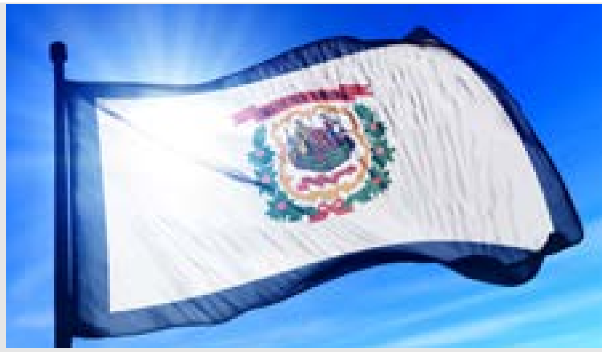
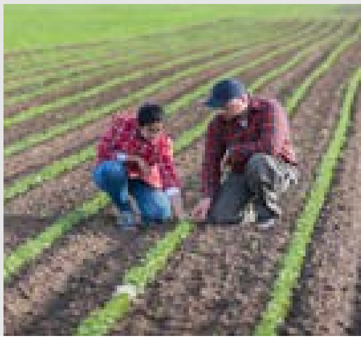
IMPACTS OF THE REIMAGINE APPALACHIA & CLEAN ENERGY TRANSITION PROGRAMS FOR WEST VIRGINIA

Job Creation, Economic Recovery, and Long-Term Sustainability





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

FEBRUARY 2021

Acknowledgments

This project was commissioned by The Heinz Endowments, the Community Foundation of the Alleghenies, Policy Matters Ohio, the Keystone Research Center and the West Virginia Center on Budget and Policy. We greatly appreciate their financial support as well as the fact that they respected our terms of engagement. Those terms included full autonomy in drafting the study and reaching the conclusions presented here.

The study benefitted substantially from discussions with Kelly Allen of the West Virginia Center on Budget and Policy, Ted Boettner of the Ohio River Valley Institute and formerly of the West Virginia Center on Budget and Policy, Stephen Herzenberg of the Keystone Research Center, Dana Kuhnline of Reimagine Appalachia, and Amanda Woodrum of Policy Matters Ohio. We also benefitted from the outstanding research assistance of Tyler Hansen, Emily Diaz-Loar, Caitlin Kline, and Chirag Lala. Kim Weinstein produced this wonderfully readable document out of our multiple cyber-piles of text and tables. PERI's Administrative Director Nicole Dunham provides a bedrock of support for all of our research work.

Table of Contents

SUMMARY OF STUDY

The COVID-19 pandemic has generated severe public health and economic impacts in West Virginia, 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. Moreover, to date, in comparison with other U.S. states, West Virginia has had one of the most successful vaccination distribution programs in the country. Still, as of this writing in mid-February 2021, infections and deaths from COVID remain at a "critical" level, both within West Virginia and throughout most of the U.S. Correspondingly, the economy remains unable to move onto a solid recovery path.

This study proposes a recovery program for West Virginia that is also capable of building a durable foundation for an economically viable and ecologically sustainable longer-term recovery. Even under the ongoing pandemic conditions, we cannot forget that we have truly limited time to take decisive action around climate change. In addition, West Virginia would receive a further major boost through a range of public investments in the areas of public infrastructure, manufacturing, land restoration and agriculture. As we show, a combination of investments in West Virginia to support climate stabilization along with strengthening the state's capacity in the areas of infrastructure, manufacturing, land restoration and agriculture will also serve as a major engine of recovery and expanding opportunities throughout the state.

The study is divided into six parts:

1. Pandemic, Economic Slump, and Conditions for Recovery
2. Clean Energy Investments, Emissions Reduction and Job Creation
3. Investment Programs for Manufacturing, Infrastructure, Land Restoration and Agriculture
4. Total Job Creation in West Virginia through Combined Investment Programs
5. Just Transition for Fossil Fuel Industry-Dependent Workers and Communities
6. Financing West Virginia's Recovery and Sustainable Transition Projects

After the relatively brief introductory section on the pandemic, job losses in West Virginia and prospects for recovery, a more detailed discussion begins with Section 2. We develop in Section 2 a clean energy investment project through which West Virginia 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 West Virginia 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, including solar, geothermal, small-scale hydro, wind, and low-emissions bioenergy power. We also show how this climate stabilization program for West Virginia can serve as a major new engine of job creation and economic well-being throughout the state. We estimate that, as an average over 2021 – 2030, a clean energy investment program scaled at about $3.6 billion per year in both private and public investments will generate about 25,000 jobs per year in West Virginia.

In Section 3, we present investment programs for West Virginia in the areas of public infrastructure, manufacturing, land restoration and agriculture. Specific investment areas include broadband, manufacturing R&D, regenerative agriculture, and plugging orphaned oil and gas wells. We have scaled this overall set of investments at $1.6 billion per year over 2021 – 2030, equal to about 2 percent of West Virginia's 2019 GDP. We estimate that the full program would generate about 16,000 jobs per year in the state.

Overall, as we highlight in the brief Section 4, the combination of investments in clean energy, manufacturing/infrastructure, and land restoration/agriculture will therefore create about 41,000 jobs in West Virginia—equal to roughly 5 percent of West Virginia'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 Sections 2 – 5.

Establishing effective public health interventions. Almost 250,000 people in West Virginia, equal to fully 31 percent of the state's workforce, filed to receive unemployment insurance beginning with the onset of the pandemic in mid-March 2020 and continuing through most of January 2021. The heaviest job losses, amounting to more than 25 percent of total statewide unemployment, have been in the leisure and hospitality industry. It is critically important that the state continue and even accelerate its thus far successful vaccination program. At the same time, employment conditions in the state prior to the COVID pandemic were themselves not satisfactory. The state therefore can benefit greatly through large-scale investments in clean energy and public infrastructure in conjunction with increasing its budgets in public health to bring the COVID pandemic fully under control.

Clean Energy Investments and Job Creation. We estimate that the public and private investments needed in West Virginia to achieve emission reduction targets consistent with the IPCC's goals are capable of producing, between 2021 – 2030, an average of about 25,000 jobs per year in West Virginia. 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, including solar, geothermal, small-scale hydro, wind and low-emissions bioenergy. We estimate the average annual budget for these programs to total $3.6 billion per year, equal to about 4.2 percent of West Virginia's average GDP between 2021 – 2030. We also estimate that roughly $3.2 billion per year, or 90 percent of the total investment budget, will come from *private sources*, while public spending, at $360 million per year, will cover 10 percent of the total annual investment budget. New job opportunities will open across the entire statewide labor market through these investments, including for, among other occupations, carpenters, vehicle mechanics, material scientists, secretaries, accountants, truck drivers, and operating engineers.

Upgrading West Virginia's Economic Base through Manufacturing, Infrastructure, Land Restoration and Agriculture Investments. West Virginia's economy would receive an additional major boost, in terms of both short-run stimulus and longer-term productivity and sustainability, by undertaking large-scale investments—at about $1.6 billion per year, or 2 percent of the state's GDP—in the areas of manufacturing/infrastructure and land restoration/agriculture. The roughly 16,000 jobs that will be generated through these investments will include a wide range of occupations. Over 35 percent of all employment directly created from manufacturing/infrastructure investments will be in construction occupations, including jobs for equipment operators, carpenters, and construction laborers. The manufacturing R&D investment areas will of course create employment for environmental scientists, chemists, and biologists. Jobs will also expand for loading machine operators, water treatment plant operators, financial managers, bookkeepers and customer service representatives. With land restoration/agriculture, the largest expansion of employment will be for farmers and community service managers. New jobs for conservation and agricultural workers, among others, will also be created.

