)*	5.6% *(share of 2/19 labor force)*

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

Industry-Specific Contractions and Job Losses

We can obtain a more detailed perspective on Pennsylvania's current economic crisis by examining data on changes in employment level by industry, combining figures for October and November 2020 with comparable figures for October/November 2019. We report these figures in Tables 1.2 and 1.3.

The first set of figures in Table 1.2 presents job loss within each industry, both for Pennsylvania and the U.S. overall. The second set of figures in Table 1.3 shows the contributions, industry-by-industry, to Pennsylvania'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 Pennsylvania with those for the U.S. overall.[4]

As we see first, in Table 1.2, the employment level declines for all 11 of the economic sectors listed. Pennsylvania's employment crisis has therefore clearly been 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 24 percent between October/November 2020 relative to the 2019 level. Three other industries experienced employment declines of 12 percent or greater and 9 of the industries saw job losses of at least 4 percent relative to 2019. Overall, state employment in Pennsylvania fell by 7.4 percent in October/November 2020 relative to 2019.

Pennsylvania's heavy job losses due to the COVID pandemic over this year were also sharper than those for the U.S. overall. Thus, for the U.S. overall, the employment decline

TABLE 1.2
Job Losses within Industries, Pennsylvania and U.S. Percentages

Figures are employment figures, not seasonally adjusted, from October/November 2019 to October/November 2020

Pennsylvania: *Decline in state employment = 7.4%*		**United States:** *Decline in national employment = 5.9%*	
Leisure and hospitality	-24.0%	Leisure and hospitality	-19.6%
Mining and logging	-17.7%	Mining and logging	-14.5%
Information	-14.6%	Information	-8.7%
Other services	-12.8%	Other services	-6.9%
Professional and business services	-6.5%	Government	-5.0%
Manufacturing	-6.4%	Manufacturing	-4.7%
Trade, transportation, and utilities	-5.7%	Professional and business services	-4.6%
Education and health services	-5.4%	Education and health services	-4.4%
Government	-4.1%	Trade, transportation, and utilities	-3.4%
Construction	-2.9%	Construction	-2.6%
Financial activities	-0.1%	Financial Activities	-0.8%

Sources: U.S. Labor Department.

TABLE 1.3
Share of Total Job Losses by Industry, Pennsylvania and U.S. Percentages
Figures are employment figures, not seasonally adjusted, from October/November 2019 to October/November 2020

Pennsylvania: *Decline in state employment = 7.4%*			**United States:** *Decline in national employment = 5.9%*		
	% of state employment	Industry job loss as % of total state employment		% of U.S. employment	Industry job loss as % of overall U.S. employment
Leisure and hospitality	9.3%	-2.2%	Leisure and hospitality	10.8%	-2.1%
Education and health services	21.6%	-1.2%	Government	15.1%	-0.8%
Trade, transportation, and utilities	18.6%	-1.1%	Education and health services	16.1%	-0.7%
Professional and business services	13.5%	-0.9%	Trade, transportation, and utilities	18.4%	-0.6%
Manufacturing	9.3%	-0.6%	Professional and business services	14.2%	-0.6%
Other services	4.3%	-0.5%	Manufacturing	8.4%	-0.4%
Government	11.8%	-0.5%	Other services	3.9%	-0.3%
Information	1.4%	-0.2%	Information	1.9%	-0.2%
Construction	4.4%	-0.2%	Construction	5.0%	-0.1%
Mining and logging	0.5%	-0.1%	Mining and logging	0.5%	-0.1%
Financial activities	5.4%	0.0%	Financial activities	5.8%	0.0%

Sources: U.S. Labor Department.

was 5.9 percent in October/November 2020 relative to October/November 2019. The leisure and hospitality job losses for the U.S. overall, at 19.6 percent, were somewhat lower than the 24.0 percent figure for Pennsylvania.

In Table 1.3, we see that, after taking account of the relative size of each of the industries in Pennsylvania's economy, the leisure and hospitality industry remains as the largest drag on overall employment. Thus, job losses in leisure and hospitality account for 2.2 percentage points of the state's overall 7.4 percent level of job loss—i.e., the contraction of the leisure and hospitality industry accounts for about 30 percent of Pennsylvania's overall job losses. Two other sectors each account for over 1 percentage point of the state's 7.4 percent decline—education and health services and trade, transportation and utilities.

The employment losses in education and health services might be among the most difficult from which to recover because these sectors are heavily dependent on inflows of tax revenue to support their operations. 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 fully 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 interventions operating in conjunction with federal stimulus support and to move Pennsylvania onto a long-term sustainable growth path. These are the issues we will examine in Sections 2 and 3 of this study.

Support for Workers and Their Families

Given these severe dislocations experienced by Pennsylvania's working population since the March onset of COVID, these workers need short-term support—provided either at the state- or federal levels or some combination—that can assist them through the latter months of the pandemic. We highlight here two measures in particular in the areas of health insurance coverage and rights at work.

Expanding Medicare Coverage

The sharp increase in job losses in Pennsylvania since March, 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 until the state and U.S. population has reached herd immunity.

Representatives Pramila Jayapal and Joe Kennedy proposed last May at the federal government level the Medicare Crisis Program, as a measure that would be critical in providing support to families over the course of the pandemic and severe economic downturn.[5] Senator Bernie Sanders introduced a similar measure in the U.S. Senate, the Health Care Emergency Guarantee Act.[6]

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, no version of this proposal has been enacted at either the federal level or within Pennsylvania. Nevertheless, such a measure should be integral to any recovery project, for Pennsylvania 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 prior to the population reaching herd immunity. 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 Pennsylvania should enact on its own at the state level if it is not incorporated in any upcoming rounds of federal stimulus legislation. In Section 5, 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 Pennsylvania throughout the remaining course of 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 protecting both the health and well-being of the workers themselves as well as 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. Overall, a viable recovery program for Pennsylvania must include an enhanced commitment to protecting workers' rights at all levels of the state economy, starting with the most vulnerable workers, such as those in Pennsylvania's crucial small-business hospitality and service workers.[7]

PART 2:

CLEAN ENERGY INVESTMENTS, JOB CREATION, AND JUST TRANSITION

2.1 Current Energy Policies in Pennsylvania

Impacts of Pennsylvania's Fracking Operations

The consumption of energy in Pennsylvania, as with the rest of the United States, is presently dominated by fossil fuels. We review details in section 2.2. But the basics are straightforward. As of 2018, the shares of overall energy that is either consumed within Pennsylvania or exported to other U.S. states included natural gas at about 38 percent, oil at 30 percent, and coal at 16 percent, for a total of 85 percent for the three fossil fuel energy sources.

In addition to fossil fuels being the dominant energy source for Pennsylvania's consumers, the state is also a significant supplier of fossil fuel energy. It ranks second among U.S. states, behind only Texas, in producing natural gas, providing 17.5 percent of overall U.S. gas supply. It also ranks third, behind Wyoming and West Virginia, in producing coal, contributing 8.4 percent of overall U.S. production.

The most significant fossil fuel energy source in Pennsylvania is the Marcellus Shale formation. Beginning in 2008, natural gas has been extracted from Marcellus Shale through horizontal drilling and hydraulic fracturing technology. These technologies are commonly referred to as both "unconventional natural gas development" (UNGD), and, more widely as "fracking." We use both terms in what follows.

The Marcellus formation extends under three-fifths of Pennsylvania as well as parts of West Virginia, New York, Ohio and Maryland. But most of the gas extraction activity in the Marcellus Shale formation has been concentrated in northeastern and southwestern Pennsylvania. This is both because the gas deposits in these parts of Pennsylvania are relatively accessible through fracking technology and also because the policy framework in Pennsylvania has supported fracking. By contrast, New York and Maryland have prohibited fracking operations to date, even though these states have potentially significant gas reserves to exploit in the portions of the Marcellus Shale that are inside their respective borders.

New York and Maryland, as well as other U.S. states, have prohibited fracking because of the negative public health and environmental impacts produced by these operations, including severe water contamination, air pollution and excessive noise. Since Pennsylvania has, by contrast, supported large-scale fracking development since 2008, it will be useful to briefly review here the evidence on the impacts of this experience—i.e., the economic impacts as well as those on the environment and public health.

Economic Impacts

Between 2007 – 2014, employment grew strongly in northeastern and, to a somewhat lesser extent, southwestern Pennsylvania, as a result of the fracking boom. But the employment expansion levelled off in 2014, and the job figures have declined since.

Thus, Lycoming County in northeastern Pennsylvania had zero reported jobs in the oil and natural gas industry in 2007. By 2012, employment in the county had grown to 1,801, the second-highest level among all counties in the state. From 2007 to 2012, Lycoming also experienced the largest gain in oil and natural gas employment. Similarly, while Bradford County had zero employment in the oil and natural gas industry in 2007, its employment had grown to 983 by 2012. Average annual pay in the oil and natural gas industry in Lycoming and Bradford Counties was also relatively high compared with that in other counties in the state. In 2012, Lycoming had an average annual pay of $75,860, the seventh-highest pay among all Pennsylvania counties in that year. Also, in 2012, Bradford had the third-highest average annual pay in the state's oil and natural gas industry, at $86,840.

In southwestern Pennsylvania, Allegheny County had the largest increase in oil and natural gas employment in the region from 2007 to 2012. Employment in this county increased by 1,283 (287.0 percent), to reach a level of 1,730 in 2012. Among all Pennsylvania counties, Allegheny experienced the second-largest employment gain in the oil and natural gas industry from 2007 to 2012. Over the same period, the county's average annual pay in that industry increased by $55,343 (63.7 percent), to $142,222, which was the highest pay among all counties in Pennsylvania in 2012.

Also, within the southwestern Pennsylvania region, Indiana County experienced a significant increase in oil and natural gas employment, adding 1,051 jobs (an increase of 78.3 percent) from 2007 to 2012. Indiana County had the highest level of employment in the oil and natural gas industry among all counties, both in 2007, when employment was 1,343, and in 2012, when employment was 2,394. In 2007, Indiana County's oil and natural gas industry also had a comparatively high average annual pay, $63,427, which was the third highest among all Pennsylvania counties. However, from 2007 to 2012, pay saw a relatively small increase of $3,553 (5.6 percent), dropping Indiana County to 10th place in terms of oil and natural gas industry pay.

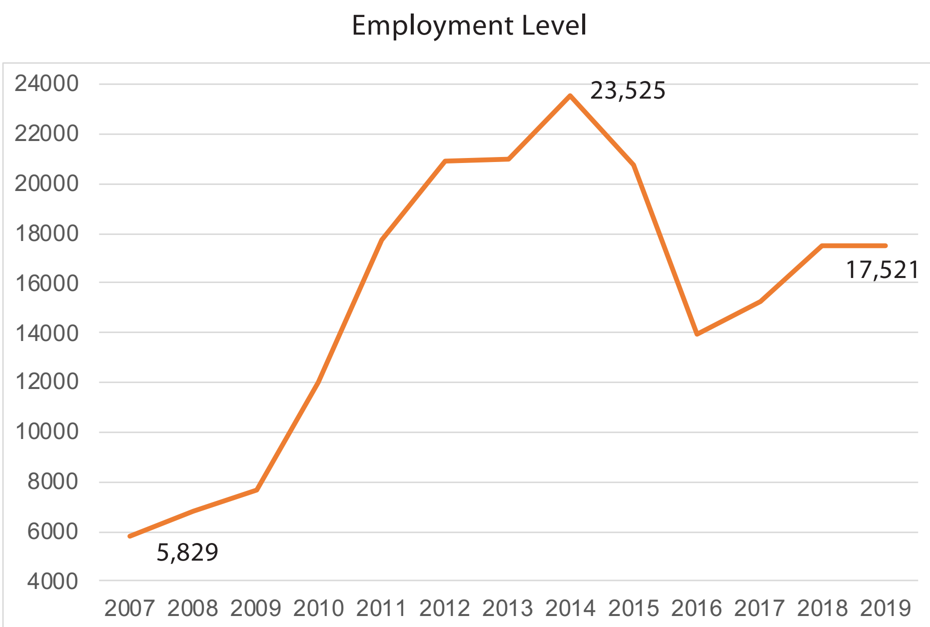
To consider the expansion of fracking in Pennsylvania overall since 2007, in Figure 1, we show state-wide employment data for three industries in the state—oil and gas extraction, drilling oil and gas wells, and support activities for oil and gas operations. As we see, employment in these oil and gas industries increased four-fold between 2007 – 2014, from 5,829 to 23,525. Employment levels do then begin falling off after 2014. As of the most recent 2019 data, statewide employment in these oil and gas sectors was at 17,521, a 25 percent decline relative to the 2014 peak.

Average real wages in oil and gas-related employment also rose sharply from 2007 – 2017, from about $75,048 to $106,203 (in 2019 dollars), a 42 percent increase. Wages did then fall by about 7 percent as of 2019, to $99,122.

Over the past year, the industry has been experiencing a sharp slump, as reflected especially in the data on employment decline. This decline began prior to the COVID-induced recession. But the recession has deepened the contraction. The New York Times reported in October 2020 as follows:

> Even before the latest shock, gas operators were reeling from self-inflicted wounds. They had taken on too much debt and drilled so many wells that they had flooded the market with gas, sending its price into a tailspin….
>
> Some energy giants have already lost faith in the region. Chevron in December took a multi-billion-dollar write-down on its Appalachian shale assets, dominated by gas reserves in Pennsylvania, and said it might sell them. The stocks of two once mighty Marcellus Shale pioneers, Range Resources and EQT, have plummeted, and their bonds are trading at steep discounts, a sign that investors believe they could default on their debts.
>
> The debts of those two companies and Southwestern Energy, another shale business focused on Pennsylvania, have increased by a combined $7 billion since 2008. Their operations

FIGURE 1: Employment Level and Real Wages for Pennsylvania Oil and Gas Operations, 2007 – 2019



Note: Figures are for oil/gas extraction, drilling and support activities.

Source: U.S. Bureau of Labor Statistics, QCEW.

> generated far too little cash to pay for their investments. In fact, the three companies' capital spending exceeded operating cash flows by $14 billion in that period. The frackers now have fewer friends on Wall Street. "All they've done is destroy shareholder value," said Ben Dell, managing partner at Kimmeridge, a private-equity firm that specializes in energy. "For the Marcellus guys, it will all stop with bankruptcy."[8]

Public Health and Environmental Impacts

A large number of reports of the negative environmental and public health impacts of fracking operations in Pennsylvania began to emerge soon after these operations expanded to a large scale in the state in 2008. In June 2020, an Allegheny County grand jury report documented these impacts in detail, based on two years of research and direct testimony.[9]

A summary of some of the findings of the grand jury report includes the following passages:

> Wells can be drilled as close as 500 feet from your front door. Once construction of a well pad begins, life changes. We heard about the clouds of dust, the grimy film, the booming and the blinding lights, day and night. The construction phase of the process is still just the beginning. Next comes the drilling and the hydraulic fracturing of the wells. These parts of the process bring their own nuisances, some of which are similar to what homeowners experienced during the construction phase. Oftentimes, the noise is far worse than it was during the construction phase and can occur 24 hours a day. Some people had to sleep in a corner of the basement trying to get away from it….
>
> Aside from the nuisances of the process, some people, as we learned from testimony, began to notice changes to their water. In many areas where unconventional oil and gas activity is common, there is no public water line. People rely entirely on water wells drilled on their own property. When the oil and gas operators spilled products used to fracture a well, or the storage facilities that held the waste-water leaked, the chemicals made their way into the aquifers that fed those water wells. The water started smelling like sulfur, or tasting like formaldehyde. It burned the skin….
>
> Then there was the air. The smell from putrefying waste water in open pits was nauseating. Airborne chemicals burned the throat and irritated exposed skin. One witness had a name for it: "frack rash." It felt like having alligator skin. At night, children would get intense, sudden nosebleeds; the blood would just pour out. Many of those living in close proximity to a well pad began to become chronically, and inexplicably, sick. (pp. 3 – 4).

The grand jury report is clear in its assessment that the state's Department of Environmental Protection (DEP) has failed to fulfill its responsibilities to the state's citizens. They conclude that:

> The agency responsible to enforce those requirements is DEP. Our investigation, however, convinced us that DEP did not take sufficient action in response to the fracking boom, and even now, more than a decade after it began, must do more to fully address the special challenges posed by the industry.

The grand jury report also found that at least part of the DEP's regulatory failures resulted from the fact that "some DEP employees saw the job more as serving the industry than the public," (p. 7).[10]

The experiences in Pennsylvania documented in the 2020 grand jury report are consistent with an extensive research literature that encompasses the experiences in Pennsylvania as well as elsewhere in the United States. This is clear from a 2019 survey of the literature by Gorski and Schwartz, "Environmental Health Concerns from Unconventional Natural Gas Development."[11] The authors summarize their findings as follows:

> The environmental impacts from UNGD [i.e., fracking] include chemical, physical, and psychosocial hazards as well as more general community impacts. Chemical hazards commonly include detection of chemical odors; volatile organic compounds (including BTEX chemicals [benzene, toluene, ethylbenzene, and xylene], and several that have been implicated in endocrine disruption) in air, soil, and surface and groundwater; particulate matter, ozone, and oxides of nitrogen (NOx) in air; and inorganic compounds, including heavy metals, in soil and water, particularly near wastewater disposal sites. Physical hazards include noise, light, vibration, and ionizing radiation (including technologically enhanced naturally occurring radioactive materials [TENORMs] in air and water), which can affect health directly or through stress pathways. Psychosocial hazards can also operate through stress pathways and include exposure to increases in traffic accidents, heavy truck traffic, transient workforces, rapid industrialization of previously rural areas, increased crime rates, and changes in employment opportunities as well as land and home values. In addition, the deep-well injection of wastewater from UNGD has been associated with increased seismic activity….
>
> By 2017, there were a number of important, peer-reviewed studies published in the scientific literature that raised concern about potential ongoing health impacts. These studies have reported associations between proximity to UNGD and pregnancy and birth outcomes; migraine headache, chronic rhinosinusitis, severe fatigue, and other symptoms; asthma exacerbations; and psychological and stress-related concerns. Beyond its direct health impacts, UNGD may be substantially contributing to climate change (due to fugitive emissions of methane, a powerful greenhouse gas), which has further health impacts. Certain health outcomes, such as cancer and neurodegenerative diseases, cannot yet be studied because insufficient time has passed in most regions since the expansion of UNGD to allow for latency considerations, (p. 1).