Just Transition for Displaced Workers in Fossil Fuel-Based Industries. About 40,000 people are employed in West Virginia in fossil fuel-based industries. This includes those engaged in extraction operations for coal, oil and natural gas. The total job figure also includes support activities for coal as well as oil and gas projects, and other ancillary sectors, such as fossil fuel-based electric 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 1,400 workers per year will be displaced in these industries between 2021 – 2030 while another roughly 650 will voluntarily retire each year. It is critical that all of these workers receive pension guarantees, , re-employment guarantees, wage insurance, and retraining support, as needed. We estimate that generous levels of transition support for all workers will cost an average of about $140 million per year.

Financing a Sustainable Recovery. A central policy proposal during President Biden's presidential campaign was his "Build Back Better" infrastructure and clean energy investment program. The proposal was for $2 trillion in federal funds to be spent over Biden's first term in office, at an annual average rate of $500 billion for four years. Of course, as of this writing, we do not know what will be either the final proposal introduced by the Biden administration or the final measure that passes Congress. As a lower-end approximation, we estimate that West Virginia could receive about $2.5 billion per year to finance a federal program along the lines of Build Back Better. That level of funding would be more than enough to fully cover the $2.1 billion per year in public investment funds that we have budgeted for the clean energy, infrastructure/manufacturing and land restoration/agriculture programs, as well as just transition support for fossil fuel industry-based workers. The West Virginia state government is also capable of making supplemental contributions to the overall set of spending programs we propose here. This is especially the case at present, since bonds issued by the state and municipalities in West Virginia are being marketed at very low interest rates.

Main Findings from Sections 2 - 5:

- Investments in Clean Energy, Manufacturing/Infrastructure, and Land Restoration/Agriculture;
- Just Transition Program for Fossil Fuel Industry Workers

These parts of the study examine the prospects for a transformative investment and just transition program for West Virginia. The first areas of focus within the overall program are the clean energy investments, undertaken in combination by the public and private sectors throughout the state. The overall investment budget of about $3.6 billion will amount to about 4.2 percent of West Virginia's average GDP for 2021 – 2030. Private sector sources should cover most of the investment budget while public funds supplement and subsidize private investments. The program will advance two fundamental goals:

- Promoting global climate stabilization by reducing carbon dioxide (CO_2) emissions in West Virginia without increasing emissions outside of the state.
- Creating roughly 25,000 new jobs per year in the state between 2021 – 2030.

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 West Virginia relative to the 2018 emissions level.
  - Emissions in West Virginia in 2018 were at roughly 90 million metric tons, including emissions produced by coal, natural gas and oil. The emissions level as of 2030 will therefore need to be no more than roughly 45 million tons.[1]

Major Areas of Clean Energy Investments

- ***Energy Efficiency.*** Dramatically improving energy efficiency standards in West Virginia'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, geothermal, small-scale hydro, wind, and low-emissions bioenergy—available at competitive prices to all sectors of West Virginia's economy.
- ***Total Investment Expenditures.*** The level of investment needed to achieve West Virginia's energy goals will average roughly $3.6 billion per year between 2021 – 2030.
  - This estimate assumes that West Virginia's economic growth proceeds at an average rate of 1.0 percent per year.
  - Clean energy investments will need to equal about 4.2 percent of West Virginia's annual GDP.
  - The average annual clean energy investment level of 4.2 percent of GDP means that roughly 96 percent of West Virginia's economic activity will be directly engaged in activities *other than* clean energy investments.

Clean Energy Investments Will Deliver Lower Energy Costs

- Raising efficiency standards enable consumers to spend less for a given amount of energy services.
- The costs of solar, geothermal, hydro, and wind power are all presently roughly equal to or lower than those for fossil fuels and nuclear energy.
- The average West Virginia household should be able to save in the range of 30 – 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 $3.6 billion per year in clean energy projects in West Virginia over 2021 – 2030 will generate an average of about 25,000 jobs per year in the state.
- 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 about $65,000 - $70,000 per year. Compensation is higher, at about $92,000 for industrial efficiency jobs and significantly lower, at about $27,000 for mass transit jobs.
- 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.

Investments in Manufacturing, Infrastructure, Land Restoration and Agriculture

- In 2018, the American Society of Civil Engineers (ASCE) gave an overall grade of D to West Virginia'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 $1.6 billion per year, equal to 2 percent of West Virginia's current GDP. Major areas of focus include broadband; water management; manufacturing R&D; repairing leaky gas pipelines; regenerative agriculture; farmland conservation; plugging orphaned oil and gas wells; and land restoration.
- Investing $1.6 billion per year in these areas would generate about 16,000 jobs per year within West Virginia.

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

- Our annual average job estimates for 2021 – 2030 include:
  - 24,797 jobs per year through $3.6 billion in spending on energy efficiency and clean renewable energy.
  - 16,144 jobs per year through investing $800 million respectively in manufacturing/public infrastructure and land restoration/agriculture.
- The total employment creation through clean energy, manufacturing/infrastructure and land restoration/agriculture will total to about 41,000 jobs.
- Job creation will average about 5.1 percent of West Virginia's workforce as of 2019.

Just Transition for Fossil Fuel Industry Dependent Workers and Communities

- About 96 percent of all energy that is either consumed in West Virginia or exported to other states as electricity comes from burning coal, natural gas, or oil. Consumption of coal, natural gas, and oil will all need to fall by 50 percent for the state to reduce CO_2 emissions by 50 percent as of 2030.
- We estimate that 40,188 workers in West Virginia are presently employed in the state's fossil fuel-based industries.
- We estimate that total job displacements will average about 1,400 per year.
  - This is after allowing that an average of about 650 workers per year will voluntarily retire.
- A just transition program for these roughly 1,400 workers per year 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 working past the traditional retirement age of 65.
- The average costs of supporting these workers will amount to about $126,000 per worker, or $42,000 per worker per year. Overall costs will amount to about $143 million per year over the duration of the just transition program.

The findings we develop in this study are in broad alignment with the December 2020 report produced by researchers at the Center for Energy and Sustainable Development at the West Virginia University College of Law, *West Virginia's Energy Future: Ramping Up Renewable Energy to Decrease Costs, Reduce Risks, and Strengthen Economic Opportunities in West Virginia.*[2]

This study presents five reasons the West Virginia electric utilities should transition to renewable energy sources over the next decade and beyond. These five reasons are:

1. Renewable energy is now cheap, and it's continuing to get cheaper.
2. Customers — both businesses and individuals — overwhelmingly are demanding renewable energy.
3. Diversifying our power resource mix is critical to competing in the growing regional renewable energy economy and, more broadly, securing a place in the 21st century energy economy.
4. The financial risk posed by emissions from power plants is growing due to majority public support for bipartisan proposals to address climate change by charging fees for carbon dioxide emissions. These fees would necessarily hit coal-fired power plants hardest because those plants emit the most carbon dioxide.
5. Major lenders and investors increasingly are withholding capital from utilities that aren't transitioning away from emission-heavy resource mixes.

In terms of its specific findings, the West Virginia University College of Law report concludes—again similar to this study—that: 1) investing in renewable energy and energy efficiency will save money for West Virginia electricity consumers relative to maintaining the state's existing utility infrastructure; 2) investments to build a renewable and efficiency-based utility infrastructure will produce a net positive impact on employment in West Virginia through 2030; and 3) the state and federal government need to develop robust policies to support workers and communities in West Virginia that are presently dependent on the fossil fuel economy.

1. PANDEMIC, ECONOMIC SLUMP, AND CONDITIONS FOR RECOVERY

1.1 The Pandemic in West Virginia

The State of West Virginia, like the rest of the United States, has been experiencing an historically unprecedented public health and economic crisis since the COVID-19 pandemic emerged full force in mid-March 2020.

The COVID pandemic is moving into its latter phases, due to the development of multiple vaccines that have demonstrated their effectiveness. Moreover, to date, in comparison with other U.S. states, West Virginia has had one of the most successful vaccination distribution programs in the country. *The New York Times* of 1/28/21 describes West Virginia's success as follows:

> Since the nation began distributing vaccines more than a month ago, it has moved far more slowly than officials hoped and has been stymied by widespread logistical problems. But West Virginia has stood out for its success in getting people vaccinated. About 9 percent of all West Virginians have received a first dose of the coronavirus vaccine, a larger segment than in every state but Alaska and double the rate of some. No state has given a larger share of its residents second doses, a crucial step to securing the best chance at immunity….
>
> "West Virginia is about at the top of the charts," said Dr. Mark McClellan, a former commissioner of the U.S. Food and Drug Administration. "We need to get more states to the point that they have the vaccination capacity of West Virginia."[3]

Despite West Virginia's relative success thus far in vaccinating its population, as of this writing in early February, the state is still experiencing a severe public health crisis. Indeed, the pandemic has intensified in severity since late summer 2020. Some important indicators of this situation are as follows:

- ***Infection rate:*** Between July 1, 2020 and January 7, 2020, the infection rate in West Virginia rose from 2.8 cases to 85 cases per 100,000 people, a *30-fold increase*. As of February 1, the infection rate has dropped to 45 cases per 100,000. This is a 47 percent reduction since early January, but still 16 times higher than in July.
- ***Death rate:*** As of July 1, 2020, the 7-day average death in the state was 0.1 per 100,000 people. As of January 10, 2021, it had spiked to 29.4 per 100,000, a *nearly 300-fold increase* in the state's 7-day average death rate. As of January 31, the 7-day average rate was 18.4. This is a 37 percent drop-off from mid-January, which is, as with the state's infection rate, a significant improvement since the January peak. But this death rate in early February remains at a critically high level.

One more favorable development is that, as of January 31, the usage rate for the state's intensive care unit beds was at 75 percent of total statewide capacity. This indicates that the state's intensive care units do still have some capacity for managing if the state's infection rate should spike again. Nevertheless, the watchdog organization COVID Act Now assesses overall public health conditions in West Virginia as of early February as "critical," concluding that "West Virginia is either actively experiencing an outbreak or is at extreme risk."[4]

Governor Jim Justice ordered a statewide lockdown in mid-March 2020. He then introduced a phased reopening program in late April.[5] But, inevitably, the state's progress in reopening has been uneven, due to the intensifying spread of the pandemic beginning in July.

As a case in point, one of the most difficult challenges has been with reopening the state's public school system to in-person instruction. As of the beginning of 2021, the schools had not yet fully opened to in-person instruction. But the Superintendent of Schools Clayton Burch did order the resumption of in-person instruction as of January 19. According to Burch, "data from the West Virginia Department of Health and Human Resources (DHHR) proves that schools are safe for in-person instruction even when counties and communities experience elevated transmission rates. Why? When masks are worn, and other protocols are practiced, the virus does not travel from host to host."[6] However, at the time of the reopening, the state's two education-system unions, the American Federation of Teachers-West Virginia and the West Virginia Education Association, sued the state to prevent mandatory reopening. The West Virginia Education Association cites "health and safety conditions and demands locals have the choice to work remotely until everyone is vaccinated."[7]

This dispute over the conditions under which West Virginia's public schools can be safely reopened underscores the central importance of the state maintaining, and in fact accelerating, its successful vaccination program. Clearly, the state's economy will not be able to transition into a full recovery mode until most of the state's population has been inoculated. It will be useful to review the experience in West Virginia's job market since the onset of the pandemic to illustrate this critical point.

1.2 Statewide Job Losses

As with the U.S. economy overall, employment conditions in West Virginia have experienced a severe decline resulting from the COVID pandemic. As one clear measure of this, we show in Table 1 figures on job losses in West Virginia since the onset of the pandemic in mid-March. Specifically, we report on initial unemployment insurance claims by workers in West Virginia from March 21, 2020 until January 23, 2021. As Table 1 shows, this figure for the number of people in the state who lost their jobs and filed to receive unemployment insurance over this period totals to 248,559. This figure amounts nearly 31 percent of West Virginia's workforce as of February 2020. That is, over the roughly 10-month period beginning with the onset of the pandemic, nearly one-third of all workers in West Virginia experienced job loss and filed for unemployment insurance.

For comparison, we show in the second column of Table 1 the figures over the comparable time period for 2019 – 2020, i.e. March 23, 2019 until January 25, 2020. As we see, total initial unemployment claims over this 10-month period a year ago totaled to 50,835, equal to 6.4 percent of West Virginia's workforce at that time. In other words, job losses over March 2020 to January 2021 jumped *nearly 5-fold* over the same time period last year.

We also report the comparable figures for the U.S. overall in rows 3 and 4. As we see, the figures for West Virginia are actually less severe than the overall U.S. economy. With the overall U.S. economy, job losses between March 21, 2020 and January 23, 2021 totaled to 46.5 percent of the U.S. labor force, while over the same time period a year ago, that figure was at 6.0 percent.

TABLE 1
Job Losses in West Virginia and U.S. During COVID-19 Pandemic and One Year Prior

Initial Unemployment Insurance Claims:
Weekly Figures Covering March 21, 2020 – January 23, 2021 and March 23, 2019 – January 25, 2020

	3/21/20 – 1/23/21 Figures	3/23/19 – 1/25/20 Figures
Figures for West Virginia		
1. Number of people filing initial unemployment insurance claims	248,559	50,835
2. Number of claims as share of February labor force	30.8%	6.4%
Figures for U.S.		
3. Number of people filing initial unemployment insurance claims	76,474,000	9,743,000
4. Number of claims as share of February labor force	46.5%	6.0%

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

Industry-Specific Contractions and Job Losses

We can obtain a more detailed perspective on West Virginia's labor market 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 2 and 3.

The first set of figures in Table 2 presents job losses *within* each industry, both for West Virginia and the U.S. overall. The second set of figures in Table 3 shows the contributions, industry-by-industry, to West Virginia's *overall* decline in employment as of October/November 2020 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 West Virginia with those for the U.S. overall.[8]

As we see first, in Table 2, the employment level declines for all 11 economic sectors listed. West Virginia's employment crisis has 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 over 16 percent between October/November 2020 relative to the 2019 level. Employment in mining and logging fell to a nearly comparable extent, declining by 13.8 percent. Seven other industries experienced job losses of at least 3 percent. Overall, state employment in West Virginia fell by 6.2 percent in October/November relative to 2019. By this measure—as opposed the figures we reported

TABLE 2
Job Losses within Industries, West Virginia and U.S. Percentages
Figures are employment figures, not seasonally adjusted, from October/November 2019 to October/November 2020

West Virginia: *Decline in state employment = 6.2%*		**United States:** *Decline in national employment = 5.9%*	
Leisure and hospitality	-16.4%	Leisure and hospitality	-19.6%
Mining and logging	-13.8%	Mining and logging	-14.5%
Professional and business services	-8.2%	Information	-8.7%
Trade, transportation, and utilities	-6.7%	Other services	-6.9%
Information	-6.2%	Government	-5.0%
Financial activities	-5.3%	Manufacturing	-4.7%
Construction	-4.6%	Professional and business services	-4.6%
Government	-4.3%	Education and health services	-4.4%
Education and health services	-3.8%	Trade, transportation, and utilities	-3.4%
Other services	-3.1%	Construction	-2.6%
Manufacturing	-1.0%	Financial activities	-0.8%

Sources: U.S. Labor Department.