Pennsylvania's Clean Energy Policies

Despite Pennsylvania's strong support for fracking development since 2008, the state has also advanced policies to promote clean energy. Thus, also in 2008, the state enacted the Pennsylvania Climate Change Act. This measure requires the state's DEP to prepare and update a Climate Change Action Plan every three years. It also requires the DEP to keep an inventory of greenhouse gas emissions in the state and administer a Climate Change Advisory Committee.

The most recent 2019 Action Plan fleshed out a program based on the January 2019 executive order signed by Governor Tom Wolf, "Commonwealth Leadership in Addressing Climate Change and Promoting Energy Conservation and Sustainable Governance."[12] The main features of Governor Wolf's executive order included both an emissions reduction target for the state overall as well as a series of performance goals for state agencies consistent with the statewide emissions reduction target.

The statewide emissions reduction target is for Pennsylvania to reduce its greenhouse gas emissions by 26 percent as of 2025 and by 80 percent as of 2050, both relative to 2005 levels. According to Governor Wolf's program, one major policy initiative for achieving these climate goals is for Pennsylvania to join the Regional Greenhouse Gas Initiative (RGGI) as of 2022. RGGI already includes Connecticut, Delaware, Maine, Maryland, Massachusetts, New Hampshire, New Jersey, New York, Rhode Island and Vermont. Under RGGI, the participating states establish mandatory limits on carbon emissions by electric utilities located in their states, but also allow these overall limits to be redistributed among the states through a 'cap-and-trade' auction system. [13]

In September 2020, the Pennsylvania House of Representatives and Senate both passed bills attempting to prohibit Governor Wolf from bringing the state into RGGI, but the governor vetoed the measure. As of this writing, Pennsylvania remains on track to join RGGI in 2020.

Governor Wolf's January 2019 executive order also specified performance goals directed at state agencies, including the following:

- Reducing overall energy consumption by 21 percent relative to 2017 levels;
- Replacing 25 percent of the state-owned passenger car fleet with battery electric and plug-in electric hybrid cars by 2025;
- Procuring renewable energy to offset at least 40 percent of the state's annual electricity consumption;
- Reducing energy consumption in any new or significantly renovated state-owned or state-leased building by at least 10 percent.

In addition, the state has subsidy programs in place to support clean energy investments. These include renewable energy and energy efficiency grants, loans, and loan guarantees. It also includes rebate programs for residential and commercial purchases of energy efficiency equipment, such as air source heat pumps.[14]

The two largest cities in Pennsylvania, Philadelphia and Pittsburgh, have established similar climate programs at the municipal level. The Philadelphia project includes a citywide 28 percent emissions reduction by 2025 relative to the 2006 level. The Philadelphia program commits the government to cut energy use by 20 percent by 2030 and to purchase 100 percent of its electricity supply for municipal operations from clean energy sources. The Pittsburgh Climate Action Plan aims to reduce citywide emissions by 50 percent below 2003 levels by 2030 and for the government to switch to 100 percent clean energy supply by 2030.

Overall, these various state- and municipal-level measures contribute towards establishing a valuable climate stabilization framework for Pennsylvania. Yet there is still a general problem with these measures, considered as a whole. It is that they are operating at too modest a scale to achieve major gains in moving the state onto a viable climate stabilization trajectory. This becomes clear with the single most important policy target, which is the 2030 statewide emissions reduction target for the state. This target—a 26 percent reduction by 2025 relative to the 2005 level—is well below the IPCC's goal of a 45 percent reduction globally relative to the 2018 level. Moreover, Pennsylvania was already close to having achieved this 2025 target as of 2017, i.e., before the target had been set in 2018. Specifically, as of 2017, overall emissions in Pennsylvania were already roughly 22 percent below the 2005 level. This meant that the state had targeted additional reductions between 2017 and 2025 of only 4 percentage points, after having achieved a 22 percent reduction between 2005 and 2017.

In short, Pennsylvania will be able to build from its existing clean energy policy framework but increase the scale of the program to a level that will move the state onto a viable emissions reduction path. In what follows, we develop a clean energy program capable of bringing statewide emissions down by 50 percent as of 2030 and to achieve net zero emissions by 2050.

2.2 Energy Sources and CO_2 Emissions for Pennsylvania

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

As one measure of how much energy is provided by 1 Q-BTU of energy, as we see in Table 2.1, total energy consumption in Pennsylvania in 2018 was 3,961.5 trillion BTUs, or ap-

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

	Buildings						
	Residential	Commercial	All buildings	Industrial	Transportation	TOTAL	% of TOTAL
Total	**965.3**	**655.1**	**1620.4**	**1403.0**	**938.1**	**3961.5**	**100.0**
% of Total	**24.4**	**16.5**	**40.9**	**35.4**	**23.7**	**100.0**	
Natural gas[1]	472.0	333.4	805.4	656.4	51.5	1513.3	38.2
Petroleum[2]	110.7	44.2	154.9	202.6	845.7	1203.2	30.4
Nuclear	327.4	253.2	580.6	288.0	4.1	872.7	22.0
Coal	175.6	136.2	311.8	330.1	2.2	644.1	16.3
Biomass	44.8	16.8	61.6	74.2	36.7	172.5	4.4
Hydro	14.6	11.3	25.8	12.8	0.2	38.8	1.0
Wind	12.2	9.4	21.6	10.7	0.2	32.5	0.8
Geothermal	1.3	0.8	2.1	0.0	0.0	2.1	0.1
Solar	2.8	1.5	4.3	0.8	0.0	5.1	0.1
Net interstate flow of electricity[3]	--	--	--	--	--	-522.9	-13.2
Net electricity imports	--	--	--	--	--	0.2	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. Excluding fossil fuels as commingled.
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=PAUS Energy Information Agency (EIA).

proximately 4.0 Q-BTUs. This means that, roughly, 1 Q-BTU would be able to provide for Pennsylvania, at its 2018 consumption level, 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 Pennsylvania's economy. As we see, about 41 percent of all consumption is used to operate buildings (1,620.4 T-BTUs), both residential and commercial structures. Of the remaining 59 percent, 35 percent is used for industrial activity (1,403.0 T-BTUs) and the remaining 24 percent for transportation (938.1 T-BTUs). In addition, as noted above, Pennsylvania exports 13.2 percent of the energy generated in the state to other states to consume as electricity.

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

As we see in row 3, natural gas is the most heavily utilized energy source in Pennsylvania, providing about 38 percent of all the state's energy supply. About 53 percent of natural gas is used for buildings in Pennsylvania, with most of the remaining 47 percent used in industry. Petroleum is the next largest energy source in Pennsylvania, at about 30 percent of all supply, and with 70 percent of petroleum used for transportation, with about 17 percent used for industry and 13 percent for buildings. Nuclear energy is a large contributor to the state's overall energy supply, at 22 percent. Nuclear energy is used to generate electricity, which then is used primarily in buildings (67 percent) but also in industry (32 percent). The contribution of coal is still substantial, at 16 percent of all supply, with coal also mainly used to generate electricity, which in turn is provided, in roughly equal proportions, for buildings and industry.

The most heavily consumed renewable energy source in Pennsylvania is bioenergy, at 173 T-BTUs, equal to 4.4 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 cheapy and rapidly growing plants such as switchgrass, and that these raw materials are refined into biofuels by relying on clean renewable energy sources. We assume that such low-emissions bioenergy sources can develop in Pennsylvania between 2021 – 2030.[15]

The supply of energy provided in Pennsylvania by all clean renewable energy sources combined—i.e., wind, solar, hydro and geothermal—remains negligible as of 2018, accounting for only 2.0 percent of Pennsylvania's total energy supply. Among the clean renewable sources, hydro power is the most developed in the state, at 1.0 percent of total supply. Wind power provides about 0.8 percent of total supply. It is clear that expanding overall energy supply in Pennsylvania from clean renewable sources will be a formidable challenge.

Electricity Supply and Demand

To further clarify the profile of energy consumption in Pennsylvania, 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 nuclear power, natural gas, and coal, as its primary sources in Pennsylvania —for its generation. It is also unique in that, as Table 2.2 shows, nearly half of all energy consumed is lost in the conversion process from the primary energy sources to electricity supply, while the other half is channeled into energy that is consumed. One evident way to raise energy efficiency, in Pennsylvania and elsewhere, would therefore entail reducing the percentage of energy losses through electricity use.[16]

The electricity sector in Pennsylvania is also distinctive relative to other U.S. states for two reasons. The first is that it exports to other states about half of all the electricity that it is generating within the state. As we see from figures in Tables 2.1 and 2.3, the state consumes 508 T-BTUs of electricity and exports 523 T-BTUs. Pennsylvania is the largest exporter of electricity among U.S. states. In addition, Pennsylvania is the second largest producer of nuclear energy among U.S. states, after Illinois. The state relies on nuclear power to produce 44 percent of its electricity.

Overall then, as Table 2.2 shows, electricity production requires 2,005 T-BTUs of Pennsylvania's total energy consumption, amounting to roughly half of all energy produced in the state, while, as an energy source to final consumers in the state's building, transportation and industrial sectors, electricity provides only about 508 T-BTUs, or 13 percent of the total energy generated within the state.

Table 2.3 provides more detail on the sources of electricity supply and demand within Pennsylvania. As we see, after nuclear power, with 44 percent of total supply, natural gas provides 28 percent and coal provides 23 percent. Among renewable energy sources, hydro is at 1.9 percent, wind is at 1.6 percent, and bioenergy is 1.3 percent. Solar and geothermal are at near-zero to zero. From these figures, it again becomes clear that, 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. This is true even if the state continues to rely on nuclear power throughout the service lifetime of its existing nuclear plants. We consider this issue in detail below.

In terms of the specific uses of electricity in Pennsylvania. we see in Table 2.3 that the most prevalent use is for the operation of buildings, accounting for about 67 percent of all electricity demand. Industrial processes utilize the remaining 33 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 2.2
Pennsylvania State Total Electricity Consumption and Energy Losses in Electricity Generation, 2018

Total energy consumed in generating electricity	2,004.9 TBTUs *(50.6% of state energy consumption)*
Electricity consumption as share of overall energy consumption	508.3 T-BTUs *(12.8% of state energy consumption)*
Energy losses as share of energy consumed in generating electricity	74.6%

Source: US EIA State Energy Data System.

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

	Buildings					
	Residential	Commercial	All buildings	Industrial	Transportation	TOTAL
Nuclear	83.0	64.2	147.2	73.0	1.0	221.3 *43.5% of total*
Natural gas	53.1	41.0	94.1	46.7	0.7	141.4 *27.8% of total*
Coal	44.5	34.4	78.9	39.2	0.6	118.7 *23.3% of total*
Hydro	3.7	2.9	6.5	3.2	0.0	9.8 *1.9% of total*
Wind	3.1	2.4	5.5	2.7	0.0	8.2 *1.6% of total*
Bioenergy	2.5	2.0	4.5	2.2	0.0	6.8 *1.3% of total*
Petroleum	0.7	0.6	1.3	0.7	0.0	2.0 *0.4% of total*
Solar	0.0	0.0	0.1	0.0	0.0	0.1 *0% of total*
Geothermal	0.0	0.0	0.0	0.0	0.0	0.0 *0% of total*
Total	190.7	147.5	338.2	167.7	2.4	508.3
Share of total (in %)	38%	29%	67%	33%	0%	100%

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

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 Pennsylvania by approximately 50 percent and to transform the state into a net zero emissions economy by 2050.

Natural Gas

We begin with natural gas, which, as we have seen, is the most heavily consumed energy source in the state at present. As we have also discussed above, natural gas production through fracking has been a major economic development project in the state since 2008. Here we focus on natural gas as a source of CO_2 and other greenhouse gas emissions.

There are large differences in the emissions levels resulting through burning oil, coal, and natural gas respectively, with natural gas generating about 40 percent fewer emissions for a given amount of energy produced than coal and 15 percent less than oil. It is therefore widely argued that natural gas can be a "bridge fuel" to a clean energy future.[17] 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.[18]

Nuclear Energy

As we have seen, nuclear energy is a major source of Pennsylvania's overall energy supply, providing 22 percent of the state's total energy consumption plus electricity exports and fully 44 percent of the state's electricity supply. At present, 8 nuclear reactors are operating in Pennsylvania, two each at the Beaver Valley, Limerick, Peach Bottom, and Susquehanna power stations.

In terms of advancing a clean energy transition in Pennsylvania, nuclear energy provides the important benefit that it does not generate CO_2 emissions or air pollution of any kind while operating. At the same time, the processes for mining and refining uranium ore, making reactor fuel, and building nuclear power plants do all require large amounts of energy.

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

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

How to weigh the benefits to Pennsylvania of nuclear energy versus these environmental and public safety concerns is a critical challenge for determining the state's future energy trajectory.

Clearly, the view is widely held in Pennsylvania, at least among those who have set energy policy in the state for the past four decades, that the risks associated with nuclear power are relatively small and manageable when balanced against its benefits. This is the case, even though, in 1979, the state experienced a nuclear reactor meltdown at the Three Mile Island facility in Middletown. At least partially, the continued support for nuclear in Pennsylvania post-Three Mile Island can be explained by the fact that, at least in official assessments, the negative effects of the accident were relatively modest. Thus, the Pennsylvania Department of Health followed for 18 years the health outcomes of 30,000 people who lived within five miles of the reactor. This study found that these people experienced no negative health effects.[19]

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

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

More recently, in 2011, Japan experienced a nuclear accident at the Fukushima Daiichi power plant of comparable severity to Chernobyl. This meltdown resulted from the massive 9.0 Tohuku earthquake and tsunami. While the full effects of the Fukushima meltdown remain uncertain nearly a decade subsequent to the disaster, the most recent estimate of the total costs of decommissioning the power plant and providing compensation to victims is $250 billion.[21]

In September 2019, what had been the one still-operating reactor at the Three Mile Island site was shut down by its owner, Exelon Corporation. Exelon reported that the plant could not compete with electricity generated by cheap natural gas extracted through low-cost fracking operations. Also in 2019, the then-owners of the Beaver Valley plant, FirstEnergy Corporation, announced that it would require state-provided subsidies to enable it to continue operating in Pennsylvania. Without subsidies, FirstEnergy stated at that time that it would also have to shut down. FirstEnergy did not receive the subsidies it requested, and did then go into bankruptcy, selling the Beaver Valley facility to Energy Harbor. Energy Harbor also initially announced plans for deactivating Beaver Valley unless the state supported it with subsidies. Even though the state still did not deliver the requested subsidies, as of May 2020, Energy Harbor reversed itself, announcing that it would continue operating in Pennsylvania without subsidies. Energy Harbor believes the plant will be able to operate profitably in Pennsylvania because of Governor Wolf's commitment for the state to join the Regional Greenhouse Gas Initiative (RGGI). As discussed above, as a participant in RGGI, Pennsylvania will become obligated to lower its emissions levels. Maintaining nuclear energy in the state as a major energy source will support the state's emission reduction project. Alternatively, if the state were to reduce its consumption of nuclear energy and increase its reliance on natural gas and coal as substitute fuels, emissions would then, of course, inexorably rise.

Notwithstanding these latest developments in Pennsylvania with its nuclear energy, it remains the case that, over the long term, continuing to rely on nuclear energy will continue to carry major environmental, public health, safety, and political risks. Given the prominent role of nuclear in Pennsylvania at present, there is a case for allowing the eight reactors now operating in the state to continue producing electricity for the next 20 – 30 years, assuming that they adhere to strict safety standards over this period. But as clean renewable energy supply expands in the state, these nuclear plants should all be phased out and no new nuclear facilities should be built. This would enable Pennsylvania to establish its net zero emissions economy on a foundation of energy sources that are both clean and safe—i.e., solar, wind, and other clean renewable sources.

Bioenergy

As we saw in Table 2.1, bioenergy—including solid biomass energy from burning wood and other raw materials as well as liquid biofuels, primarily corn ethanol—provides 4.4 percent of Pennsylvania'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, bioenergy is not a clean energy source under most circumstances. This is, first of all, because burning solid biomass can generate significant emissions levels, depending on the raw materials used and the processes used for converting raw materials into energy. The emissions that result through burning wood are significantly greater than those produced by burning coal, and are far in excess of those produced through either oil or natural gas combustion. Despite this, in the official methodology for measuring CO_2 emissions used in the U.S. (and elsewhere), biomass is treated as a carbon-neutral energy source. This approach is based on the fact that when new crops of trees are planted and grown, they absorb CO_2 by the same amount as the CO_2 that is emitted when trees are burned.

However, this approach to accounting for biomass emissions has been widely refuted in the recent research literature.[22] 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.[23]

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.[24]

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 Pennsylvania. In fact, emissions from biomass and biofuels vary widely.[25] As a rough approximation, we assume that emissions levels from bioenergy in Pennsylvania 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 Pennsylvania 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. Nearly 60 percent of Pennsylvania's overall land area is presently covered by forest. Indeed, Pennsylvania is the only state to have been named for its forests.[26] Thus, forest growth in Pennsylvania can provide a significant offset to the emissions generated through combusting fossil fuels and biomass to produce energy. As such, Pennsylvania 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 2.11, which focuses on the path for Pennsylvania 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.[27] The technologies being researched now aim to artificially replicate the impact of the Mount Pinatubo eruption through deliberately injecting sulfate particles into the stratosphere. Some researchers contend that to do so would be a cost-effective method of counteracting the warming effects of greenhouse gases.