TABLE 3
Share of Total Job Losses by Industry, West Virginia and U.S. Percentages
Figures are employment figures, not seasonally adjusted, from October/November 2019 to October/November 2020

West Virginia: *Decline in state employment = 6.2%*			**United States:** *Decline in national employment = 5.9%*		
	% of state employment	Industry job loss as % of total state employment loss		% of U.S. employment	Industry job loss as % of overall U.S. employment loss
Leisure and hospitality	10.2%	-1.7%	Leisure and hospitality	10.8%	-2.1%
Trade, transportation, and utilities	17.9%	-1.2%	Government	15.1%	-0.8%
Government	21.3%	-0.9%	Education and health services	16.1%	-0.7%
Professional and business services	9.6%	-0.8%	Trade, transportation, and utilities	18.4%	-0.6%
Education and health services	18.0%	-0.7%	Professional and business services	14.2%	-0.6%
Mining and logging	3.0%	-0.4%	Manufacturing	8.4%	-0.4%
Construction	5.1%	-0.2%	Other services	3.9%	-0.3%
Financial Activities	4.0%	-0.2%	Information	1.9%	-0.2%
Other services	3.3%	-0.1%	Construction	5.0%	-0.1%
Information	1.1%	-0.1%	Mining and logging	0.5%	-0.1%
Manufacturing	6.4%	0.1%	Financial activities	5.8%	0.0%

Sources: U.S. Labor Department.

above on unemployment insurance claims—West Virginia's heavy job losses due to the COVID pandemic over this year were also somewhat sharper than those for the U.S. overall. Thus, for the U.S. overall, the employment decline was 5.9 percent in October/November relative to September/October 2019.

In Table 3, we see that, after taking account of the relative size of each of the industries in West Virginia's economy, the leisure and hospitality industry remains as the largest source of overall employment losses. Thus, job losses in leisure and hospitality account for 1.7 percentage points of the state's overall 6.2 percent level of job loss—i.e. the contraction of the leisure and hospitality industry accounts for about 27 percent of West Virginia's overall job losses. Trade, transportation and utilities is the other sector of the economy that accounts for over 1 percentage point of the state's 6.2 percent decline. The employment declines in government, professional/business services, and education/health services have been the next most impactful, accounting for between 0.7 and 0.9 percentage points respectfully of the state's overall 6.2 percent employment decline.

1.3 Prospects for Recovery

Of course, the state's leisure and hospitality industry will not return to its 2019 level of activity until the public health issues around COVID-19 have been successfully brought under control. Public sector employment losses, concentrated primarily in the government and education/health sectors, are tied to the decline in state- and municipal-level tax revenues. The state's public sector employment levels will therefore not be able to recover until government funding sources improve, either through the state's tax revenues returning to pre-recession levels or through an increased level of deficit spending coming from either the state or federal government levels.

These major obstacles to achieving an economic recovery in West Virginia are reflected in the most recent January 2021 forecast by the Bureau of Business & Economic Research at West Virginia University's College of Business and Economics. John Deskins, director of the research center, estimates that, within the current policy environment, employment levels in the state will not return to their pre-COVID levels until the later part of 2022, i.e. between roughly 18 months to two years from the time of this writing.[9]

In addition to this forecast, a November 2020 report from the West Virginia Center on Budget and Policy emphasizes that employment conditions in the state prior to the COVID pandemic were themselves not satisfactory. The author of the report, Sean O'Leary, writes as follows:

> It's important to bear in mind, getting the state back to where it was pre-pandemic isn't saying much. West Virginia's economy was underperforming even before COVID-19 struck. Previous Economic Outlook projections from WVU forecasted that the state would see 0.6 percent average annual employment growth from 2016 to 2021. But through 2019, West Virginia's actual average annual employment growth was -0.2 percent.[10]

In combination, this range of considerations underscores the priority of West Virginia 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 both federal and state-level deficit financing may be necessary to advance these investment priorities both as a package of short-term stimulus interventions and to move West Virginia onto a long-term sustainable growth path. These are the issues we will examine in Sections 2 and 3 of this study.

2. CLEAN ENERGY INVESTMENTS, EMISSIONS REDUCTION, AND JOB CREATION

2.1 West Virginia's Existing Clean Energy Policies

To date, West Virginia has not been active in advancing climate change policies. This becomes clear in contrast with policy measures that have been implemented in other U.S. states. Some relevant comparisons include that West Virginia is:

- 1 of 16 states with no climate action plan;
- 1 of 27 states with no greenhouse gas emissions targets;
- 1 of 12 states with no requirements or targets for promoting renewable energy sources in electricity generation;
- 1 of 22 states with no requirements or targets for raising energy efficiency levels.[11]

Nevertheless, some clean energy and climate-related policies are operating in the state. These can be seen as an initial framework on which to build in advancing a program to reduce CO_2 emissions in the state by 50 percent as of 2030 and to deliver dramatically expanded employment opportunities in the process. These enacted policies in West Virginia include the following:

Solar Energy

In March 2020, Governor Justice signed into law Senate Bill 583 that promotes the development of utility-scale solar energy projects in the state.[12] The bill creates "a program to authorize electric utilities to provide a portion of the state's electricity needs through a process that allows them to plan, design, construct, purchase, own and operate [solar] electric generating facilities, energy storage resources, or both, pursuant to this section is in the public interest of the state." Eligible sites include: "any site in this state that has been previously used in electric generation, industrial, manufacturing or mining operations." Utilities are allowed to recover costs through a rate increase to customers.

The legislation does specifically include a measure that also supports the current level of coal-fired generating capacity. Solar developments are targeted only for supplying increased demand for electricity in the state or replacing retiring coal-fired capacity. Nevertheless, the measure has attracted considerable initial interest, even during the COVID-induced 2020 recession.[13]

Wind Energy

In March 2007, West Virginia enacted legislation (SB 441) which established lower tax rates for wind energy generating facilities in the state. This included a reduction in the Business and Operations tax rate from 40 percent of the nameplate capacity of the generating unit to 12 percent. It also reduced the effective property tax rate on wind turbines to approximately 25 percent of the rate that applies to most other newly-constructed electric-generating units in the state.[14]

Energy Efficiency

Building energy codes. As of September 2013, building codes in West Virginia for residential buildings began following the International Energy Conservation Code. As of April 2019, building codes for commercial buildings began following the American Society of Heating, Refrigerating and Air-Conditioning Engineers standard. These codes require higher levels of energy efficiency in new buildings. According to the U.S. Department of Energy, "Energy cost savings for West Virginia resulting from the state updating its commercial and residential building energy codes in accordance with federal law are significant, estimated to be on the order of nearly $50 million annually by 2030." [15]

Rebate programs for residential and non-residential appliance purchases. Appalachian Power operates a voluntary rebate program that includes a $25 rebate for items such as high-efficiency freezers to $750 for ground source heat pumps. American Electric Power as well as Appalachian Power offer to non-residential customers rebates of 6 – 7 cents per kilowatt hour saved for operating high efficiency equipment. These include refrigerators/freezers, water heaters, lighting, lighting controls/sensors, chillers, heat pumps, air conditioners, programmable thermostats, building insulation, motor VFDs, food service equipment, commercial cooking equipment, and commercial refrigeration equipment. The maximum rebate for the non-residential programs is $150,000 per account number per year and cannot exceed 50% of installed project cost. [16]

These initiatives are supportive of moving West Virginia onto a clean energy transition path. But to date, none of them come close to operating at a sufficiently large scale relative to the challenge of achieving a 50 percent reduction in state-level CO_2 emissions as of 2030. In Section 2.7, we will describe the scale of clean energy investment activity that will be necessary to successfully move West Virginia onto a clean energy transition path.

At the same time, even if these measures were to operate on a much larger scale, they would still need to be supported by strong regulatory policies in the state. This should include effective renewable portfolio and energy efficiency standards.

All such initiatives to move West Virginia onto a clean energy transition path will also have to be fully complemented by just transition policies that will support the workers and communities in West Virginia that are presently dependent on the state's fossil fuel industries for their livelihoods. We will examine the features of a just transition program for West Virginia in detail in Section 5.

2.2 Energy Sources and CO_2 Emissions for West Virginia

In this section, we review the sources of energy supply and demand in West Virginia, 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 for advancing a viable just transition program for the state.

Table 4 shows West Virginia's energy consumption profile in terms of sources 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 neces-

TABLE 4
West Virginia State Energy Consumption and Electricity Exports by Energy Source, 2018
Figures are T-BTUs

	Total	% of Total
1) Total in-state consumption + electricity exports to other states *(= row 2 + row 8)*	1,158	100%
2) Non-renewables and high-emissions bioenergy *(= rows 3 – 7)*	1,125	97.2%
3) Coal	662	57.2%
4) Natural Gas	223	19.3%
5) Petroleum	219	18.9%
6) High-emissions bioenergy	21	1.8%
7) Nuclear	0	0
8) Clean renewables *(= rows 9 – 12)*	33	2.8%
9) Hydro	17	1.5%
10) Wind	16	1.3%
11) Solar	0	0
12) Geothermal	0	0
13) Electricity exports to other states	324	28.0%
14) In-state energy consumption *(= row 1 - row 13)*	834	72.0%

Source: US Energy Information Agency (EIA), https://www.eia.gov/state/?sid=WV.

sary 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 4, total energy consumption plus electricity exports in West Virginia in 2018 was 1,158 trillion BTUs, or approximately 1.1 Q-BTUs. In-state energy consumption was at 834 T-BTUs and electricity exports to other states was 324 T-BTUs. This means that, at roughly its 2018 consumption level, 1 Q-BTU would be able to provide for West Virginia all the energy consumed for the year plus most of the additional energy needed generated enough electricity for the state's export market.

Moving into the specifics of Table 4, in rows 2 – 12, we see how the state's energy supply is broken down by energy source. These figures include energy consumed as electricity, both within the state and for the export market.

As we see in row 3, coal remains, by far, the state's largest energy source, supplying 662 T-BTUs, equal to over 57 percent total primary energy supply. Natural gas and petroleum both provide about 19 percent respectively of total supply. These three fossil fuel sources alone therefore account for 95.4 percent of total supply.

The remaining roughly 5 percent of the state's energy supply is divided fairly evenly between high-emissions bioenergy (1.8 percent), and, among clean renewable sources hydro (1.5 percent) and wind (1.3 percent). To date, the state operates with no nuclear energy, and close to zero solar and geothermal power.

From these figures, it is clear that West Virginia faces major challenges, both in terms of reducing fossil fuel consumption in the state significantly and equally, in building a major clean energy infrastructure in the state from its existing near-zero starting point.

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 West Virginia 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 second most heavily consumed energy source in the state at present, after coal. In fact, 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 West Virginia.

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

- ***Radioactive wastes.*** These wastes include uranium mill tailings, spent reactor fuel, and other wastes, which according to the U.S. Energy Information Agency (EIA) "can remain radioactive and dangerous to human health for thousands of years" (EIA 2020b, p. 1).

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

How to weigh the benefits to West Virginia of nuclear energy versus these environmental and public safety concerns is a critical challenge for determining the state's future energy trajectory. Overall, it remains the case that, over the long term, nuclear energy will continue to carry major environmental, public health, safety, and political risks, in West Virginia and elsewhere. The safest course for West Virginia would therefore be for the state to continue to operate without any contributions from nuclear power to its overall energy supply.

Bioenergy

As we saw in Table 4, bioenergy—including solid biomass energy from burning wood and other raw materials as well as liquid biofuels, primarily corn ethanol—provides 1.8 percent of West Virginia's total energy supply. To date, it is the largest source of renewable energy in the state, with hydro at 1.5 percent and wind at 1.3 percent, while solar and geothermal supplies are negligible. However, 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.[19] 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.[20]

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.[21]

For the purposes of our calculations on emissions sources in West Virginia, we do not focus on those generated by bioenergy, since, to date, the amounts remain small. But for advancing a clean energy project for West Virginia moving forward, it will be critical for the state to phase out its consumption of high-emissions bioenergy and to create a large-scale presence for low-emissions bioenergy supplies.

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 80 percent of West Virginia's overall land area is presently covered by forest.[22] Thus, forest growth in West Virginia can provide a significant offset to the emissions generated through combusting fossil fuels and biomass to produce energy.

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.[23] The technologies being researched now aim to artificially replicate the impact of the Mount Pinatubo eruption through deliberately injecting sulfate particles into the stratosphere. Some researchers contend that to do so would be a cost-effective method of counteracting the warming effects of greenhouse gases.

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

> Proposed climate geoengineering techniques cannot be relied on to be able to make significant contributions…towards counteracting climate change in the context of the Paris Agreement. Even if climate geoengineering techniques were actively pursued, and eventually worked as envisioned on global scales, they would very unlikely be implementable prior to the second half of the century….This would very likely be too late to sufficiently counteract the warming due to increasing levels of CO_2 and other climate forces to stay within the 1.5^{0}C temperature limit—and probably even the 2^{0}C limit—especially if mitigation efforts after 2030 do not substantially exceed the planned efforts of the next decade, (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 West Virginia 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.[24]

Estimating Costs of Efficiency Gains

How much will it cost to achieve major gains in energy efficiency, in general and with respect to West Virginia 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.[25] 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 region 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 West Virginia.

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 West Virginia 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 West Virginia, 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 West Virginia, 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 West Virginia 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.[26]

2.5 Prospects for Clean Renewable Energy

A critical factor for building a net zero economy in West Virginia, 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 5 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 5, 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.[27]

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.[28] 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 West Virginia, the U.S., and global economies approach the net zero emissions goal

TABLE 5
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.

by 2050. However, over the decade 2021 – 2030, these issues will not be pressing. This is because coal, natural gas and petroleum will continue supplying roughly 95 percent of West Virginia's total energy supply as of 2021, with that figure still maintained at over 80 percent as of 2030, even as West Virginia achieves major improvements in energy efficiency. Thus, the economy's baseload energy sources will continue to be fossil fuels through 2030 and several years beyond.

Keeping all such considerations in mind, we can still roughly conclude from these figures that, for the most part, clean renewable energy sources are rapidly emerging into a position at which, in West Virginia as elsewhere, 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.

The December 2020 study *West Virginia's Energy Future* by the West Virginia University College of Law summarized the evidence on the relative costs of renewable energy versus coal for the generating the state's electricity supply as follows:

> As of 2018, 74 percent of U.S. coal capacity could be replaced by nearby renewable energy generation with immediate cost savings, whereas in 2025 that percentage will increase to 86 percent… The coal facilities that will be more expensive than local renewable energy in 2025 include every single coal power plant in West Virginia. Other recent analyses have confirmed that certain West Virginia coal-fired power plants have already been losing millions of dollars over the past three years and are likely to continue losing money into the future.[29]

Clean renewable energy sources do themselves present environmental challenges that will need to be addressed, in West Virginia as elsewhere. The most significant is with hydro power. To begin with, there is virtually no potential for expanding large-scale hydro capacity in West Virginia or elsewhere in the U.S. because the most favorable sites are already built and operating at capacity. There are also likely to be serious negative environmental impacts resulting from additional large-scale dam construction in terms of disrupting existing communities and ecosystems.