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

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

Energy Efficiency and Clean Renewable Energy

Given these major problems with bioenergy, natural gas, nuclear energy and geoengineering, it follows, in advancing a program to cut emissions by 50 percent as of 2030 and to net zero emissions by 2050, that Pennsylvania 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.[28]

Estimating Costs of Efficiency Gains

How much will it cost to achieve major gains in energy efficiency, in general and with respect to Pennsylvania 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.[29] 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 Pennsylvania.

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 Pennsylvania 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 Pennsylvania, 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 Pennsylvania, 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 Pennsylvania 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.[30]

2.5 Prospects for Clean Renewable Energy

A critical factor for building a net zero economy in Pennsylvania, 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 2019, on the "levelized costs" of supplying electricity through alternative energy sources. Levelized costs take account of *all costs* of producing and delivering a kilowatt of electricity to a final consumer. The cost calculations begin with the upfront capital expenditures needed to build the generating capacity, include both fixed and variable operations and maintenance costs, continue through to the transmission and delivery of electricity, and include the costs of energy that is lost during the electricity-generation process.

As we see in Table 2.4, the levelized costs for fossil-fuel generated electricity range between 5.0 and 17.7 cents per kilowatt hour as of 2019. The average figures for the four clean renewable sources are all within this range for fossil fuels as of 2019, with solar at 6.8 cents, onshore wind at 5.3 cents, hydro at 4.7 cents and geothermal at 7.3 cents. The costs of geothermal and hydro did not fall, and actually rose somewhat, between 2010 and 2019. However, the costs of onshore wind fell by 38 percent, from 8.6 to 5.3 cents. 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.[31]

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.[32] In particular, solar and wind energy costs will vary significantly by region and season. Moreover, both solar and wind energy are intermittent sources—i.e., they only generate energy, respectively, when the sun is shining or the wind is blowing. These issues of energy storage will become significant as Pennsylvania, 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

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.

petroleum, natural gas, coal and nuclear power will be supplying roughly 85 percent of Pennsylvania's total energy supply as of 2021, with that figure still maintained at over 60 percent as of 2030, even as Pennsylvania achieves major improvements in energy efficiency. Thus, the economy's baseload energy sources 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 component.[33] 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.[34] 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 Pennsylvania'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 Pennsylvania. 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 Pennsylvania. 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 Pennsylvania 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 Pennsylvania by 2030 and to reach net zero emissions by 2050.

2.6 Determinants of Pennsylvania's CO_2 Emission Levels

Table 2.6 shows how, as of 2018, Pennsylvania generated approximately 238 million tons of CO_2 from burning natural gas, oil and coal, and a small amount of bioenergy to supply the state with energy. We also see the shares of total emissions generated by the respective sources, with petroleum at 81 million tons, natural gas at 80 million tons, coal at 61 million tons, and bioenergy at 16 million tons.

It is clear from these figures that driving down overall emissions in Pennsylvania from about 238 to roughly 120 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 1,203 to 722 T-BTUs as of 2030, natural gas falls from 1,513 to 908 T-BTUs, coal falls from 644 to 193 T-BTUs and bioenergy falls from 173 to 104 T-BTUs. Through following this scenario, total CO_2 emissions in Pennsylvania will fall by nearly half, from approximately 238 to 124 (a 48 percent decline). 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 Pennsylvania: *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	1,203.2	81.0	67.3	721.9	48.6
Natural gas	1,513.2	80.2	53.0	907.9	48.1
Coal	644.1	61.4	95.3	193.2	18.4
Fossil fuel totals	3,360.5	222.6	---	1,823.0	115.1
Bioenergy	172.6	15.5	90— *rough approximation*	103.6	9.3
Totals, including bioenergy estimate	**3,533.1**	**238.1**	---	**1,926.26**	**124.4**

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 Pennsylvania'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 Pennsylvania, 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 Pennsylvania, 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 Pennsylvania, and, for comparison purposes, the United States overall and India, as well as six other states: Ohio, 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*
Pennsylvania	18.0	$58,204	5.1	60.6
United States	17.2	$60,062	5.0	57.2
India	1.8	$2,104	13.4	66.8
Ohio	18.6	$55,347	5.6	59.3
Kentucky	26.7	$45,082	8.3	71.6
New York	8.7	$81,887	2.3	46.5
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 biomass emissions. India data from https://www.iea.org/countries/india

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

By contrast, per capita income in Pennsylvania as of 2017 was about $58,000. This is about 3 percent below the average figure for the U.S. overall, at $60,062. Pennsylvania's ranking in 2017 was 20th in per capita income among the 50 U.S. states.

With respect to this average income level, Pennsylvania could, hypothetically, reduce its per capita emissions figure by half as of 2030 by also cutting per capita GDP in half, to around $29,000, 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 of no more than about 120 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 Pennsylvania'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 just 2 percent worse than the national average, with an energy intensity ratio of 5.1 Q-BTUs per $1 trillion in GDP versus the U.S. national average of 5.0. Pennsylvania's neighboring state of Ohio is also fairly close to the national average of energy intensity, with a 5.6 ratio. Pennsylvania's energy intensity ratio is significantly lower than both Texas and Kentucky, whose ratios are 8.1 and 8.3 respectively. But Pennsylvania 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 Pennsylvania 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 19 percent more efficiently than Pennsylvania. One of the main policy initiatives in Pennsylvania should therefore be to raise energy efficiency so that, by 2030, it reaches a standard somewhere within the range of where California is at present.
2. ***Clean-burning energy***: Pennsylvania's emissions intensity ratio of 60.6 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 Pennsylvania can correspond closely with the project for the U.S. overall.

In addition to these factors explaining Pennsylvania'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.

TABLE 2.8
Determinants of Pennsylvania State Per Capita CO2 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	261.8	12.0 million	21.8	$598.2 billion	$49,850	3,771	6.3	69.4
2018	238.1	12.8 million	18.6	$808.7 billion	$63,180	3,962	4.9	60.1

Source: See Table 2.7.

As the table shows, per capita emissions fell between 1999 and 2018 from 21.8 to 18.6 tons, while per capita GDP rose from $49,900 to $63,200. This amounts to an average reduction in emissions per capita of about 0.8 percent per year while average per capita incomes rose by 1.2 percent per year. In a similar pattern, *total* emissions—i.e., not factoring in the size of Pennsylvania's population, fell from 268 to 238 million metric tons between 1999 and 2018, a -0.5 percent average annual rate of decline, while overall GDP in the state rose from $598.2 to $808.7 billion, an average annual increase in GDP of 1.5 percent. These figures showing absolute decoupling in the state 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 between 1999 to 2018 from 6.3 to 4.9, a 22 percent improvement. This is equal to a 1.2 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 modestly higher than the figure for the U.S. overall, 21 percent higher than Colorado and 45 percent higher than California. There is clearly considerable room for significantly greater efficiency gains. Pennsylvania's emissions intensity also fell over this period, from 69.4 to 60.1 in CO_2 emissions per Q-BTU of energy consumed in the state, a 0.7 percent average annual improvement.

Pennsylvania'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 6.3 percent per year. We assume that this more than 6 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 1.5 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 Pennsylvania down by 50 percent, to approximately 120 million tons by 2030, from its 2018 level of 238 million tons. The second is to advance this climate stabilization program while the Pennsylvania 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 Pennsylvania 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 Pennsylvania overall economy (GDP) 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 the same growth rate that Pennsylvania experienced over the recent 20-year period, i.e., 1999 – 2018. If we assume that the Pennsylvania 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 1930's Great Depression and the current COVID-based crisis. In addition, the aim of the full program we are proposing for Pennsylvania 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 Pennsylvania'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, Pennsylvania's real GDP will be approximately $967 billion in 2030, growing from the 2018 figure of $809 billion. Assuming again a 1.5 percent average annual growth rate, the 2021 GDP

TABLE 2.9

Pennsylvania GDP Levels, 2018 Actual and Projections for 2021, 2026, and 2030

Figures are in 2018 dollars

2018 GDP	$808.7 billion
Projected average growth rate through 2030	1.5%
Projected 2021 GDP	$845.6 billion
Projected 2030 GDP	$966.9 billion
Projected midpoint GDP between 2021 – 2030 (average of 2025 and 2026)	$904.3 billion

Source: BEA and authors' calculations.

will be $846 billion. The midpoint over the 2021 – 2030 decade will be effectively January 1, 2026. Pennsylvania's real GDP will be at $904 billion at that midpoint.

Within this framework, we can then project an energy and CO_2 emissions profile for Pennsylvania for 2030. We consider two distinct scenarios. For the first 2030 scenario, we assume that the state's energy infrastructure as of 2018 remains basically intact through 2030. We see the results of this scenario in Table 2.10. Specifically, in column 1 of Table 2.10, we show the actual breakdown of energy consumption and emissions as of 2018. In column 2, we then present projected figures, assuming Pennsylvania'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 Pennsylvania. 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 3, columns 1 and 2, that Pennsylvania's energy intensity ratio remains constant between 2018 and 2030, at 4.9 Q-BTUs per $1 trillion in GDP. The state's emissions intensity ratio also remains unchanged, at 60.1, as shown in row 19, 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 18 of Table 2.10. That is, total CO_2 emissions increase from 238 to 285 million tons, an increase of 19.7 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 124 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 Pennsylvania economy. Following from that prior discussion, we assume that, by 2030, Pennsylvania is capable of reducing the economy's energy intensity ratio from the 2018 level of 4.9 to 3.2 Q-BTUs per $1 trillion of GDP. This would be a 35 percent gain in overall energy efficiency in the state. It would bring Pennsylvania by 2030 to an efficiency level that is still 14 percent above the level at which California operated in 2017. Correspondingly, total energy consumption at the 2030 GDP level, would fall from approximately 4,000 to 3,100 T-BTUs (i.e., 4.0 to 3.1 Q-BTUs).

We then need to consider the energy mix that will be necessary to allow for 3,100 T-BTUs of consumption while still maintaining emissions at no more than 124 million tons. As we have seen in Table 2.6, in order to bring overall CO_2 emissions in Pennsylvania down to 124 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 908 T-BTUs as of 2030, oil is at 722, coal is at 193, and high-emissions bioenergy is at 104. Pennsylvania then continues to utilize nuclear energy at its 2018 consumption level of 873 T-BTUs. In combination then, the non-renewable energy sources along with high-emissions bioenergy would provide Pennsylvania with a total of about 2,800 T-BTUs of energy in 2030 (rounded from 2,799.3 T-BTUs). We finally also assume that Pennsylvania will increase its electricity exports by 625 T-BTUs, the level that reflects a 1.5 percent average growth rate relative to the 2018 figure.

This then entails that 920 T-BTUs of energy will need to be provided by clean renewable sources in order for Pennsylvania's overall energy consumption plus its electricity exports to reach 3,719 T-BTUs in 2030.

TABLE 2.10

Pennsylvania 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 *(in 2018 dollars)*	$808.7	$966.9	$966.9
2) In-state energy consumption *(T-BTUs)*	3,961.6	4,738.8	3,094.1
3) Energy intensity ratio *(Q-BTUs consumption/ $1 trillion of GDP)*	4.9	4.9	3.2
4) Electricity exports to other U.S. states	522.9	625.2	625.2
5) In-state consumption + electricity exports *(T-BTUs)(= rows 2 + 4)*	4,484.8	5,363.0	3,719.3
Energy mix			
6) Non-renewables and bioenergy *(T-BTUs—rows 7 - 11)*	*4,405.8*	*5,267.7*	*2,799.3*
7) Natural gas	1,513.2	1,809.2	907.9
8) Petroleum	1,203.2	1,438.6	721.9
9) Coal	644.1	770.1	193.2
10) High-emissions bioenergy	172.6	206.4	103.6
11) Nuclear	872.7	1,043.4	872.7
12) Clean renewables *(T-BTUs—rows 5 - 6)*	*79.0*	*95.3*	*920.0*
13) Solar	5.1	6.1	460.0
14) Wind	32.5	38.9	184.0
15) Low-emissions bioenergy	0	0	138.0
16) Geothermal	2.2	2.6	69.0
17) Hydro	38.8	46.4	69.0
Emissions			
18) Total CO_2 Emissions *(million metric tons)*	238.1	284.7	124.4
19) Emissions Intensity Ratio *(CO2 Emissions per in-state-consumed Q-BTUs = row 18 / (row 2/1000)*	60.1	60.1	40.2

Note: Emissions figures exclude electricity exported to other states and countries.
Source: EIA, State Energy Data System (SEDS): https://www.eia.gov/state/seds/seds-data-complete.php?sid=US#Consumption.

As of 2018, all clean renewable sources—solar, wind, low-emissions bioenergy, geothermal, and hydro—combined to supply only 79 T-BTUs of energy to Pennsylvania. Effectively then, 841 T-BTUs of *new supply* needs to be provided by wind, solar, hydro, and geothermal in order to bring Pennsylvania's total energy supply—for both in-state consumption and electricity exports—to 3,719 T-BTUs in 2030, with emissions falling by 48 percent, from 238 to 124 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 Pennsylvania by 841 T-BTUs, will require $168 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 841 T-BTUs in 2030 will be $16.8 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.*** $5.8 billion per year in energy efficiency investments between 2021 – 2030, amounting to about 0.6 percent of Pennsylvania's projected midpoint GDP between 2021 – 2030. These efficiency investments will generate 1,644 T-BTUs of energy savings relative to the steady state growth path for Pennsylvania through 2030.
- ***Clean renewables***. $16.8 billion per year for investments in solar, wind, low-emissions bioenergy, geothermal, and small-scale hydro power. This will amount to about 1.9 percent of Pennsylvania's projected midpoint GDP between 2021 – 2030. It will generate an increase of 841 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 $22.6 billion per year, or 2.5 percent of Pennsylvania's projected midpoint GDP between 2021 – 2030. Overall, this program will generate 2,485 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 Pennsylvania in 2030 will be 124 million tons, slightly less than 50 percent of its level for 2018. Pennsylvania will have achieved this roughly 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 $22.6 Billion per Year in Clean Energy Investments Realistic for Pennsylvania?

The short answer is "yes." To understand why, it is important to consider our estimate of Pennsylvania's annual clean energy investment needs within the broader context of the state's overall economic trajectory. As we have already noted above, this $22.6 billion annual investment figure represents about 2.5 percent of Pennsylvania'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 Pennsylvania's annual clean energy investment needs for bringing CO_2 emissions down in the state by 50 percent as of 2030 implies that 97.5 percent of all economic activity in Pennsylvania can continue to be directly engaged in activities *other than* clean energy investments.

TABLE 2.11
Pennsylvania Clean Energy Investment Program for 2021- 2030

A) Energy Efficiency Investments

1. 2030 Energy Intensity Ratio	3.2 Q-BTUs per $1 trillion GDP *(35% improvement over 4.9 Q-BTU per $1 trillion GDP steady state figure)*
2. Total energy in-state consumption	3,094.1 T-BTUs *(= 35% reduction relative to 4,737.8 T-BTU steady state figure)*
3. Energy savings relative to steady state	1,643.7 T-BTUs *(= 4,737.8 – 3,094.1 T-BTUs)*
4. Average investment costs per Q-BTU in efficiency gains	$35 billion per Q-BTU
5. Costs of energy savings	$57.5 billion *(= $35 billion x 1.644 Q-BTUs in savings)*
6. Average annual costs over 2021 – 2030	$5.8 billion *(= $57.5 billion/10)*
7. Average annual costs of efficiency gains as % of midpoint GDP	0.6% *(= $5.8 billion/$904.3 billion*

B) Clean Renewable Energy Investments

1. Total renewable supply necessary	920.0 T-BTUs *(= 3,719.3 T-BTUs – 2,799.3 T-BTUs supplied by non-renewables/biomass)*
2. Expansion of renewable supply relative to 2018 level	841.0 T-BTUs *(= 920.0 – 79.0 T-BTUs)*
3. Average investment costs per Q-BTU for expanding renewable supply	$200 billion per Q-BTU
4. Costs of expanding renewable supply	$168.2 billion *(= 0.841 Q-BTUs x $200 billion)*
5. Average annual costs over 2021 – 2030	$16.8 billion *(= $168.2 billion/10)*
6. Average annual costs of renewable supply expansion as % of midpoint GDP	1.9% *(= $16.8 billion/$904.3 billion)*

C) Overall Clean Energy Investments: Efficiency + Clean Renewables

1. Total clean energy investments	$225.7 billion *(= $57.5 billion for energy efficiency + $168.2 billion for renewables)*
2. Average annual investments	$22.6 billion *(= $225.7 billion/10)*
3. Average annual investments as share of midpoint GDP	2.5% *(= $22.6 billion/$904.3 billion)*
4. Total energy savings or clean renewable capacity expansion	2,484.7 T-BTUs *(= 1,643.7 T-BTUs in energy saving + 841.0 T-BTUs in clean renewable supply expansion)*

Sources: Tables 2.9 – 2.10.

It is also critical to recognize that Pennsylvania'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.

Leveraging Public Funds for Expanding Total Clean Energy Investments

What level of public funding will be needed to generate an average of roughly $23 billion per year in total new clean energy investments in Pennsylvania? To help answer that question, it will be useful to briefly review the experience with the federal Department of Energy Loan Guarantee Program, which was one part of the 2009 American Recovery and Reinvestment Act—i.e., the Obama stimulus program. This program helped underwrite about $14 billion in new clean energy investments between 2009 – 2013. Even after taking full account of the large-scale and widely publicized failure of the Northern California solar company Solyndra, the default rate and corresponding financial obligations stemming from this program were modest. According to our estimates discussed in Pollin et al. (2014), total losses covered by the government's loan guarantees amounted to about $300 million, i.e., equal to about 2.1 percent of the $14 billion in new loans for clean energy investments that the government guaranteed. This means that the leverage rate for the loan guarantee program was about $47 in additional clean energy investments underwritten by $1 of federal support.