At the same time, it is still realistic to anticipate that hydro capacity could expand significantly through developing small-scale hydro power sites, which are abundant in West Virginia and throughout the U.S. As described in a 2006 study by the Idaho National Laboratory for the U.S. Department of Energy, small-scale hydro projects operate as follows: "The development model included a penstock running parallel to the stream, culminating in a powerhouse whose tailwater returned the working flow to the stream."[30]

A 2010 study by Lea Kosnik summarizes this case for such small-scale hydro operations more broadly, as follows:

> Such small generation facilities have very few of the negative riverine impacts to which larger, more conventional hydropower plants have been prone to. As the main criticism of conventional

hydropower development has been the local impact on fishery resources and riverine ecosystems, small scale hydropower presents an alternative, win-win situation: no carbon emissions and a negligible carbon footprint.[31]

An issue that applies more generally with a large-scale expansion of clean renewable energy capacity is whether there will be sufficient supplies of the full set of raw material to meet the expanded demand. Broadly speaking, some short-term supply bottlenecks are likely to emerge for some of the required materials, but none of the likely shortages will be insurmountable. One solution will be to greatly expand the industry for recycling the needed minerals and metals. Opportunities will also emerge to economize on the level of minerals and metals necessary, and to develop substitute materials for those that become in short supply.[32]

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

As we will discuss further later, we will assume that with West Virginia's clean energy investment project, the expansion of clean renewable energy capacity will consist of 30

TABLE 6
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
Geothermal	$76 billion
Small-scale hydro	$138 billion
Onshore wind	$110 billion
Low-emissions bioenergy	$148 billion
Weighted average costs *Assuming investments are 30% solar; 20% geothermal; 20% small-scale hydro; 15% onshore wind; and 15% low-emissions bioenergy*	**$111 billion**

Sources: 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.

percent solar PV, 20 percent geothermal and small-scale hydro respectively, and 15 percent respectively for onshore wind and low-emissions bioenergy. With these relative proportions, a weighted average of the capital costs for expanding the clean renewable energy supply by 1 Q-BTU would be $111 billion, as we show in Table 6.

This $111 billion figure can serve as a benchmark for estimating the average costs of expanding the supply of clean renewable energy within West Virginia. 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. 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 West Virginia will be $200 billion per Q-BTU, i.e. about 80 percent higher than the $111 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 West Virginia by 2030 and to reach net zero emissions by 2050.

2.6 Determinants of West Virginia's CO_2 Emission Levels

Table 7 shows how, as of 2018, West Virginia generated approximately 90 million tons of CO_2 from burning coal, oil and natural gas.[35] We also see the shares of total emissions generated by the respective sources, with coal at 63 million tons, natural gas at 12 million tons and petroleum at 15 million tons.

It is clear from these figures that driving down overall emissions in West Virginia from about 90 to roughly 45 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 coal, oil and natural gas will all fall by 50 percent as of 2030. Thus, as we see in Table 7, coal falls from 662 to 331 T-BTUs, natural gas falls from 223 to 112 T-BTUs and oil falls from 219 to 110 T-BTUs. Through following this scenario, total CO_2 emissions in West Virginia will fall by half, from approximately 90 to 45 million tons. Columns 4 and 5 of Table 7 present the calculations through which we derive this result.

TABLE 7
Sources of CO_2 Emissions for West Virginia: *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)*
Coal	661.8	63.1	95.3	331	32
Natural gas	222.9	12.0	53.8	112	6
Petroleum	218.6	14.6	66.8	110	7
TOTALS	**1,103.3**	**89.7**	**---**	**553**	**45**

Notes: Assumption made for the 2030 projected scenario is that oil, natural gas and coal are reduced by 50 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 West Virginia'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 West Virginia, 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 West Virginia, 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 8, we show these ratios for West Virginia, as well as, for comparison purposes, the United States overall and India, as well as seven other states: Pennsylvania, 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.

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 extremely low, at about $2,100.

TABLE 8

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 current U.S.$)*	Energy intensity ratio: *(in-state consumption only)* (*Q-BTUs/trillion dollars GDP*)	Emissions intensity ratio: *(in-state consumption only)* *CO_2 emissions in millions of tons/Q-BTU*
West Virginia	50.7	$40,500	10.3	121.2
United States	17.2	$60,062	5.0	57.2
India	1.8	$2,104	13.4	66.8
Pennsylvania	18.0	$58,204	5.1	60.6
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 are from https://www.iea.org/countries/india.

By contrast, per capita income in West Virginia as of 2017 was about $40,000. This is the lowest per capita income level among the 50 U.S. states for 2017. Still, West Virginia could, hypothetically, reduce its per capita emissions figure by half as of 2030 by also cutting per capita GDP in half, to around $20,000, 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 45 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 West Virginia's current level of per capita emissions at present. These are:

1. ***Energy efficiency:*** There are two ways in which we can measure West Virginia's energy efficiency level: in terms of the in-state energy consumption level only, or inclusive of the electricity generated in the state that is then exported to other states. We initially focus here on in-state consumption only, to simplify the comparison with other U.S. states, some of which are electricity importers and others are exporters. In discussions below, we also include in our efficiency measure the energy generated in West Virginia that is exported to other states as electricity.

   In terms of in-state energy consumption, West Virginia operates at an energy intensity ratio of 10.3 Q-BTUs of energy per $1 trillion in GDP. This 10.3 energy intensity ratio for West Virginia is fully twice as high as the U.S. average intensity ratio of 5.0. In other words, considering its in-state consumption level only, West Virginia consumes energy at only one-half the efficiency level of the U.S. overall. Its energy intensity ratio is also nearly twice as high as two other Appalachian states, Pennsylvania and Ohio. It is also 24 percent higher than Kentucky, a third Appalachian state. In terms of a broader set of states, West Virginia's energy intensity ratio is more than three times higher than New York and California, more than twice as high as Colorado and 25 percent higher than Texas.

   From this evidence, it is clear that West Virginia has a major opportunity to invest in dramatically raising the state's energy efficiency standards. Achieving major gains in energy efficiency will save significant amounts of money for all the state's energy consumers. It will also be the least expensive path through which the state can cut its emissions in half by 2030. We return to this point below.

2. ***Clean-burning energy:*** Considering still, for now, in-state energy consumption figures only—exclusive of energy generated in West Virginia for exports—the state's emissions intensity ratio of 121.2 million tons per Q-BTU of energy is more than twice as high as the U.S. average figure of 57.2. As such, a program to create a significant presence in the state for clean energy sources—solar, geothermal, small-scale hydro, wind, and low-emissions bioenergy—will be in full alignment with this project for the U.S. overall.

In addition to emphasizing these poor relative figures for West Virginia in terms of its energy intensity and emissions intensity ratios, we do need to also 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 average income in the state has grown. We can see the factors driving the absolute decoupling trend in Table 9. As the table shows, per capita emissions fell between 1999 and 2018 from 63.8

to 49.8 tons, while per capita GDP rose from roughly $38,000 to $44,000. This amounts to an average reduction in emissions per capita of about 1.2 percent per year while average per capita incomes rose by 0.7 percent per year. In a similar pattern, *total* emissions—i.e. not factoring in the size of West Virginia's population—fell from 115 to 90 tons, a -1.2 percent average annual rate of decline, while overall GDP in the state rose from $69 billion to $79 billion, an average annual increase in GDP of 0.8 percent. The state's population remained constant at 1.8 million over this 20-year period. These figures showing absolute decoupling in the state resulted solely through reducing the state's emissions intensity ratio from 161 to 104. This mostly reflects the growing role of natural gas in the state's energy mix between 1999 – 2018.