If Pennsylvania 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 $500 million per year to deliver $23 billion in total clean energy investments in Pennsylvania. 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 $22.5 billion would be coming from private investors. The $500 million in public funding would amount to about 1.5 percent of the state's total budget of roughly $89 billion for fiscal year 2020 – 2021 (i.e., enacted pre-COVID).[35]

However, for various reasons, this leverage ratio is almost certainly too high. One factor is that, to date, Pennsylvania's existing clean energy programs that we discussed in Section 2.1 have been operating at a small scale, including the renewable energy and energy efficiency grant, loan, loan guarantee and rebate programs. The existing administrative capacity operating these programs at present is therefore not likely to be sufficient to operate them at a scale equivalent to the 2009 federal program. On the other hand, the framework does exist to bring these programs to scale, to match the challenge of building a clean energy infrastructure and to 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 Pennsylvania's state and municipal budgets. A reasonable low-end assumption would be that Pennsylvania 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 $21 billion (with $23 billion/year being the midpoint amount over 2021 – 2030). For 2021, this would imply that the state would need to contribute about $2.1 billion on clean energy projects, an amount that would then be matched by $19 billion in private sector investments. The $2.1 billion in public investments would amount to about 2.4 percent of Pennsylvania's 2020 – 2021 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 – 2013.

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 Pennsylvania. 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 average annual level of investment spending we have proposed for between 2021 – 2030, i.e., $5.8 billion in energy efficiency and $16.8 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 0.8 jobs for expanding the high efficiency automobile fleet to 15.3 jobs for public transportation expansion and upgrades.

In Table 2.13, we show the level of job creation through spending an average of $5.8 billion per year on these efficiency projects in Pennsylvania between 2021 – 2030. We have

TABLE 2.12
Job Creation in Pennsylvania through Energy Efficiency Investments
Job creation per $1 million in efficiency investments

	Direct jobs	Indirect jobs	Direct + indirect jobs	Induced jobs	Direct, indirect + induced jobs
Building retrofits	4.4	2.0	6.4	2.4	8.8
Industrial efficiency, including combined heat and power	2.4	1.5	3.9	2.8	6.7
Electrical grid upgrades	3.0	1.3	4.3	2.6	6.9
Public transportation expansion/upgrades, including rail	13.8	1.5	15.3	3.3	18.6
Expanding high efficiency automobile fleet	0.2	0.6	0.8	0.8	1.6

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

TABLE 2.13
Job Creation in Pennsylvania through Energy Efficiency Investments, 2021 – 2030
Job creation through average annual spending of $5.8 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 + indirect jobs	Induced jobs	Direct, indirect + induced jobs
Building retrofits	$2.3 billion	10,120	4,600	14,720	5,520	20,240
Industrial efficiency, including combined heat and power	$1.2 billion	2,880	1,800	4,680	3,360	8,040
Electrical grid upgrades	$870 million	2,610	1,131	3,741	2,262	6,003
Public transportation expansion/upgrades, including rail	$870 million	12,006	1,305	13,311	2,871	16,182
Expanding high efficiency automobile fleet	$580 million	-	-	-	-	-
TOTALS	**$5.8 billion**	**27,616**	**8,836**	**36,452**	**14,013**	**50,465**

Sources: See Tables 2.11 and 2.12.

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

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 $5.8 billion per year in efficiency investments in Pennsylvania will be the creation of 27,616 direct jobs and 8,836 indirect jobs, for a total of 36,452 direct plus indirect jobs created through this energy efficiency investment program. Including induced jobs adds another 14,013 jobs to the total figure. This brings the total job creation figure for efficiency investments, including induced jobs to 50,465 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 3.0 direct plus indirect jobs per $1 million in expenditure for onshore wind projects to 7.7 direct and indirect jobs for investing $1 million in small-scale hydro. Adding induced jobs brings the range to 5.0 jobs for wind, 6.0 for solar, 6.9 for low-emissions bioenergy, 10.0 for geothermal and 11.1 for small-scale hydro.

Based on these proportions, we see in Table 2.15 the levels of job creation in Pennsylvania generated by spending an average of $16.8 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 Pennsylvania by this large-scale expansion in the state's clean renewable energy supply will be 70,210 jobs. If we include induced jobs, then the total rises to 111,236 jobs.

TABLE 2.14
Job Creation in Pennsylvania through Clean Renewable Energy Investments:
Job creation per $1 million in clean renewable investments

	Direct jobs	Indirect jobs	Direct + indirect jobs	Induced jobs	Direct, indirect + induced jobs
Solar	2.1	1.5	3.6	2.4	6.0
Onshore wind	1.7	1.3	3.0	2.0	5.0
Low-emissions bioenergy	3.3	1.3	4.6	2.3	6.9
Geothermal	5.0	1.8	6.8	3.2	10.0
Small-scale hydro	6.1	1.6	7.7	3.4	11.1

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

TABLE 2.15
Annual Job Creation in Pennsylvania through Clean Renewable Energy Investments, 2021 – 2030
Job creation through average annual spending of $16.8 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	$8.4 billion	17,640	12,600	30,240	20,160	50,400
Onshore wind	$3.4 billion	5,780	4,420	10,200	6,800	17,000
Low-emissions bioenergy	$2.5 billion	8,250	3,250	11,500	5,750	17,250
Geothermal	$1.26 billion	6,300	2,268	8,568	4,032	12,600
Small-scale hydro	$1.26 billion	7,686	2,016	9,702	4,284	13,986
TOTALS	**$16.8 billion**	**45,656**	**24,554**	**70,210**	**41,026**	**111,236**

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 $22.6 billion per year on this project in Pennsylvania 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 average direct and indirect job creation for 2021 – 2030 is 106,662 jobs and 161,701 jobs when we add induced jobs to the total. As we see in row 13, this level of job creation amounts to between 1.7 and 2.6 percent of the total workforce in Pennsylvania 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 Pennsylvania. 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 Pennsylvania. 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 Pennsylvania. The jobs created through the indirect and induced channels will be more diffuse in their characteristics. Indeed, the

TABLE 2.16

Annual Job Creation in Pennsylvania 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
$5.8 billion in energy efficiency		
1) Building retrofits	14,720	20,240
2) Industrial efficiency,including combined heat and power	4,680	8,040
3) Electrical grid upgrades	3,741	6,003
4) Public transportation expansion/ upgrades,including rail	13,311	16,182
5) Total energy efficiency job creation	**36,452**	**50,465**
$16.8 billion in clean renewables		
6) Solar	30,240	50,400
7) Onshore wind	10,200	17,000
8) Low emissions bioenergy	11,500	17,250
9) Geothermal	8,568	12,600
10) Small-scale hydro	9,702	13,986
11) Total job creation from clean renewables	70,210	111,236
12) TOTALS *(= rows 5+11)*	**106,662**	**161,701**
13) TOTAL AS SHARE OF 2019 PENNSYLVANIA LABOR FORCE *(Labor force at 6.2 million)*	**1.7%**	**2.6%**

Sources: Tables 2.13 and 2.15.

TABLE 2.17

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

	Energy Efficiency Investments				Clean Renewable Energy Investments				
	1. Building retrofits *(10,120 workers)*	**2. Industrial efficiency** *(2,880 workers)*	**3. Grid upgrades** *(2,610 workers)*	**4. Mass transit** *(12,006 workers)*	**5. Solar** *(17,640 workers)*	**6. Wind** *(5,780 workers)*	**7. Low-emissions bioenergy** *(8,250 workers)*	**8. Geo-thermal** *(6,300 workers)*	**9. Small-scale hydro** *(7,686 workers)*
Average total compensation	$68,800	$87,000	$79,900	$34,000	$81,900	$77,400	$66,800	$79,700	$72,500
Health insurance coverage, percentage	46.3%	53.7%	50.9%	41.7%	53.4%	52.3%	44.2%	51.8%	48.1%
Retirement plans, percentage	36.8%	41.4%	39.1%	35.7%	41.8%	42.0%	34.4%	40.5%	38.6%
Union membership, percentage	22.1%	5.2%	17.4%	16.7%	15.2%	18.4%	20.3%	16.8%	20.4%

Sources: See Appendix 2.

characteristics of the induced jobs created will simply reflect the overall characteristics of Pennsylvania's present-day workforce.

Starting with compensation figures, we see that the averages range between about $34,000 for workers in the mass transit sector to about $87,000 in the industrial efficiency sector.

The range for workers carrying employer-based health insurance coverage is narrower, from 42 percent of workers in the mass transit and bioenergy sectors to 54 percent in industrial efficiency. Thus, including all of the areas of employment, no more than roughly half of all workers are 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 mass transit, in which about 36 percent of workers have retirement plans. The highest figure is with the wind and solar industries, at about 42 percent. Thus, across-the-board, 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 5 – 22 percent of the respective workforces. Nevertheless, the level of union representation in most industries 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 Pennsylvania 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 Pennsylvania, the state should therefore require neutrality with respect to union organizing campaigns in any clean energy investment projects that are either state-owned or partially financed by the state.

More generally, these indicators of job quality will be valuable for purposes of comparison when we consider the jobs that will be lost in Pennsylvania because of the contraction of fossil fuel production and consumption in the state through 2030. What is especially important to highlight now—in anticipating our discussion in Section 2.9 on workers in Pennsylvania'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 Pennsylvania 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 Pennsylvania 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 Pennsylvania 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 are generally similar across industries. Thus, in 8 of the 9 industries listed, between 46 – 64 percent of the workers

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

	Energy Efficiency Investments				Clean Renewable Energy Investments				
	1. Building retrofits *(10,120 workers)*	**2. Industrial efficiency** *(2,880 workers)*	**3. Grid upgrades** *(2,610 workers)*	**4. Mass transit** *(12,006 workers)*	**5. Solar** *(17,640 workers)*	**6. Wind** *(5,780 workers)*	**7. Low-emissions bioenergy** *(8,250 workers)*	**8. Geo-thermal** *(6,300 workers)*	**9. Small-scale hydro** *(7,686 workers)*
Share with high school degree or less	59.9%	21.1%	63.5%	55.3%	46.1%	52.3%	60.4%	49.6%	56.6%
Share with some college or Associate degree	23.3%	19.1%	26.8%	26.9%	20.4%	21.8%	22.8%	21.4%	23.1%
Share with Bachelor's degree or higher	16.8%	59.8%	9.7%	17.7%	33.5%	25.9%	16.8%	28.9%	20.3%
Racial and gender composition of workforce									
Pct. non-white	14.8%	16.5%	10.2%	32.5%	15.8%	15.0%	14.6%	15.4%	14.1%
Pct. female	8.8%	32.6%	6.2%	32.0%	22.0%	16.5%	11.6%	18.3%	10.2%

Sources: See Appendix 2.

have high school degrees or less. The one exception is industrial efficiency, in which only 21 percent of the workers have high school degrees or less, while 60 percent have Bachelor's degrees or higher. Otherwise, with the other 8 industries, the share of workers with Bachelor's degrees or higher ranges between 10 – 33 percent.

If we consider this range of clean energy investment areas as a whole, a significant share of the newly generated jobs in the various clean energy sectors will be open to workers with 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, with one exception, is between 10 – 17 percent of the workforce. The one exception is mass transit, in which non-white workers account for 33 percent of the workforce. 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 Pennsylvania population is 18 percent. As such, the growth of Pennsylvania's clean energy economy will certainly create increased opportunities for people of color in the state.

The representation of women in the clean energy sectors of Pennsylvania's economy is even lower than that for people of color. The share of female employment is between 9 – 33 percent in Pennsylvania's clean energy economy at present, even while women make up a 51 percent majority of Pennsylvania's workforce.

Despite these disparities in the current composition of the workforce associated with clean energy investments in Pennsylvania, 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 Pennsylvania 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 Pennsylvania Industry
(Job categories with 5 percent or more employment)

Job category	Percentage of direct jobs created	Representative occupations
Construction	57.5%	Electricians; first-line supervisors; plumbers
Management	20.3%	General managers; sales managers; chief executives
Installation and maintenance	6.6%	Telecommunications line installers; telecommunications equipment repairers; truck mechanics

Sources: See Appendix 2.

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

Job category	Percentage of direct jobs created	Representative occupations
Management	21.7%	Operations managers; marketing managers; construction managers
Business operation specialists	18.6%	Logisticians, purchasing agents; human resource workers
Construction	11.7%	Pipelayers; carpenters; construction laborers
Architecture and engineering	10.0%	Drafters, mechanical engineers; architects
Office and administrative support	9.9%	Data entry keyers; customer service representatives; secretaries
Computer and mathematical science	9.6%	Operations research analysts; computer support specialists; computer systems analysts

Sources: See Appendix 2.

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

Job category	Percentage of direct jobs created	Representative occupations
Transportation	61.1%	Transportation attendants; truck drivers; bus drivers
Construction	14.3%	First-line supervisors; electricians; pipefitters
Management	7.8%	Marketing managers; transportation managers; chief executives
Office and administrative support	6.2%	Transportation ticket agents; bookkeeping clerks; administrative assistants

Sources: See Appendix 2.

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

Job category	Percentage of direct jobs created	Representative occupations
Construction	41.4%	Pipelayers; electricians; construction laborers
Management	21.0%	Financial managers; sales managers; chief executives
Life, physical and social science	8.1%	Biological scientists; physical scientists; physical science technicians
Office and administrative support	6.2%	Office clerks; accounting clerks; information clerks
Installation and maintenance	5.3%	Telecommunications equipment installers; mobile equipment service technicians; air conditioning 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 58 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 49 percent of jobs in other areas of renewable energy investments, along with 14 percent in public transportation and 12 percent in industrial efficiency. The specific types of construction industry jobs will vary widely, given the different types of construction projects that will be pursued. Thus, investments in building retrofits as well as the other areas of efficiency investments 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.

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

Job category	Percentage of direct jobs created	Representative occupations
Construction	48.7%	First-line supervisors; steamfitters; carpenters
Management	20.8%	Marketing managers; agricultural managers; construction managers
Installation and maintenance	6.1%	Telecommunications equipment repairers; heavy vehicle mechanics; heating installers

Sources: See Appendix 2.

Jobs in management also constitute a large share of overall job creation across all categories, accounting for about 20 percent in all industries other than public transportation, and with 8 percent in public transportation. 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 Pennsylvania 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 Pennsylvania through clean energy investments in the range of $23 billion per year, or 2.5 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 $34,000 for workers in the mass transit sector to about $87,000 in the industrial efficiency sector. As an overall average, these compensation figures are roughly comparable to the average compensation level for U.S. workers overall, which is about $65,000. But they are 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.[36] In addition, as we will review below, the compensation figures in the current clean energy sectors remain below those for workers in Pennsylvania'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 minimum wage in Pennsylvania is at the national figure of $7.25. 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).[37] A worker employed full-time year-round at Pennsylvania's minimum of $7.25 would make under $15,000. 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. Raising 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 0.4 percent.[38]

By contrast, as we have seen, the level of union membership in Pennsylvania's clean energy sectors is well above the economywide national average for private sector workers. The expansion of Pennsylvania'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 Pennsylvania 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 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).

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/).

It is clear therefore that high-quality and accessible workforce training programs need to be included as an important component of Pennsylvania'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 Pennsylvania, 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. Pennsylvania's construction industry has been permitted to operate since early May within a framework of COVID-focused public health and safety guidelines.[39] However, it is not clear that the public health guidelines have been followed scrupulously to date.[40] Moving forward, it will be critical that they are 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.

As we saw in Table 2.12, the energy efficiency investment program will generate about 9 jobs in building retrofits per $1 million in expenditures within Pennsylvania. Thus, $2.3 billion in annual energy efficiency investments included in the Table 2.13 calculations will generate about 20,000 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 2.5 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 Pennsylvania to bring total CO_2 emissions down from its 2018 level of 238 million tons to no more than about 120 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 85 percent of Pennsylvania's overall energy supply in 2018 including electricity exports to other states, and high-emissions bioenergy contributed another 4 percent. That is, these are the predominant sources of energy supply in Pennsylvania at present.

The issue on which we focus in this section is what the impact will be on workers in industries in Pennsylvania 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 state—i.e., natural gas, oil and bioenergy by 40 percent, and coal by 70 percent.[41] 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 Pennsylvania 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 Pennsylvania 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 Pennsylvania 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 Pennsylvania'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 Pennsylvania 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 Pennsylvania as of 2018.[42] As we see, as of 2018, there are 63,518 people employed in the fossil fuel and ancillary industries in Pennsylvania. Of these, 15,563 (25 percent) are em-

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

Industry	2018 Employment levels	Industry share of total fossil fuel-based employment
Oil and gas extraction	15,563	24.5%
Support activities for oil/gas	13,665	21.5%
Coal mining	6,276	9.9%
Natural gas distribution	5,923	9.3%
Fossil fuel electric power generation	3,985	6.3%
Wholesale -petroleum and petroleum products	3,517	5.5%
Drilling oil and gas wells	3,301	5.2%
Pipeline transport	2,595	4.1%
Pipeline construction	2,398	3.8%
Petroleum refining	2,133	3.4%
All other petroleum and coal products manufacturing	2,106	3.3%
Support activities for coal	1,155	1.8%
Mining machinery and equipment manufacturing	721	1.1%
Oil and gas field machinery and equipment manufacturing	180	0.3%
Fossil Fuel Industry Total	***63,518***	***100.0%***
TOTAL FOSSIL FUEL EMPLOYMENT AS SHARE OF PENNSYLVANIA STATE EMPLOYMENT *(Pennsylvania 2018 employment = 6,150,782)*		**1.00%**

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

ployed in oil and gas extraction, 13,665 (22 percent) work in oil and gas support activities, and 5,923 are in natural gas distribution (9 percent). Thus, these three sectors—extraction, support activities and natural gas distribution together account for 56 percent of total employment in all of Pennsylvania's fossil fuel-based industries. The other major employment category is coal mining, with 6,276 jobs, nearly 10 percent of the total.

Characteristics of Fossil Fuel-Based Industry Jobs

Table 2.27 provides basic figures on the characteristics of the direct jobs in Pennsylvania for workers in fossil-fuel based sectors. We first see that, on average, these are relatively high-paying jobs. The average overall compensation is a bit less than $94,000, about 15 percent more than the $82,000 average pay level for solar industry workers, who, on average, are the highest paid in Pennsylvania's clean energy sector.

TABLE 2.27
Characteristics of Workers Employed in Pennsylvania's Fossil Fuel-Based Sectors

Average total compensation	$93,900*
Health insurance coverage	78.0%**
Retirement benefits	60.0%**
Union membership coverage	13.1%
Educational credentials	
Share with high school degree or less	45.0%
Share with some college or Associate degree	26.2%
Share with Bachelor's degree or higher	28.7%
Racial and gender composition of workforce	
Pct. non-white workers	6.7%
Pct. female workers	15.7%

Note:
*This total compensation figure excludes proprietors in the pipeline transportation sector because the compensation associated with such employment is an extreme outlier, with an average income of $192 million. Such employment comprises only 0.04 percent of the total fossil fuel sector-related employment loss.
**Due to small sample sizes, these figures are based on the mid-Atlantic region rather than Pennsylvania only.
Source: See Appendix 2.

In terms of private health insurance coverage, the fossil fuel industries are, for the most part, providing coverage for their workers, with 78 percent of workers receiving employer-based insurance. This level of health insurance coverage is consistently much higher than is generally the case with the industries that would expand as a result of clean energy investments. As we saw in Table 2.17, the extent of health insurance coverage in the clean energy industries ranges between 42 – 54 percent.

Union membership is at about 13 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 the fossil fuel-based sectors, as well the percentages of workers who are women and people of color. With respect to educational credentials, the overall level of attainment is relatively high, with about 29 percent having Bachelor's degree or higher, and another 26 percent have some college or an Associate degree. The remaining 45 percent have high school degrees only or less. Women account for only 16 percent of the workforce, and people of color account for 7 percent.

In Table 2.28, we gain further detailed information on workforce and employment conditions for workers in Pennsylvania'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 Pennsylvania provide a wide range of employment opportunities for the nearly 64,000 workers currently employed in these industries. As we see, the largest share of jobs, at roughly 16 percent each are in two categories, management and extraction. But other job categories—including construction, transportation, production, office support, architecture and engineering—each account for 5 percent or more of the total.

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

Job category	Percentage of direct jobs lost	Representative occupations
Management	15.6%	Marketing managers; property managers; financial managers
Extraction	15.6%	Explosives workers; earth drillers; service unit operators
Construction	11.7%	Carpenters; construction laborers; operating engineers
Transportation and material movers	11.7%	Loading machine operators; industrial truck operators; pumping station operators
Architecture and engineering	9.4%	Drafters; petroleum engineers; engineering technicians
Installation and maintenance	8.7%	First-line supervisors; diesel engine specialists; electrical power line installers and repairers
Office and administrative support	6.8%	Shipping and receiving clerks; accounting clerks; secretaries
Production	5.0%	Power plant operators; inspectors; first-line supervisors

Source: See Appendix 2.

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 Pennsylvania, 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 Pennsylvania's fossil fuel-based activities. As such, any just transition program to support displaced workers in Pennsylvania'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 Pennsylvania transitions out of CO_2-generating energy sources.

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:

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 Pennsylvania. 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

TABLE 2.29
Policy Package for Displaced Workers in Pennsylvania's Fossil Fuel-Based Sectors

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

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 Pennsylvania will successfully implement a relatively smooth contraction of its fossil fuel sectors.[43] 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 Pennsylvania's fossil-fuel based industries over 2021 – 2030 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

TABLE 2.30
Attrition by Retirement and Job Displacement for Fossil Fuel-Based Workers in Pennsylvania

	Fossil fuel workers
1) Total workforce as of 2018	63,518
2) Job losses over 10-year transition, 2021-2030	28,702
3) Average annual job loss over 10-year production decline *(= row 2/10)*	2,870
4) Number of workers reaching 65 over 2021-2030 *(=row 1 x % of workers 54 and over in 2019)*	13,200 *(20.9% of all workers)*
5) Number of workers per year reaching 65 during 10-year transition period *(=row 4/10)*	1,320
6) Number of workers per year retiring voluntarily	1,056 *(80% of 65+ workers)*
7) Number of workers requiring re-employment *(= row 3 – row 6)*	1,814

Source: 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..

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.[44] We therefore assume that this same 20 percent of older workers will choose to continue working while the fossil fuel-based sectors undergo their contractions between 2021 – 2030. Specifically, we incorporate into our calculations in Table 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 again see in column 2 of Table 2.30, there were, as of the most recent 2018 figures, 63,518 workers in Pennsylvania 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 28,702 as of 2030, which means that there will be another 34,816 jobs retained. If we then assume that the contraction in these industries proceeds at a steady rate between 2021 – 2030, this means that 2,870 jobs in these industries will be lost each year, as we see in row 3 (i.e., 28,702 job losses in total/10 years of industry contraction = 2,870 job losses per year).

We see in row 4 that, of the workers presently employed in these sectors in Pennsylvania, 13,200, or 21 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 1,320 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 1,056 workers employed in these sectors will retire voluntarily every year between 2021 – 2030.

Given that total job losses each year will average 2,870 over the 2021 – 2030 period, that in turn means that the total number of workers currently employed in Pennsylvania's fossil fuel-based sectors that will require re-employment will be 1,814 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 1,056 workers per year moving into voluntary retirement; and 2) Providing all the forms of re-employment support, including the re-employment guarantee, for the 1,814 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 Pennsylvania 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 2,000 per year. Given that there are nearly 64,000 people employed presently in Pennsylvania's fossil fuel-based industries, we acknowledge that it may appear implausible that there should be only about 2,000 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.

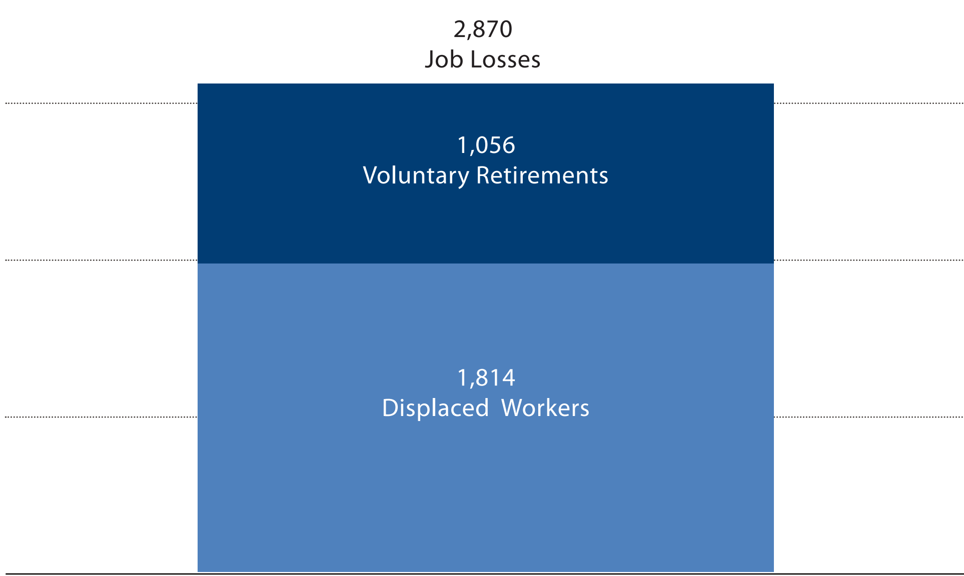
In Figure 2, we illustrate the main results of our calculations in Table 2.30.

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 Pennsylvania'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 through 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 Pennsylvania 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.[45]

FIGURE 2: Estimated Annual Job Losses, Voluntary Retirements, and Workers Displaced in Pennsylvania's Fossil Fuel Related Industries, 2021–2030



Source: See Table 2.30.

Guaranteed Re-employment

New employment opportunities will certainly open up in the expanding clean energy sectors, with approximately 107,000 new direct plus indirect jobs created per year in Pennsylvania through clean energy investments at the level of $23 billion per year (see Table 2.16).[46] 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 2,000 in total. It will not be difficult for the state to set aside 2,000 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 part of this study, an additional 60,000 direct and indirect jobs should be created through an additional $8.2 billion per year invested in manufacturing and public infrastructure investment in Pennsylvania, as well as agriculture and land restoration. Here again, the state could easily set aside approximately 2,000 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 2,000 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 Pennsylvania at present is about $94,000. This compares with the average compensation in the clean energy areas, ranging, as we saw in Table 2.17, between about $34,000 – $87,000 per year in the various specific sectors. The overall average compensation figure for the full set of clean energy jobs is roughly $70,000. 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., 1,814 workers per year. Row 2 then shows their average compensation level of $93,900. In row 3, we show the mean compensation level for all of Pennsylvania's clean energy sectors, as reported in Table 2.17, which is $69,600. From this difference in average compensation levels, we then calculate that the annual cost of compensation insurance for 1,814 workers will be about $132 million.

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

1. Number of fossil fuel-based displaced workers per year requiring re-employment	1,814
2. Average compensation for displaced workers	$93,900
3. Average compensation for clean energy sector jobs	$69,600
4. Average compensation difference between fossil fuel-based and clean energy jobs *(= row 2 – row 3)*	$24,300
5. Annual cost of compensation insurance for 1,814 workers *(= row 4 x row 1)*	$44.1 million
6. Total cost of compensation insurance for 3 years *(= row 5 x 3)*	$132.2 million

Source: See Tables 2.17, 2.27, and 2.30.

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 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 Pennsylvania is around $14,000.[47] 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 1,814 workers would be about $26 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 1,814 displaced workers per year will need relocation allowances, at an average of $75,000 per displaced worker.[48] That would bring the annual relocation budget to about $68 million for 907 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 1,814 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 1,814 displaced workers will receive support through the just transition program, including wage insurance, retraining and relocation support, as needed. As we can see in column 4, these full costs will amount to $137.7 million in 2021. Costs increase in 2022, since we now have two cohorts of displaced workers receiving

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

Year	Income support *(3 years of support for 1,814 workers)*	Retraining support *(2 years of support for 1,814 workers)*	Relocation support *(1 year of support for 907 workers)*	Total *(cols. 1+2+3)*
2021	$44.1 million (1 cohort)	$25.6 million (1 cohort)	$68.0 million	$137.7 million
2022	$88.2 million (2 cohorts)	$51.2 million (2 cohorts)	$68.0 million	$207.3 million
2023	$132.2 million (3 cohorts)	$51.2 million (2 cohorts)	$68.0 million	$251.4 million
2024	$132.2 million (3 cohorts)	$51.2 million (2 cohorts)	$68.0 million	$251.4 million
2025	$132.2 million (3 cohorts)	$51.2 million (2 cohorts)	$68.0 million	$251.4 million
2026	$132.2 million (3 cohorts)	$51.2 million (2 cohorts)	$68.0 million	$251.4 million
2027	$132.2 million (3 cohorts)	$51.2 million (2 cohorts)	$68.0 million	$251.4 million
2028	$132.2 million (3 cohorts)	$51.2 million (2 cohorts)	$68.0 million	$251.4 million
2029	$132.2 million (3 cohorts)	$51.2 million (2 cohorts)	$68.0 million	$251.4 million
2030	$132.2 million (3 cohorts)	$51.2 million (2 cohorts)	$68.0 million	$251.4 million
2031	$88.2 million (2 cohorts)	$25.6 million (1 cohort)		$113.7 million
2032	$44.1 million (1 cohort)			$44.1 million
Total	**$1.3 billion**	**$511.5 million**	**$680 million**	**$2.5 billion**
Average annual costs	**$110.2 million** *(12 years of support)*	**$46.5 million** *(11 years of support)*	**$68.0 million** *(10 years of support)*	**$209.5 million** *(12 years of support)*

Source: Tables 2.29 – 2..31.

income and retraining support, as well as one cohort receiving relocation support. Thus, total costs in 2022 rise to $207.3 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 $251.4 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 $113.7 million, then to $44.1 million.

In total, just transition benefits provided to 1,814 displaced workers per year in Pennsylvania will total to $2.5 billion, or an average of $209.5 million per year over 12 years, in total costs and about $115,000 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 Pennsylvania 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 Pennsylvania 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 Pennsylvania is relatively low, at about 64,000 jobs. This amounts to about 1 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 Pennsylvania 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

TABLE 2.33
Pennsylvania 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
Greene County	1,789	17.3%
Indiana County	1,216	5.0%
Sullivan County	47	4.0%
McKean County	446	3.5%
Armstrong County	443	3.2%
Somerset County	598	3.0%
Susquehanna County	198	2.7%
Warren County	342	2.7%
Tioga County	275	2.7%
Clearfield County	665	2.6%
Potter County	114	2.6%
Jefferson County	342	2.4%
Bradford County	433	2.2%
Washington County	1,714	2.1%

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

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 14 counties in Pennsylvania 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. Greene County will experience the most severe proportional employment losses, with 1,789 job losses, equal to 17.3 percent of total county employment. At present, oil and gas extraction operations is the largest employer in the county, so it follows that the county will be hard hit as these industries are phased down.

Indiana County will be the next most severely impacted by the state's fossil fuel industry contraction in terms of share of overall employment losses. Total job losses in Indiana County will total to 1,216 jobs, equal to 5.0 percent of the county's overall private sector job pool of about 24,000 jobs. In terms of absolute job losses, Washington County is the second most impacted, with 1,714 losses. But overall employment in Washington County is about 86,000. Proportionally, therefore, the losses in Washington County are more modest, at just above 2 percent.

Total job losses in these 14 counties will amount to 8,622 jobs, equal to 30 percent of the 28,702 overall jobs that will be lost in Pennsylvania between 2021 – 2030 through a 40 percent cut in the state's oil and gas industries and a 70 percent cut in coal. In other words, the other 70 percent of job losses will occur in counties in which these losses amount to less than 2 percent of overall countywide employment. As such, the broad picture that emerges from these figures is that, with a few exceptions, starting with Greene County, job losses in Pennsylvania 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 or fracking operation 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. Washington County experienced such a shutdown when Consol Energy closed its underground mining complex there in April 2020.

This overall result suggests that a community transition program for Pennsylvania should include two features. It should, first, focus on supporting the areas, such as Greene, Indiana, Washington, or Sullivan 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 Pennsylvania'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.[49]

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.[50] 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.[51] 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.[52] 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.[53] 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.[54] 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.[55] 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.[56]

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.[57] 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.[58]

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.[59] 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 pumpedstorage hydroelectric reservoir that acts like a giant battery. The capacity is enough to power more than 400,000 homes in North-Rhine Westphalia.[60] 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 Pennsylvania 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, as well as in manufacturing development, public infrastructure, land restoration and agriculture that we discuss below. As we will summarize in Part 4, our estimate is that, in combination, these investments will generate roughly 240,000 jobs in Pennsylvania.

2.11 Achieving a Zero Emissions Economy by 2050

If Pennsylvania is able to bring overall CO_2 emissions in the state down to approximately 120 million tons by 2030—a 50 percent decline relative to the 2018 level of 238 million tons—it should also be able to establish a zero emissions economy by 2050.

In fact, bringing Pennsylvania into 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 20 million tons of CO_2 emissions can be absorbed through afforestation and the expansion of organic agricultural practices within Pennsylvania 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 Pennsylvania 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.

Pennsylvania should be able to establish a zero-emissions energy infrastructure as of 2050 basically through continuing the clean energy investment project that would have proceeded 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 120 million tons by 2030 was about 2.5 percent of Pennsylvania's GDP per year between 2021 – 2030. Over 2031 – 2050, as we will see, we estimate that the average annual clean energy investment costs necessary to bring emissions down to zero to be about 1.6 percent of Pennsylvania's average GDP. The impact of the smaller investment project on job opportunities throughout the state is therefore likely to also be more modest than during 2021 – 2030, though still strongly in the positive direction.

We do not attempt to develop here a full assessment as to the technical requirements for achieving a zero emissions economy in Pennsylvania 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).[61]

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 Pennsylvania 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 Pennsylvania will have achieved major gains in energy efficiency between 2021 – 2030, specifically that the state's energy intensity ratio will have fallen from 4.9 to 3.2 Q-BTUs per $1 trillion of GDP—a 35 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 $181 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 Pennsylvania could become a zero emissions economy by 2050. We present these results in Tables 2.34 – 2.39.

In Table 2.34, we show Pennsylvania'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 $970 billion. This figure is itself a projection, of course, which we derived through assuming that Pennsylvania's GDP would grow at an average annual rate of 1.5 percent between 2018 – 2030, starting from the 2018 actual GDP level of $809 billion. Based on these assumptions, as we see in Table 2.34, Pennsylvania's GDP will be $1.3 trillion in 2050. We then calculate the midpoint GDP level between 2031 – 2050 under this scenario. As we see, this midpoint figure is $1.1 trillion.

In Table 2.35, we then estimate the investment costs necessary to bring Pennsylvania's energy intensity ratio down from the 2030 figure of 3.2 to 2.0 Q-BTUs of energy/$1 trillion in GDP. We had projected in Table 2.10 that Pennsylvania would be at the 3.2 intensity ratio by 2030 under the clean energy investment program we outlined for 2021 – 2030. Table

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

Projected 2030 GDP level *From Table 2.9*	$966.9 billion
Projected 2031 GDP level	$981.4 billion
Projected 2050 GDP level	$1.3 trillion
Midpoint GDP level for investment spending estimates *(= (2031 GDP + 2050 GDP)/2)*	$1.1 trillion

Source: See Table 2.9; authors' calculations.