West Virginia's absolute decoupling trajectory between 1999 – 2018 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 0.8 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.

TABLE 9
Determinants of West Virginia State Per Capita CO_2 Emissions, 1999 and 2018
Level of growth, energy intensity, and energy mix

	Total CO_2 emissions *(in million metric tons)*	Population	Per capita emissions *(in metric tons)*	GDP *(in 2018 dollars)*	Per capita GDP *(in 2018 dollars)*	Energy consumption *(in T-BTUs)*	Energy intensity ratio *(Q-BTUs per trillion of 2018 dollars GDP)*	Emissions intensity ratio *(CO_2 emissions in millions of tons/Q-BTU)*
1999	114.8	1.8 million	63.8	$68.5 billion	$38,056	714	10.4	160.8
2018	89.7	1.8 million	49.8	$79.3 billion	$44,033	859	10.8	104.4

Source: See Table 8.

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 West Virginia down by 50 percent, to approximately 45 million tons by 2030, from its 2018 level of 90 million tons. The second is to advance this climate stabilization program while the West Virginia 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 West Virginia 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 West Virginia overall economy (GDP) will grow in real (i.e. inflation-adjusted) terms between now and 2030 at an average rate of 1.0 percent per year. This is modestly higher than the 0.8 percent average annual growth rate that West Virginia experienced over the recent 20-year period, i.e. 1999 – 2018. If we assume that the West Virginia 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 West Virginia 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 10, we first report on West Virginia'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 1.0 percent through 2030. We see that, under this growth assumption, West Virginia's real GDP will be $89.4 billion in 2030, growing from the 2018 figure of $79.3 bil-

TABLE 10
West Virginia GDP Levels, 2018 Actual and Projections for 2021, 2026, and 2030
Figures are in 2018 dollars

2018 GDP	$79.3 billion
Projected average growth rate through 2030	1.0%
Projected 2021 GDP	$81.7 billion
Projected 2030 GDP	$89.4 billion
Projected midpoint GDP between 2021 – 2030 (average of 2025 and 2026)	$85.4 billion

Source: BEA and authors' calculations.

lion. Assuming again a 1.0 percent average annual growth rate, the 2021 GDP will be $81.7 billion. The midpoint over the 2021 – 2030 decade will be effectively January 1, 2026. West Virginia's real GDP will be at $85.4 billion at that midpoint.

Within this framework, we can then project an energy and CO_2 emissions profile for West Virginia 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 11. Specifically, in column 1 of Table 11, we show the actual breakdown of energy consumption and emissions as of 2018. In column 2, we then present projected figures, assuming West Virginia's economy grows at an average annual rate of 1.0 percent through 2030 and the state's energy infrastructure remains basically intact. We term this the "steady state" energy infrastructure trajectory for West Virginia. In this scenario, all energy sources grow at exactly the state's overall 1.0 percent annual GDP growth rate.

In these figures, we now incorporate into the overall energy consumption figures the amount of energy consumed in the state to generate electricity for exporting to other U.S. states. The figures in this table for the energy intensity and emissions intensity ratios reflect this additional level of amount of energy consumed to produce the state's electricity exports. As noted above, in Table 8, we reported West Virginia's energy consumption level for its in-state consumption only, exclusive of electricity exports to other states. We now incorporate electricity exports into our calculations on the assumption that West Virginia will want to keep exporting electricity as a significant business activity in the state. The question on which to focus here is how West Virginia can achieve a 50 percent reduction in emissions while still maintaining a healthy electricity export market. Thus, starting in row 3, columns 1 and 2, we now report West Virginia's energy intensity ratio at 14.6, as opposed to the 10.3 figure shown in Table 8. Working from this 14.6 energy intensity ratio for 2018, we then hold this ratio constant in 2030 under the steady state scenario.

When we include West Virginia's energy consumption to produce for the export market, the state's emissions intensity ratio for 2018, as shown in row 17, falls to 77.5 million tons of CO_2 emissions per Q-BTU of consumed energy. This contrasts with the emissions intensity ratio shown in Table 8 of 121.2, in which we excluded electricity exports, as described above. By assumption within the steady-state framework for 2030, we hold this emissions intensity ratio, inclusive of electricity exports, at 77.5. Thus, in this steady state scenario between 2018 and 2030, we maintain West Virginia's basic energy infrastructure intact, with constant energy intensity and emissions intensity ratios.

Given the assumption of a stable energy infrastructure between 2018 and 2030 while the state's economy grows at 1.0 percent per year, we then see the impact on statewide CO_2 emissions in row 16 of Table 11. That is, total CO_2 emissions increase from 89.7 to 101 million tons, an increase of 12.6 percent.

In column 3 of Table 11, 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 45 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 West Virginia economy. Following from that prior discussion, we assume that, by 2030, West Virginia is capable of reducing the economy's energy intensity ratio, inclusive of electricity exports, from the 2018 level of 14.6 to 7.3 Q-BTUs per $1 trillion of GDP. This would be a 50 percent gain in overall energy efficiency

TABLE 11
West Virginia 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 1.0% average annual rate)*	3) 2030 through Clean Energy Investment Program
1) Real GDP *(in 2018 dollar)*	$79.3 billion	$89.4 billion	$89.4
2) In-state energy consumption + electricity exports *(T-BTUs)*	1,158	1,305	653
3) Energy intensity ratio, including in-state consumption + electricity exports *(Q-BTUs consumption/ $1 trillion of GDP)*	14.6	14.6	7.3
Energy mix			
4) Non-renewables and bioenergy (T-BTUs—rows 5 – 9)	*1,125*	*1,268*	*553*
5) Coal	662	746	331
6) Natural gas	223	251	112
7) Petroleum	219	247	110
8) High-emissions bioenergy	21	24	0
9) Nuclear	0	0	0
10) Clean renewables (T-BTUs—rows 2 to 4)	*33*	*37*	100 *(expansion = 67; 100 – 33)*
11) Solar (30% of expansion)	0	0	20
12) Geothermal (20% of expansion)	0	0	13
13) Hydro (20% of expansion)	17	19	30
14) Wind (15% of expansion)	16	18	26
15) Low-emissions bioenergy (15% of expansion)	0	0	10
Emissions			
16) Total CO_2 emissions *(million metric tons)*	89.7	101.0	45.0
17) Emissions Intensity Ratio *(CO_2 Emissions per in-state-consumption plus electricity exports, in Q-BTUs = row 16 / (row 2/1000))*	77.5	77.5	68.9

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.

in the state. It would bring West Virginia by 2030 to an efficiency level that is still almost 50 percent above the average U.S. level as of 2018. But as a result of this 50 percent gain in West Virginia's energy efficiency level, total energy consumption in 2030 under the clean energy investment program would fall from the steady-state figure of 1,305 T-BTUs to 653 T-BTUs.

We then need to consider the energy mix that will be necessary to allow for 653 T-BTUs of in-state consumption plus electricity exports while still maintaining emissions at no more than 45 million tons. As we have seen in Table 7, in order to bring overall CO_2 emissions in West Virginia down to 45 million tons by 2030, one viable path would be for the consumption of coal, natural gas, and oil to all fall by 50 percent relative to their 2018 levels. As we see in column 3 of Table 11, this implies that coal consumption is at 331 T-BTUs as of 2030, natural gas is at 112, and oil is at 110. West Virginia then continues to forego nuclear energy and allows high-emissions bioenergy to also phase-out completely.