TABLE 2.35
Energy Efficiency Investments Needed to Bring Pennsylvania Energy Intensity Ratio to 2.0 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*	$1.3 trillion
2) Total 2050 energy consumption at 3.2 energy intensity ratio *(=3.2 x $1.3 trillion)*	4.2 Q-BTUs
3) Total energy consumption at 2.0 energy intensity ratio *(=2.0 x $1.3 trillion)*	2.6 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: Table 2.34 and authors' projections.

2.35 shows that to arrive at a 2.0 energy intensity ratio by 2050 will require $56 billion in new energy efficiency investments between 2031 – 2050 under the 1.5 percent growth scenario. Considered on an annual basis, these total costs amount to an average of $2.8 billion 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 2.0 energy intensity ratio for 2050. This then entails that, in 2050, overall energy consumption in Pennsylvania will be at 2.6 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 0.92 Q-BTUs. This means that the net expansion of clean renewables by 2050 will need to be 1.68 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 $15.2 billion per year.

In Table 2.37, we then summarize these results for achieving zero emissions in Pennsylvania as of 2050. As we see, we estimate these overall costs to be $360 billion, which averages to $18.0 billion per year over 2031 – 2050. As a share of Pennsylvania's projected midpoint GDP over 2031 – 2050, these annual cost figures would amount to 1.6 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 Pennsylvania's CO_2 emissions down to 120 million tons by 2030. We estimated those costs to amount to about 2.5 percent of the state's average GDP between 2021 – 2030.

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

1) 2050 Energy consumption level with 2.0 energy intensity ratio *From Table 2.35*	2.6 Q-BTUs
2) Total clean renewable energy supply required *(= 100% clean energy supply)*	2.6 Q-BTUs
3) Clean renewable energy supply as of 2030 *From Table 2.11*	0.92 Q-BTUs
4) Renewable energy expansion needed by 2050 *(= rows 2-3)*	1.68 Q-BTUs
5) Midpoint cost per Q-BTU of expanding clean renewable supply *Assumes average costs decline at 1% per year relative to 2030*	$181 billion
6) Total costs of reaching 2.4 Q-BTUs in renewable supply *(= rows 4 x 5)*	$304 billion
7) Average annual costs over 20-year investment cycle *(= row 6/20)*	$15.2 billion

Sources: Tables 2.11 and 2.35 and authors' projections..

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

1) Total energy efficiency investment costs *From Table 2.35*	$56 billion
2) Total renewable energy investment costs *From Table 2.36*	$304 billion
3) Total clean energy investment costs *(= rows 1 + 2)*	$360 billion
4) Average annual costs per year for 20-year investment cycle *(= row 3/20)*	$18.0 billion
5) Average annual costs per year as percentage of midpoint GDP *(= row 4/Table 2.34 figure)*	1.6%

Sources: See Tables 2.34, 2.35, and 2.36.

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 Pennsylvania's CO_2 emissions 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 is 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 $22.6 billion per year would be about 162,000 jobs. This rounded figure of 162,000 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 79.6 percent. From this figure, we then generate an estimate of 118,000 jobs being created each year 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 2.26 and 2.30.

With the 2021 – 2030 analysis, we reported in Table 2.26 that a total of 63,518 workers were employed in Pennsylvania 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 28,702 of these jobs, equal to 45 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

TABLE 2.38
Average Annual Pennsylvania 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*	162,000 jobs
2) Approximate average annual investment spending 2031 – 2050 as pct. of 2021 – 2030 spending *From Tables 2.11 and 2.37*	79.6%
3) Average annual employment creation 2031 – 2050 with fixed productivity *(= row 1 x row 2)*	130,000 jobs
4) Average annual employment creation 2031 – 2050 with 1% labor productivity growth *(= row 3 x 0.91, midpoint productivity relative to 2030)*	118,000 jobs

Sources: See Tables 2.11, 2.16, and 2.37.

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

1) Projected number of workers employed in fossil fuel industries in 2030	34,816
2) Employment contraction, 2031 – 2050 (*100% contraction)*	34,816
3) Average employment contraction per year *(= row 2/20)*	1,741
4) Projected number of workers reaching retirement between 2031 – 2050 *(workers 45 years and over in 2031; assume 50%)*	17,408
5) Average annual attrition through voluntary retirement *(= row 4 x 80%/20)*	696
6) Average number of workers displaced annually, 2031 – 2050 *(= row 3 – row 5)*	1,045
7) Average annual costs of 100% just transition: compensation insurance, retraining and relocation support *(= row 6 x $115,000 per worker)*	$121 million
8) Average annual costs of just transition as share of average 2031 – 2050 GDP *(= row 7/$1.1 trillion)*	0.01%

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

employment levels. This result also implies that, as of 2030, 34,816 jobs will remain in these industries across Pennsylvania (63,518 – 28,702 = 34,816).

Starting from the goal that Pennsylvania is going to achieve zero emissions by 2050, this means that all 34,816 jobs will be phased out between 2031 – 2050. This amounts to 1,741 jobs lost 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 696 workers per year will voluntarily retire over this same period. This then means that an average of 1,045 workers per year in Pennsylvania'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 about $115,000 per worker. Thus, the average annual costs of just transition support for 1,045 Pennsylvania workers will be $121 million. As we note in row 8 of Table 2.39, this figure amounts to about 0.01 percent of Pennsylvania's average GDP between 2031 – 2050 of $1.1 trillion. In short, covering the full costs of just transition for all of Pennsylvania'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

Pennsylvania'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 Pennsylvania's current GDP level of $809 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 $4.1 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--$4.1 billion per year

1. Broadband development: $1.2 billion/year
2. Water/wastewater/inland waterways upgrades: $1.2 billion/year
3. Manufacturing R&D: $580 million/year
4. Bioplastics R&D: $580 million/year
5. Dams/Levees upgrades: $350 million/year
6. Repairing existing gas distribution pipelines: $230 million/year.

Land Restoration and Agriculture--$4.1 billion per year

1. Regenerative agriculture: $1.7 billion/year
2. Farmland conservation: $1.2 billion/year
3. Plugging orphaned oil and gas wells: $600 million/year
4. Land restoration: $600 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 2018 assessment of the American Society of Civil Engineers as to the conditions of Pennsylvania'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.[62]

In the area of "Creating Millions of Good, Safe Jobs with Access to Unions," the THRIVE Agenda includes the following as priorities[63]:

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 Pennsylvania's public infrastructure. In 2018, the ASCE provided a detailed study, *Report Card for Pennsylvania's Infrastructure, 2018.*[64] Their assessment is that Pennsylvania's infrastructure deserves an overall grade of C-. The ASCE summarized its findings as follows:

> The 2018 Report Card for Pennsylvania's Infrastructure gives the Commonwealth an overall grade of C-, which reflects that Pennsylvania has some of the oldest infrastructure in the country, and improvements continue to be needed. Unfortunately, the 2018 overall grade of a C- reflects the same letter grade as the 2014 Report Card for Pennsylvania's Infrastructure, indicating that while some aspects of our state's infrastructure have improved, others have degraded. Much of Pennsylvania's infrastructure continues to serve well beyond its intended lifespan and has deteriorated (2018, p. 4).

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[65]:

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 2.1 direct plus indirect jobs per $1 million in expenditure for repairing gas distribution pipelines to 9.3 direct and indirect jobs for upgrading the state's dams and levees. Adding induced jobs brings the range to 4.6 per $1 million for broadband to 12.9 for dams/levees.

Based on these proportions, we see in Table 3.2 the levels of job creation in Pennsylvania generated by spending an average of $4.1 billion per year between 2021 – 2030 in these areas of manufacturing and public infrastructure investments at the levels we have assigned

TABLE 3.1
Job Creation in Pennsylvania 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	1.6	1.2	2.8	1.8	4.6
Water/wastewater/inland waterways	5.2	1.7	6.9	2.8	9.7
Manufacturing R&D	3.2	2.3	5.5	3.1	8.6
Bioplastics R&D	3.2	2.3	5.5	3.1	8.6
Dams/levees	7.4	1.9	9.3	3.6	12.9
Gas distribution pipelines—repairing leaks	0.8	1.3	2.1	3.5	5.6

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

TABLE 3.2
Manufacturing and Public Infrastructure Investments for Pennsylvania, 2021 – 2030
Overall Program at $4.1 billion per year
0.5 percent of 2019 Pennsylvania GDP (= $809 billion)

	Budget	Direct jobs	Indirect jobs	Direct+ indirect jobs	Induced jobs	Direct, indirect+ induced jobs
Broadband	$1.2 billion	1,920	1,440	3,360	2,160	5,520
Water/wastewater/ inland waterways	$1.2 billion	6,240	2,040	8,280	3,360	11,640
Manufacturing R&D	$580 million	1,856	1,334	3,190	1,798	4,988
Bioplastics R&D	$580 million	1,856	1,334	3,190	1,798	4,988
Dams/levees	$350 million	2,590	665	3,255	1,260	4,515
Gas distribution pipe-lines—repairing leaks	$230 million	184	299	483	805	1,288
TOTALS	**$4.1 billion**	14,646	7,112	21,758	11,181	32,939

Source: Table 3.1.

to each area: $1.2 billion each for broadband and water infrastructure; $580 million each for R&D both for manufacturing in general and bioplastics specifically; $350 million for dams/ levees and $230 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 Pennsylvania by these investments will be roughly 22,000 direct plus indirect jobs and just under 33,000 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 2.2 per $1 million in expenditure for plugging orphaned wells, 8.0 for land restoration, 9.0 for farmland conservation, and 11.5 for regenerative agriculture. Adding induced jobs brings the range to 5.8 per $1 million for plugging orphaned wells to 13.8 for regenerative agriculture.

Based on these proportions, we see in Table 3.4 the levels of job creation in Pennsylvania generated by spending an average of $4.1 billion per year between 2021 – 2030 in these areas of land restoration and agriculture at the levels we have assigned to each area: $1.7 billion for regenerative agriculture; $1.2 billion for farmland conservation; and $600 million each for plugging orphaned wells and general land restoration.

TABLE 3.3
Job Creation in Pennsylvania 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	9.3	2.2	11.5	2.3	13.8
Farmland conservation	7.2	1.8	9.0	3.4	12.4
Plugging orphaned oil and gas wells	0.9	1.3	2.2	3.6	5.8
Land restoration	6.4	1.6	8.0	3.2	11.2

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

TABLE 3.4
Land Restoration and Agriculture Investment Program for Pennsylvania, 2021 – 2030
Overall Program at $4.1 billion per year
0.5 percent of 2019 Pennsylvania GDP (= $809 billion)

	Budget	Direct jobs	Indirect jobs	Direct+ indirect jobs	induced Jobs	Direct, indirect+ Induced jobs
Regenerative agriculture	$1.7 billion	15,810	3,740	19,550	3,910	23,460
Farmland conservation	$1.2 billion	8,640	2,160	10,800	4,080	14,880
Plugging orphaned oil and gas wells	$600 million	540	780	1,320	2,160	3,480
Land restoration	$600 million	3,840	960	4,800	1,920	6,720
TOTALS	**$4.1 billion**	28,830	7,640	36,470	12,070	48,540

Source: Table 3.3.

Following from these budgetary assumptions, we see that total direct plus indirect job creation generated in Pennsylvania by these investments will be 36,470 jobs and 48,540 jobs total if we include induced jobs.

Table 3.5 summarizes our employment creation estimates for the full range of investments in the areas of manufacturing/infrastructure and land restoration/agriculture. As we see, direct and indirect jobs totals to over 58,000, equal to 0.9 percent of Pennsylvania's 2019 workforce; and when induced jobs are included, the total comes to roughly 81,500 jobs, equal to 1.3 percent of the 2019 Pennsylvania workforce.

TABLE 3.5
Annual Job Creation in Pennsylvania through Combined Manufacturing/ Infrastructure and Land Restoration/Agriculture Investment Programs
Average annual figures for 2021 – 2030

Industry	Number of direct and indirect jobs created	Number of direct, indirect and induced jobs created
$4.1 billion in manufacturing development and public infrastructure		
1) Broadband	3,360	5,520
2) Water/wastewater/inland waterways	8,280	11,640
3) Manufacturing R&D	3,190	4,988
4) Bioplastics R&D	3,190	4,988
5) Dams/levees	3,255	4,515
6) Gas distribution pipelines-repairing leaks	483	1,288
7) Total job creation from manufacturing development and public infrastructure *(= rows 1 – 6)*	21,758	32,939
$4.1 billion in land restoration and agriculture		
8) Regenerative agriculture	19,550	23,460
9) Farmland conservation	10,800	14,880
10) Plugging orphaned oil and gas wells	1,320	3,480
11) Land restoration	4,800	6,720
12) Total job creation from land restoration/ agriculture *(= rows 8 – 11)*	36,470	48,540
13) Total for all investment areas *(= rows 7 + 12)*	58,228	81,479
13) TOTAL AS SHARE OF 2019 PENNSYLVANIA LABOR FORCE *(Labor force at 6.2 million)*	**0.9%**	**1.3%**

Sources: See Tables 3.2 and 3.4.

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

TABLE 3.6
Indicators of Job Quality in Pennsylvania's Manufacturing/Infrastructure and Land Restoration/Agriculture Investments
Direct Jobs Only

	Manufacturing Develpment and Public Infrastructure					
	1. Broad-band (1,920 workers)	2. Water/ wastewater (6,240 workers)	3. Manufac-turing R&D (1,856 workers)	4. Bio-plastic R&D (1,856 workers)	5. Dams/ levees (2,590 workers)	6. Gas pipe-line repairs (184 workers)
Average total compensation	$98,200	$69,100	$114,800	$114,800	$69,900	$131,000*
Health insurance coverage, percentage	51.4%	50.1%	70.0%	70.0%	51.4%	72.7%**
Retirement plans, percentage	40.1%	42.6%	52.7%	52.7%	41.1%	71.5%**
Union membership, percentage	20.3%	20.7%	1.3%	1.3%	18.1%	33.4%

	Land Restoration/Agriculture Investments			
	7. Regen-erative ag. (15,810 workers)	8. Farmland conserv. (8,640 workers)	9. Plug orphaned wells (540 workers)	10. Land restoration (3,840 workers)
Average total compensation	$17,800	$57,300	$113,700*	$68,200
Health insurance coverage, percentage	25.9%	50.7%**	69.8%**	48.2%
Retirement plans, percentage	14.4%	39.5%**	60.9%**	35.6%
Union membership, percentage	4.0%	3.5%	23.8%	6.9%

Notes:
*This total compensation figure excludes proprietors in the pipeline transportation sector because the compensation associated with such employment is an extreme outlier, with an average income of $192 million. Such employment comprises less than 0.3 percent of each sector's employment (i.e., gas pipeline repairs and plugging orphaned wells).
**Due to small sample sizes, the figures for the sectors "Gas Pipeline Repairs," "Farmland Conservation," and "Plug Orphaned Wells" are estimated from the Middle Atlantic Division region (New Jersey, New York, and Pennsylvania) rather than the state of Pennsylvania alone.

Sources: See Appendix 2.

Starting with compensation figures, we see that the averages for manufacturing/infrastructure range widely. At the lower end are the jobs in water/wastewater and dams/levees, which pay between about $70,000 on average. At the high end are the manufacturing and bioplastics R&D jobs that pay about $115,000 and higher still are the small number of jobs repairing gas pipelines that pay about $130,000 on average. In between are the jobs in broadband, paying a bit less than $100,000.

Average compensation also ranges widely in the areas of land restoration/agriculture. The figure for regenerative agriculture is extremely low, at $17,800, while, by contrast, plugging orphan wells pays an average of $113,700. In between are farmland conservation, at $57,300 and land restoration, at $68,200.

Overall, half of the 10 sectors shown in Table 3.6 compensate workers at a level comparable to or better than the workers employed in Pennsylvania's fossil fuel sectors, who earn, on average, about $94,000. The other half of the sectors are paying well below the fossil fuel sector standard.

The figures for workers receiving health insurance from their employers also vary widely. About 70 percent of the workers employed in manufacturing and bioplastics R&D, pipeline repairs and plugging orphan wells receive employer-based coverage. With regenerative agriculture, only 26 percent of workers are covered with employer-based health care. About half the workers employed in the remaining sectors—broadband, water/wastewater, dams/levees, farmland conservation and land restoration—are covered with employer-based health care.

The range of coverage is also wide with respect to private retirement plans. The low-end figure is with regenerative agriculture, in which only 14 percent of the nearly 16,000 workers are provided with an employer-based pension. The high-end figure is 72 percent for the workers repairing gas pipelines, though this benefit is received, at present, by only 132 workers in this sector. Sixty-one percent of the workers employed plugging orphaned wells receive private pensions, but again, this applies to a small number of 540 workers at present. With the remaining 7 sectors, between 36 – 53 percent of the workers are covered with private pensions.

Unionization rates vary still more widely by the various specific activities. With manufacturing and bioplastics R&D, only about 1 percent of workers are union members. With regenerative agriculture, farmland conservation and land restoration, about 4 – 7 percent of workers are unionized—figures that are low, but basically in line with the 6.2 percent average for the overall U.S. private sector. But in the areas of gas pipeline repairs, water management, dams/levees, broadband, and plugging orphaned wells, unionization rates are significantly higher, ranging between 18 – 33 percent.

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

Implementing a $15 minimum wage standard for these jobs would also be important. Of the direct jobs created by manufacturing/infrastructure spending, 13 percent pay less than $15.00 per hour. The figure for agriculture/land restoration investments is significantly higher: over one-third—34 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 1 percent increase in investment spending.

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 Pennsylvania as well as the race and gender composition of these workers.

TABLE 3.7

Educational Credentials and Race/Gender Composition of Workers in Pennsylvania's Manufacturing/Infrastructure and Land Restoration/Agriculture Investments

Direct Jobs Only

	Manufacturing Development and Public Infrastructure Investments					
	1. Broad-band (1,920 workers)	2. Water/ wastewater (6,240 workers)	3. Manufac-turing R&D (1,856 workers)	4. Bio-plastic R&D (1,856 workers)	5. Dams/ levees (2,590 workers)	6. Gas pipe-line repairs (184 workers)
Share with high school degree or less	54.7%	55.3%	8.8%	8.8%	53.1%	26.2%
Share with some college or Associate degree	23.6%	22.0%	13.1%	13.1%	22.7%	29.5%
Share with Bachelor's degree or higher	21.7%	22.6%	78.1%	78.1%	24.2%	44.3%
Racial and gender composition of workforce						
Pct. non-white	14.7%	16.0%	19.2%	19.2%	14.8%	4.5%
Pct. female	13.2%	14.7%	56.4%	56.4%	14.4%	21.7%

	Land Restoration/Agriculture Investments			
	7. Regen-erative ag. (15,810 workers)	8. Farmland conserv. (8,640 workers)	9. Plug orphaned wells (540 workers)	10. Land restoration (3,840 workers)
Share with high school degree or less	66.0%	20.8%	38.3%	40.1%
Share with some college or Associate degree	18.0%	27.0%	26.0%	19.9%
Share with Bachelor's degree or higher	16.0%	52.2%	35.6%	40.0%
Racial and gender composition of workforce				
Pct. non-white	13.0%	15.7%	5.9%	18.2%
Pct. female	32.9%	64.0%	19.1%	31.0%

Sources: See Appendix 2.

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 close to 80 percent of workers holding Bachelor's degrees or higher. By contrast, with most of the other activities, 38 percent or more 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.

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 more than half of all jobs are held by women and 19 percent are held by people of color. These figures roughly reflect the composition of Pennsylvania's population as a whole. The representation of women is also high, at 64 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 22 percent. Outside of the two R&D activities, the share of jobs held by people of color ranges between 4 and 18 percent. Across-the-board, these figures are below the non-white share of Pennsylvania's population overall, at 22 percent. Thus, as is the case with Pennsylvania'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.

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 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 Pennsylvania that will have been displaced by the contraction of the state's fossil fuel industry activities.

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

Job category	Percentage of direct jobs created	Representative occupations
Construction	27.7%	First-line supervisors; pipelayers; electricians
Management	19.3%	Sales managers; financial managers; chief executives
Life, physical and social science	8.4%	Biological scientists; physical scientists; life science technicians
Office and administrative support	8.0%	Information clerks; customer service representatives; administrative assistants
Production	7.8%	Welding workers; inspectors; wastewater plant treatment operators
Transportation and material moving	5.2%	Recyclable material collectors; industrial truck operators; freight movers
Installation and maintenance	5.0%	Telecommunications line installers; telecommunications equipment repairers; heating mechanics

Source: See Appendix 2.

TABLE 3.9
Agriculture and Land Restoration: Prevalent Job Types in Pennsylvania Industry
(Job categories with 5 percent or more employment)

Job category	Percentage of direct jobs created	Representative occupations
Management	31.8%	Construction managers; chief executives; farmers
Farming, fishing, and forestry	16.5%	Agricultural inspectors; conservation workers; agricultural workers
Office and administrative support	7.9%	Office clerks; customer service representatives; auditing clerks
Education	5.5%	Postsecondary teachers; teacher assistants; library workers
Personal care and services	5.1%	Ticket takers; tour guides; nonfarm animal caretakers
Transportation	5.0%	Tractor operators; recyclable material collectors; packers

Source: See Appendix 2.

PART 4:

TOTAL JOB CREATION IN PENNSYLVANIA 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:

1. Investments in energy efficiency and clean renewable energy, targeted at bringing down CO_2 emissions in Pennsylvania by 50 percent as of 2030.
2. 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.
3. 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 $30.8 billion per year over 2021 – 2030, equal to about 3.4 percent of Pennsylvania's projected average GDP for 2021 – 2030. The proposed budget allocations include $22.6 billion per year for clean energy, including $16.8 billion in clean renewable energy and $5.8 billion in energy efficiency. This is the figure that we have estimated will be needed to achieve a 50 percent reduction in Pennsylvania's CO_2 emissions by 2030. We have also budgeted $4.1 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 about 165,000 direct and indirect jobs per year in Pennsylvania, amounting to about 2.7 percent of Pennsylvania's labor force as of 2019. When we include induced job creation (i.e., "multiplier effects"), total job creation rises to 243,000 jobs, equal to about 3.9 percent of Pennsylvania's 2019 labor force.

As a simple exercise to illustrate the potential impact of this level of job creation in Pennsylvania, 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 Pennsylvania'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.

TABLE 4.1

Annual Job Creation in Pennsylvania through Combined Investment Programs

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

Estimates are annual averages for 2021 – 2030

Overall Investments at $30.8 billion/year; 3.4% of Pennsylvania mid-point GDP

	Number of direct and indirect jobs created	Number of direct, indirect and induced jobs created
1) $16.8 billion/year in clean renewable energy	70,210	111,236
2) $5.8 billion/year in energy efficiency	36,452	50,465
3) $4.1 billion/year in manufacturing/public infrastructure	21,758	32,939
4) $4.1 billion/year in land restoration/agriculture	36,470	48,540
5) Total for all investment areas *(= rows 1 - 4)*	164,890	243,180
13) TOTAL AS SHARE OF 2019 PENNSYLVANIA LABOR FORCE *(labor force at 6.2 million)*	**2.7%**	**3.9%**

Sources: See Tables 2.16 and 3.5.

PART 5:
FINANCING A FAIR AND SUSTAINABLE RECOVERY

As we discussed in Part 1, as of this writing, Pennsylvania is experiencing an "uncontrolled spread" of COVID-19, with infection rates at their highest level since the onset of the pandemic in March. This situation has forced Governor Wolf and the state's public health officials to establish a new round of restrictions on economic activity in the state. As such, it is not likely that the state's economy will begin moving onto a strong recovery path from the recession during the first three months of 2021, and perhaps longer. This is because the state's economy is unlikely to begin a strong recovery from the pandemic-induced recession until most of the state's population has been vaccinated. According to Rachel Levine, Pennsylvania's Secretary of Health, this is not likely to occur until late Spring 2021.

As a result of these circumstances, the state and municipal-level governments in Pennsylvania, along with their equivalents throughout the country, face the real possibility of major revenue shortfalls over the coming year. In this part of the study, we examine the current fiscal prospects for the state and consider financing measures to both counteract the likely short-term revenue gaps and to enable the state to move onto a long-term sustainable growth path.

For the 2020 fiscal year that ended in June 2020, the state's tax revenue fell short by around $3.2 billion. This represented a budget gap of about 9 percent relative to the $34 billion 2020 fiscal year budget.[66] A revenue shortfall of this magnitude follows from the figures we reviewed in Part 1 on the employment contraction in the state since March. More than 70 percent of the state's tax revenue comes from income and sales taxes alone.[67] Any sharp increase in unemployment will generate corresponding declines in incomes and spending. In turn, the income and spending declines will depress income and sales tax revenues.

In May, the state senate passed a $25.8 billion temporary general fund spending plan for fiscal year 2021. This stopgap measure provides full funding for public education at all levels for the full 2021 fiscal year. It also funded most other state agencies for the five months through Nov. 30. In addition, it enabled the state to cover its debt servicing obligations and its contributions to the pension plans for state employees at their full actuarially-determined levels.[68]

In November, Gov. Wolf signed a $35.5 billion budget to fund the remaining months of the fiscal year, amounting to a 4 percent spending increase compared to fiscal year 2020.[69] The new budget includes $2 billion in federal funds for enhanced medical and social service program payments and $531 million in transfers from special state funds. It also includes $1.3 billion in remaining funds that Pennsylvania received from the federal government in March through the Coronavirus Aid, Relief, and Economic Security (CARES) Act—the federal stimulus program enacted in Congress and signed by President Trump in March 2020. These CARES Act funds will be used to fund state government payrolls. We discuss the support Pennsylvania received from the CARES Act in more detail below.[70]

Overall then, the state government's primary response thus far to the pandemic and economic collapse has been to prevent major spending cuts. But Governor Wolf has indicated that this may not be possible for another fiscal year, given the current COVID resurgence, and the resulting likelihood that the state economy will not move onto a strong recovery path at least for the first three months of 2021.[71] The state's official forecast as of May 2020 was for a budget shortfall of up to $5 billion in its general fund on a combined basis for fiscal years 2020 and 2021. This amounts to about 7.1 percent of combined general fund expenditures for these two fiscal years.[72]

The situation becomes still more serious when we incorporate the prospects for major revenue shortfalls at the level of Pennsylvania's municipal governments as well. A 6/29/20 study by the Federal Reserve Bank of Cleveland found that, in fiscal year 2020, local governments in Pennsylvania lost $1.4 billion in revenues, amounting to 3.1 percent of the total revenue from the municipal-level sources of funds. They also risk losing up to another $2.7 billion, 6.1 percent of total revenue, in fiscal year 2021, if, as now seems inevitable, the economy is not recovering during the current and coming months.[73]

More generally, a May 2020 report by the National Association of Counties expects counties nationwide to face a 21 percent budgetary shortfall over fiscal year 2021, resulting from both lost revenues from income and sales taxes, as well as reduced charges and fees, along with increased expenses resulting from the pandemic.[74] The federal CARES Act in March did provide Pennsylvania's state and local governments with $5 billion in support. However, the state and local governments could use these funds only to cover costs related to COVID-19. They could not be used to cover basic services, and therefore provide no assistance with general funding shortfalls.

Considering these prospects for Pennsylvania, it is imperative that the public entities at all levels undertake serious consideration of some non-conventional 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 federal government. Recognizing the range of possibilities around all of these options will be the most effective approach toward preventing the worst-case scenario for Pennsylvania 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 Pennsylvania's economy in Table 5.1, dividing the total CARES funding received by Pennsylvania into three categories: assistance to public entities, private businesses and individuals respectively.

Considering first the support for public entities, we see in Table 5.1 that general relief funding authorized to the Pennsylvania state government was $3.9 billion, equal to about 0.5 percent of the state's 2019 GDP.[75] In addition, $1.0 billion was available for eligible local governments.[76] An additional estimated $5.4 billion was authorized for specific beneficiaries by their function, such as transport authorities or local government housing programs.[77] Total support for public entities thus amounted to $10.4 billion, equal to 1.3 percent of Pennsylvania's 2019 GDP.

In terms of support for Pennsylvania's businesses, the main source of support was provided through the Paycheck Protection Program, which disbursed $20.7 billion through 8/08/20.[78] Pennsylvania received an additional $5.0 billion in Economic Injury Disaster Loans through 8/24/20.[79] The total level of business support was therefore $25.7 billion, equal to 3.2 percent of state GDP by end of August.

Support for individuals through the CARES Act through supplemental unemployment insurance, the separate cash assistance fund, and the Lost Wages Assistance Program, was an estimated $34.1 billion through 10/17/20, another 4.2 percent of Pennsylvania GDP.[80]

TABLE 5.1
Federal COVID-19 Related Funding to Pennsylvania

Industry	Funding level	Funding as share of Pennsylvania 2019 GDP
Assistance to Public Entities		
Coronavirus Relief Fund to state government	$3.9 billion	0.5%
Funding to local government	$1.0 billion	0.1%
Funding to other public entities*	$5.4 billion	0.7%
Total assistance to public entities	**$10.4 billion**	**1.3%**
Assistance to Businesses		
Paycheck Protection Program (through 8/8/20)	$20.7 billion	2.5%
Economic Injury Disaster Loans (through 8/24/20)	$5.0 billion	0.6%
Total assistance to businesses	**$25.7 billion**	**3.2%**
Assistance to Individuals		
Supplemental unemployment insurance for all standard employees (through 10/17/20) **	$18.6 billion	2.3%
Supplemental unemployment insurance for freelancers, self-employed and gig workers (through 10/17/20)	$4.5 billion	0.6%
Cash assistance (as of 6/28/20)	$11.0 billion	1.4%
Total assistance to individuals	**$34.1 billion**	**4.2%**
TOTAL ASSISTANCE	**$70.2 billion**	**8.6%**

Source: Noted in text.
Parts may not always sum 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 through the week of 9/5/20.

Overall then, the federal government's total level of support for Pennsylvania beginning in March, via the CARES Act and related measures, totaled to $70.2 billion. This amounted to 3.5 percent of the total amount of funds allocated and 8.6 percent of Pennsylvania's 2019 GDP.[81]

As a follow up to the CARES Act, in May 2020, the U.S. House of Representatives passed a second stimulus program, the HEROES Act. The HEROES Act was budgeted at an even higher overall spending figure, at $3 trillion. But this measured was opposed by the then Republican-controlled Senate and then President Trump, and never passed into law. However, on December 21, the Congress and President Trump did agree to pass the 2020 COVID Relief bill. This is a $900 billion package overall. The main areas funded in this bill include:[82]

- $325 billion for small business grants and loans;
- $166 billion for direct payments at $600 per eligible person;

- $120 billion for supplemental unemployment insurance, at $300 per week per eligible worker;
- $82 billion for schools;
- $69 billion for vaccine development and distribution.

To date, the precise allocation of funds by state remains uncertain. But if Pennsylvania were to again receive 3.5 percent of the total budgetary allocation, as with the CARES Act, that would amount to $31.5 billion in funds for the state in the coming months. This would equal 3.7 percent of Pennsylvania's projected GDP for 2021.

In its initial days in office, the Biden Administration has proposed an additional $1.9 trillion short-term stimulus package. It is also planning to advance a further large-scale program focused on long-term measures to "build back better" from the COVID-induced recession. The main components of Biden's $1.9 trillion short-term measure include the following[83]:

- $465 billion in direct payments to individuals up to $1,400 each;
- $350 billion in aid to state and local governments;
- $350 billion for supplemental unemployment insurance benefits of $400 per week;
- $170 billion for reopening schools and universities;
- $160 billion for COVID-19 vaccination, testing and tracing;
- $120 billion for child tax credit expansion.

This Biden proposal aligns with the main features of the CARES Act, with the exception of funding for small businesses. However, as noted above, the December stimulus package does already include $325 billion for small business support. Biden's longer-term proposal is also likely to include further support for small businesses through both grants and loans.

If Pennsylvania were to receive the same 3.5 percent of the total $1.9 trillion initial stimulus program under Biden, that would amount to $67 billion, equal to 7.9 percent of projected 2021 GDP. This level of additional funding support should be sufficient for Pennsylvania's economy to transition onto a viable recovery path, as we discuss further below.

State-Level Funding Prospects

As of this writing in mid-January 2021, it remains unclear as to how much funding Pennsylvania will be receiving from the from federal stimulus programs, including the 2020 COVID Relief measure as well further measures, such as those proposed by the Biden Administration. Given this ongoing uncertainty, Pennsylvania also 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.[84] Such capital projects could, for example, be in the areas of traditional infrastructure such as roads or school buildings. Capital projects could also include public-sector led clean energy investments to, for example, raise energy efficiency standards in public buildings through retrofitting projects. Financing of such capital projects is only limited by the constitutional debt limit whereby capital project debt cannot exceed 1.75 times the annual tax base of the state. In February 2019, the state had used up only $11 billion of $69 billion available for borrowing under this provision, amounting to only 16 percent of the state's available borrowing capacity. As such, substantial capacity remains under this provision for the state to increase its borrowing to support vital investment projects.[85] Beyond this, the state can also increase its borrowing further, for any purpose, if such a measure is approved through a voter referendum.

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.[86] 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.[87] Under this program, the state government and municipalities in Pennsylvania are able to sell up to $12.6 billion in bonds to the Fed.[88] 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 recession, Pennsylvania'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.

What Are Pennsylvania's Funding Needs?

As we have discussed, there is a great deal of uncertainty regarding the trajectory of the Pennsylvania economy over the next year. This is equally true, more generally, for the U.S. and global economies. It is therefore not possible to know what funding amounts would be sufficient to move Pennsylvania 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 longer-term investment projects in health and education, clean energy, public infrastructure, manufacturing, 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 in this study. 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 at bolstering small businesses. But 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.[89]

Thus, starting with the 3-month time period, Table 5.2 first includes $11 billion in one-time cash assistance, at the level provided in March under the CARES Act. It then proposes $5 billion in supplemental unemployment insurance. This figure is equivalent to the level of unemployment insurance support Pennsylvania received from the CARES Act through 10/17/20, as reported in Table 5.1, scaled to a shorter three-month period, January – March 2021. It also assumes that a lower number of workers claim unemployment insurance over this three-month period.[90]

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 Pennsylvania Public Health, Short-Term Stimulus, and Long-Term Investment and Recovery Programs

	Budget level	Time frame for spending
State Government Support		
Cash assistance	$11.0 billion	3 months—reassess in March
Supplemental unemployment insurance	$5.0 billion	3 months—reassess in March
Medicare crisis health insurance	$1.5 billion	3 months—reassess in March
Supplemental public health/safety interventions	$4.2 billion	1 year
Clean energy investments—public funds	$2.1 billion	1 year
Manufacturing, infrastructure, land restoration, and agriculture	$8.2	1 year
Total state-level support	**$32.0**	**Combined 3 months and 1 year**
Municipal Government Support	**$2.7 billion**	**1 year**
TOTAL STATE PLUS MUNICIPAL GOVERNMENT SUPPORT	**$34.7 billion**	**Combined 3 months and one year**
TOTAL SUPPORT AS SHARE OF PENNSYLVANIA PROJECTED 2021 GDP *(= $845 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 was $106 billion, assuming that, on average during the first three months of the COVID crisis, 30 million people would have been receiving unemployment benefits throughout the U.S.[91] The corresponding Pennsylvania figure for residents receiving unemployment insurance would be about 400,000 people, based on the figures for initial and continued unemployment claims at the end of 2020.[92]

Moving into the longer-term budgetary allocations listed in Table 5.2, the $4.2 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 $42 billion included in the proposed 2021 fiscal year's budget from February. We roughly estimate this as being the amount of additional financial support necessary in Pennsylvania over the next year to provide adequate public health interventions to control the spread of the virus as well as to successfully administer the vaccine throughout the state over the coming months.

These public health investments will also generate major increases in employment for health care workers. As we saw in Table 1.2, employment in Pennsylvania's health care and education service sector declined by 5.4 percent in September/October 2020 relative to 2019. This is at precisely the time at which the state was focused intensively on controlling the spread and mitigating the impact of COVID-19. Jobs in public health need to be restored and expanded in Pennsylvania to sustain a safe reopening of the economy.

The $8.2 billion for investments in public infrastructure, manufacturing, land restoration and agriculture, and $2.1 billion in public funding for clean energy investments are the amounts that we derived in the discussions on these respective programs, in Parts 2 and 3 above. Note that from our Part 2 discussion, we assumed that $2.1 billion in public funds for clean energy investments will be matched by about $19 billion in private funding.

Finally, Table 5.2 includes $2.7 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 Pennsylvania in the areas of public health, unemployment insurance, cash assistance, public infrastructure and clean energy as being $34.7 billion. This is equal to about 4.1 percent of what we have projected will be Pennsylvania's GDP in 2021. The figure would of course be higher still if it included assistance to businesses in the state. If businesses in Pennsylvania were to receive further support through the Paycheck Protection Program or an alternative at the 2.5 percent of state GDP figure provided through the CARES Act, the total for a new round of funding would rise to about $56 billion, or 6.6 percent of GDP. This level of support, including now for business assistance, would still be below the overall funding level provided through the CARES Act, which, as we saw in Table 5.1, provided about $70 billion to Pennsylvania through its various channels, equal to about 8.6 percent of state GDP.

Where to Find the Funds?

As discussed above, if Pennsylvania were to receive 3.5 percent of the $900 billion in funds coming from the 2020 COVID Relief Act, that would total to $31.5 billion. That would also cover more than 90 percent of the total $34.7 billion budget we have proposed for the combined spending levels on cash assistance, supplemental unemployment insurance, Medicare Crisis insurance over the next three months, as well as supplemental public spending over the next year on public health, clean energy, manufacturing, infrastructure, land restoration, agriculture, and municipal government support. If the Biden short-term stimulus measures were to become law more or less as they have been proposed, that would likely provide, as noted above, an additional roughly $67 billion for the state. The specific areas of funding support in both the 2020 COVID Relief Act and the Biden short-term stimulus proposal do not include spending on clean energy, infrastructure, land restoration and agriculture. But these areas are likely to be included as major components of the second Biden program, focused on long-term recovery measures.

In the event that any funding deficiencies should result relative to our proposals in the areas of clean energy, infrastructure, manufacturing, land restoration and agriculture, we should recognize that financial asset purchases by the Federal Reserve to support financial markets have totaled to more than $2.5 trillion since the onset of the COVID crisis, i.e., more than 11 percent of U.S. GDP.[93] These interventions operate through bond purchases from both private and public entities, including state and municipal governments.

Overall then, more than sufficient support should be available to finance a robust second and third round of stimulus injections into the Pennsylvania economy, beginning in February 2021. This support for Pennsylvania from the federal stimulus programs could then be supplemented, as needed, through Federal Reserve purchases of state and municipal bonds from Pennsylvania at highly concessionary interest rates. At present, bonds issued by the state and municipalities in Pennsylvania are being sold at mostly very low yields. For example, the yields for the bonds sold on 1/13/21 ranged between 0.5 and 1.5 percent.[94] These rates could also fall still further—i.e., to near-zero—and remain at this level to the extent that the Federal Reserve engages in an active program to purchase Pennsylvania's public sector bonds. With Pennsylvania's state and municipal governments having the capacity 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 be needed to move the Pennsylvania economy onto a strong recovery path.

Appendix 1
Employment Estimating Methodology

The employment estimates for Pennsylvania 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 Pennsylvania 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.[95] 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 Pennsylvania, 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/ hybrid vehicles	30% automobile manufacturing, 20% light truck manufacturing, 12.5% storage battery manufacturing, 5% motor vehicle electrical and electronic, 10% other motor vehicle part, 2% motor vehicle stamping, 8% motor vechicle body, 12.5% motor vehicle gasoline engine and engine parts.
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)	7.0	5.0
Solar PV	8.6	6.0
Geothermal	11.7	10.0
Small-scale hydro	12.9	11.1

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 March CPS 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.[96]

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:

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

where S is a scalar equal to the number of direct jobs produced overall by the level of investment being considered. For example, say Pennsylvania'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 a Pennsylvania-only analysis, despite pooling five years of data (2015 – 2019). As a result, we estimated these job features using data from the entire Middle Atlantic region. This region includes Pennsylvania, as well as, New York and New Jersey.

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 Pennsylvania 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
- proprietors employment which includes self-employed workers in unincorporated businesses.

The BEA's concept of employment is more expansive than what it typically used by the U.S. Labor Department's Bureau of Labor Statistics (BLS). Well-known BLS employer-based data on employment, such as from the Quarterly Census of Employment and Wages (QCEW), for example, do not include the unincorporated self-employed. The BLS' CPS data, on the other hand, does include the unincorporated self-employed. However, the CPS data on employment are based on household surveys and only counts the employment of the unincorporated self-employed if their self-employment is their primary job. Moreover, each person can only represent one job. The BEA's concept of proprietor's employment allows for the unincorporated self-employed to represent multiple units of employment. For example, if an individual has various different businesses operating during the year, each business would count as a unit of employment. To ensure that we use a consistent measure of employment effects in terms of both job *creation* from clean energy 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 Our basic measures of CO_2 emissions throughout this study are units of metric tons. However, to simplify, for the most part we refer hereafter to this unit as "tons" of CO_2 emissions.

2 https://coronavirus.jhu.edu/data/new-cases-50-states/pennsylvania.

3 https://states.aarp.org/pennsylvania/covid-19-vaccine-distribution.

4 Formally, the figures reported in Table 1.3 are derived by multiplying the industry-specific employment loss figures shown in Table 1.2 by the percent of overall employment—in Pennsylvania and the U.S. overall—as shown in the "industry job loss as % of total state employment loss" columns in Table 1.3.

5 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/.

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

7 In August, Governor Tom Wolf announced the availability of $50 million in grant funding to help employers provide hazard pay to employees in life-sustaining occupations during the COVID-19 pandemic. Hazard pay is intended to keep front-line employees working in vital industry sectors across Pennsylvania. This program is a welcome, if modest gesture. However, providing workers with a modest supplement of hazard pay is not a substitute for enabling them to take paid sick leave when necessary. https://www.governor.pa.gov/newsroom/icymi-brookings-metropolitan-policy-program-calls-pennsylvanias-hazard-pay-program-a-promising-model-for-other-states/#:~:text=In%20August%2C%20Governor%20Tom%20Wolf,vital%20industry%20sectors%20across%20Pennsylvania.

8 https://www.nytimes.com/2020/03/31/business/energy-environment/pennsylvania-shale-gas-fracking.html.

9 https://www.attorneygeneral.gov/wp-content/uploads/2020/06/FINAL-fracking-report-w.responses-with-page-number-V2.pdf.

10 Both the DEP itself and industry representatives took strong issue with the findings of the grand jury report (see, e.g. https://www.bayjournal.com/news/energy/natural-gas-fracking-under-fire-in-pa/article_37169bd4-f1dc-11ea-aee1-772a61b111bd.html https://www.bayjournal.com/news/energy/natural-gas-fracking-under-fire-in-pa/article_37169bd4-f1dc-11ea-aee1-772a61b111bd.html). Our focus is not to adjudicate the details of specific charges and counter-charges, but rather to recognize the centrality of natural gas extraction through fracking as an energy development program for Pennsylvania since 2008, and the problems that have resulted from this strategy.

11 https://oxfordre.com/publichealth/view/10.1093/acrefore/9780190632366.001.0001/acrefore-9780190632366-e-44.

12 https://www.governor.pa.gov/newsroom/executive-order-2019-01-commonwealth-leadership-in-addressing-climate-change-and-promoting-energy-conservation-and-sustainable-governance/.

13 RGGI describes its policy framework as follows: "RGGI is composed of individual CO_2 Budget Trading Programs in each participating state. Through independent regulations, based on the RGGI Model Rule, each state›s CO_2 Budget Trading Program limits emissions of CO_2 from electric power plants, issues CO_2 allowances and establishes participation in regional CO_2 allowance auctions." https://www.rggi.org/program-overview-and-design/elements.

14 https://www.legis.state.pa.us/CFDOCS/Legis/PN/Public/btCheck.cfm?txtType=PDF&sessYr=2007&sessInd=1&billBody=H&billTyp=B&billNbr=0001&pn=0086; https://programs.dsireusa.org/system/program/detail/5945; http://www.puc.pa.gov/consumer_info/electricity/energy_efficiency_conservation_info.aspx.

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

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

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

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

19 See, e.g.: https://www.nrc.gov/reading-rm/doc-collections/fact-sheets/3mile-isle.html; and https://www.

thebalance.com/three-mile-island-nuclear-accident-facts-impact-today-3306337 For a dramatically more negative assessment of these health impacts, see http://www.greens.org/s-r/50/50-12.html.

20 https://globalhealth.usc.edu/2016/05/24/the-financial-costs-of-the-chernobyl-nuclear-power-plant-disaster-a-review-of-the-literature/.

21 Rachel Mealey, "TEPCO: Fukushima Nuclear Clean-Up, Compensation Costs Nearly Double Previous Estimate at $250 Billion," abc.net.au, December 16, 2016; "FAQs: Health Consequences of Fukushima Daiichi Nuclear Power.

22 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.

23 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.

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

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

26 According to Wikipedia: "On March 4, 1681, Charles II of England granted a land tract to William Penn for the area that now includes Pennsylvania. Penn then founded a colony there as a place of religious freedom for Quakers, and named it for the *Latin sylva, silva* ("meaning "wood""), thus "Pennsylvania" (Penn's woods)," https://en.wiktionary.org/wiki/Pennsylvania.

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

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

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

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

31 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.

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

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

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

35 https://www.budget.pa.gov/PublicationsAndReports/CommonwealthBudget/Documents/2020-21%20Proposed%20Budget/2020-21%20Budget%20in%20Brief.pdf.

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

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

38 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 11,724 direct jobs (73,275 direct jobs x 16 percent). These workers earn, on average, $11.40 and work 36 hours weekly. We then assume these workers work 50 weeks over the year. Therefore, raising these workers' wages by $3.60 per hour to $15.00 would sum to just under $76 million ($3.60/hr. x 36 hrs./wk. x 50 wks. x

11,724 direct jobs = $76 million). $76 million is equal to 0.3 percent of the annual clean energy investment figure of $22.6 billion.

39 https://www.governor.pa.gov/covid-19/construction-industry-guidance/.

40 https://www.bizjournals.com/pittsburgh/news/2020/11/13/covid-cases-rise-shell.html.

41 We emphasize that this assumption of a 40 percent decline in production and employment in Pennsylvania'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 Pennsylvania'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 Pennsylvania's fossil fuel and bioenergy related industries will be commensurate with the decline in statewide consumption.

42 We do not report in this section the comparable figures for Pennsylvania's various bioenergy sectors, since the employment levels are quite small and the relevant data are not consistently reliable. We do have reliable figures on the state's biomass electricity sector. This sector provides 1.3 percent of Pennsylvania's total electricity supply. But it accounts for only 325 jobs, equal to only 0.5 percent of the state's fossil fuel employment level as of 2018, according to the 2020 IMPLAN database. There are not comparably reliable employment data in IMPLAN for the state's other bioenergy-related activities, even though these other bioenergy activities—fuel ethanol, biodiesel and co-products—provide Pennsylvania with about 40 percent of the amount of energy provided by biomass electricity (i.e. 121 T-BTUs for biomass electricity versus 52 T-BTUs for the other sectors). For the purposes of our policy analysis, we assume that the forms of just transition policy support provided for fossil fuel-based industry workers will also be available to workers facing displacement through the contraction of Pennsylvania's bioenergy industry activities.

43 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 Pennsylvania. Employment in Pennsylvania's bioenergy sector is modest, and is not clearly reported in the government statistical sources.

44 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.

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

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

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

48 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.

49 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/.

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

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

52 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.

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

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

55 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/.

56 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).

57 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.

58 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.

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

60 See, for example, Chow (2017).

61 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?"

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

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

64 https://www.infrastructurereportcard.org/state-item/pennsylvania/.

65 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.

66 https://www.inquirer.com/economy/spl/coronavirus-pennsylvania-tax-revenues-shortfall-budget-20200702.html, http://pennwatch.pa.gov/budget/Pages/default.aspx

67 http://www.ifo.state.pa.us/download.cfm?file=Resources/Documents/Revenue-Estimate-2020-05.pdf

68 https://www.spotlightpa.org/news/2020/05/pennsylvania-short-term-budget-passes-wolf/, https://www.spglobal.com/ratings/en/research/articles/200629-as-covid-19-grips-u-s-state-finances-some-budget-debates-will-continue-well-beyond-the-deadline-11550876

69 https://pittsburgh.cbslocal.com/2020/11/23/gov-wolf-signs-budget-through-june-2021/

70 https://www.inquirer.com/economy/spl/coronavirus-pennsylvania-tax-revenues-shortfall-bud-

get-20200702.html, https://www.inquirer.com/politics/pennsylvania/spl/pennsylvania-budget-coronavirus-relief-aid-cases-35-billion-20201120.html

71 https://www.penncapital-star.com/covid-19/with-a-bottom-line-rocked-by-covid-19-pa-lawmakers-set-to-pass-stop-gap-budget-this-week/

72 http://www.ifo.state.pa.us/download.cfm?file=Resources/Documents/Revenue-Estimate-2020-05.pdf

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

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

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

76 Eligible units must have a population of more than 500,000 according to the U.S. Census: https://home.treasury.gov/system/files/136/Census-Data-and-Methodology-Final.pdf

77 The Pennsylvania disbursement to other public entities is reported at http://www.ifo.state.pa.us/download.cfm?file=Resources/Documents/Revenue-Estimate-2020-05.pdf

78 https://www.sba.gov/sites/default/files/2020-08/PPP_Report%20-%202020-08-10-508.pdf

79 https://www.sba.gov/sites/default/files/2020-08/EIDL%20COVID-19%20Loan%208.24.20-508.pdf

80 Unemployment assistance totals can be found at the state's Office of Unemployment Compensation site: https://www.uc.pa.gov/COVID-19/Statistics/Pages/default.aspx Individual Economic Impact payment totals can be found here: https://www.irs.gov/newsroom/irs-statement-on-economic-impact-payments-by-state-as-of-aug-28-2020

81 At the same time, these headline figures may overstate the actual level of support that the Pennsylvania economy has actually received. This is because not all the amounts shown in Table 5.1 as having been authorized were actually spent. For instance, through 8/12/20, state and local governments had expended only $1.3 billion, or 26.7 percent, of their $4.9 billion relief fund. Indeed, some $1.3 billion of these funds are slated to be spent only over the time period covered in the November 2020 budget. https://home.treasury.gov/system/files/136/Interim-Report-of-Costs-by-Category-Incurred-by-State-and-Local-Recipients-through-June-30.pdf

82 https://www.investopedia.com/congress-agrees-on-second-stimulus-here-s-what-s-in-it-and-what-s-not-5093226

83 http://www.crfb.org/blogs/biden-unveil-19-trillion-covid-response-plan

84 Pennsylvania Constitution, Article 8, § 7: https://www.legis.state.pa.us/WU01/LI/LI/CT/HTM/00/00.HTM

85 See Table 1 in a recent bond disclosure: https://www.budget.pa.gov/PublicationsAndReports/InvestorInformation/Documents/OS%20Final%201st%20Ref%202019.pdf

86 https://www.peri.umass.edu/publication/item/1286-the-federal-reserve-public-education-emergency-financing-facility-peeff-a-proposal.

87 https://www.marketwatch.com/story/fed-expands-municipal-debt-purchase-plan-to-allow-more-counties-and-cities-to-participate-2020-04-27.

88 https://www.newyorkfed.org/medialibrary/media/markets/mlf/municipal-liquidity-facility-eligible-issuers-200603

89 https://www.washingtonpost.com/business/2020/12/01/ppp-sba-data/

90 Of course, we do not know how many workers in Pennsylvania will claim unemployment insurance through January – March 2021. For the purposes of this calculation, we assume that the figure will average 400,000 workers. This is roughly the number of workers in Pennsylvania receiving unemployment insurance as of the end of 2020.

91 Pollin, R., Wicks-Lim J. and Arno P. (2020). *Assessing the Medicare Crisis Proposal*. Department of Economics and Political Economy Research Institute (PERI) University of Massachusetts-Amherst https://www.peri.umass.edu/publication/item/1287-assessing-the-medicare-crisis-proposal.

92 https://www.bls.gov/eag/eag.pa.htm

93 https://www.federalreserve.gov/monetarypolicy/quarterly-balance-sheet-developments-report.htm

94 https://pennsylvania.municipalbonds.com/bonds/recent/

95 In recent data sets, IMPLAN has started reporting electricity generation from some renewable sources — biomass, solar, geothermal, hydro, etc., which primarily captures the operation and maintenance of the industry.

96 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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