This then entails that 100 T-BTUs of energy will need to be provided by clean renewable sources in order for West Virginia's overall energy consumption plus its electricity exports to be at 653 T-BTUs in 2030.

As of 2018, all clean renewable sources—solar, wind, low-emissions bioenergy, geothermal, and hydro—combined to supply only 33 T-BTUs of energy to West Virginia. Effectively then, 67 T-BTUs of *new supply* needs to be provided by solar, geothermal, hydro, wind and low-emissions bioenergy in order to bring West Virginia's total energy supply—for both in-state consumption and electricity exports—to 653 in 2030, with emissions falling by 50 percent, from 90 to 45 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 West Virginia by 67 T-BTUs, will require $13.4 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 67 T-BTUs in 2030 will be $1.3 billion per year.

In Table 12, panels A-C, we summarize the main features of the 2030 clean energy investment program. These include the following:

- ***Efficiency.*** $2.3 billion per year in energy efficiency investments between 2021 – 2030, amounting to about 2.7 percent of West Virginia's projected midpoint GDP between 2021 – 2030. These efficiency investments will generate 652 T-BTUs of energy savings relative to the steady state growth path for West Virginia through 2030.
- ***Clean renewables.*** $1.3 billion per year for investments in solar, geothermal, hydro, wind, and low-emissions bioenergy. This will amount to about 1.5 percent of West Virginia's projected midpoint GDP between 2021 – 2030. It will generate an increase of 67 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 $3.6 billion per year, or 4.2 percent of West Virginia's projected midpoint GDP between 2021 – 2030. Overall, this program will generate 719 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 West Virginia in 2030 will be 45 million tons, 50 percent lower than its level for 2018. West Virginia will have achieved this 50 percent emissions reduction while the state's economy also will have grown at an average rate of 1.0 percent per year through 2030.

TABLE 12

West Virginia Clean Energy Investment Program for 2021– 2030

A) Energy Efficiency Investments

1. 2030 In-state energy intensity ratio	7.3 Q-BTUs per $1 trillion GDP *(50% improvement over 14.6 Q-BTUs per $1 trillion GDP steady-state figure)*
2. Total energy in-state consumption	653 T-BTUs *(= 50% reduction relative 1,305 T-BTU steady-state figure)*
3. Energy saving relative to steady state	652 T-BTUs *(= 1,305 – 653 T-BTUs)*
4. Average investment costs per Q-BTU in efficiency gains	$35 billion per Q-BTU
5. Costs of energy savings	$22.8 billion *(= $35 billion x 0.652 Q-BTUs in savings)*
6. Average annual costs over 2021 – 2030	$2.3 billion *(= $22.8 billion/10)*
7. Average annual costs of efficiency gains as % of mid-point GDP	2.7% *(= $2.3 billion/$85.4 billion)*

B) Clean Renewable Energy Investments

1. Total clean renewable supply necessary	100 T-BTUs (= 653 T-BTUs total in-state consumption – 553 T-BTUs supplied by non-renewables/bioenergy)
2. Expansion of clean renewable supply relative to 2018 level	67 T-BTUs *(= 100 – 33 T-BTUs)*
3. Average investment costs per Q-BTU for expanding clean renewable supply	$200 billion per Q-BTU
4. Costs of expanding clean renewable supply	$13.4 billion *(= 0.067 Q-BTUs x $200 billion)*
5. Average annual costs over 2021 – 2030	$1.3 billion *(= $13.4 billion/10)*
6. Average annual costs of clean renewable supply expansion as % of midpoint GDP	1.5% *(= $1.3 billion/$85.4 billion)*

C) Overall Clean Energy Investments: Efficiency + Clean Renewables

1. Total clean energy investments	$36.2 billion *(= $22.8 billion for energy efficiency + $13.4 billion for clean renewables)*
2. Average annual investments	$3.6 billion *(= $36.2 billion/10)*
3. Average annual investments as share of midpoint GDP	4.2% *(= $3.6 billion/$85.4 billion)*
4. Total energy savings or clean renewable capacity expansion	719 T-BTUs *(= 652 T-BTUs in energy saving + 67 T-BTUs in clean renewable supply expansion)*

Sources: Tables 10 and 11.

Is $3.6 Billion per Year in Clean Energy Investments Realistic for West Virginia?

The short answer is "yes." To understand why, it is important to consider our estimate of West Virginia's annual clean energy investment needs within the broader context of the state's overall economic trajectory. As we have already noted above, this $3.6 billion annual investment figure represents about 4.2 percent of West Virginia's average GDP over 2021 – 2030, assuming that the state grows, on average, at about 1.0 percent per year over that 10-year period. In other words, our estimate of West Virginia's annual clean energy investment needs for bringing CO_2 emissions down in the state by 50 percent as of 2030 implies that 95.8 percent of all economic activity in West Virginia can continue to be directly engaged in activities *other than* clean energy investments.

It is also critical to recognize that West Virginia'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, geothermal, hydro, wind, and low-emissions bioenergy 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 $3.6 billion per year in total new clean energy investments in West Virginia? 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 West Virginia were able to utilize its set of effective state-level subsidies, 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 $7.7 million per year to deliver $3.6 billion in total clean energy investments in West Virginia. 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 $3.5 billion would be coming from private investors. The $7.7 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).[36]

However, for various reasons, this leverage ratio is almost certainly too high. The primary reason is that, to date, West Virginia has almost no capacity in terms of operating financial incentives in support of energy efficiency and renewable energy investments. On the other hand, we assume that the federal government will play a major role in advancing this program in West Virginia, both in terms of direct public funding and in terms of supporting various financial incentive programs for private investors.

It is still 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 West Virginia's state and municipal budgets. A reasonable low-end assumption would be that West Virginia 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.

As we have seen, the average level of funding for the investment program will be $3.6 billion per year. This would imply that state and federal government sources would need to contribute about $360 million on clean energy projects, an amount that would then be matched by about $3.2 billion in private sector investments. If we then assume that West Virginia state funds would provide 25 percent of the overall public funding while the federal government would supply 75 percent, that would imply that the state would need to contribute about $90 million per year in support of the investment program. The $90 million in state-level support would amount to about 2 percent of West Virginia's 2020 – 2021 state budget.

2.8 Clean Energy Investments and Job Creation

In Tables 13 and 14, we present our estimates as to the job creation effects of investing in energy efficiency in West Virginia. Tables 15 and 16 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. $2.3 billion in energy efficiency and $1.3 billion in clean renewable energy.

Direct, Indirect and Induced Job Creation

Before reviewing the actual data on job creation in Tables 13-16, 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 13-16, 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 13, we show the job creation figures per $1 million in spending for our five categories of efficiency investments: building retrofits; public transportation expansion and upgrades; industrial efficiency, including combined heat and power (CHP) technology; electrical grid upgrades; and expanding the high efficiency auto fleet, including electric vehicles. As Table 13 shows, direct plus indirect job creation per $1 million in spending ranges between a high of 18.0 jobs for public transportation expansion and upgrades to a negligible 0.06 jobs for expanding the high efficiency automobile fleet. Clearly, at least at present, West Virginia does not have any capacity for building electric or other high-efficiency automobiles, or any of the components of these vehicles along their supply chains. Of course, this could change in the future, through investments in manufacturing R&D and related activities in the state. We take up this topic in Section 3.

TABLE 13

Job Creation in West Virginia 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	4.0	1.9	5.9	1.8	7.7
Public transportation expansion/upgrades, including rail	14.5	1.2	15.7	2.3	18.0
Industrial efficiency, including combined heat and power	2.0	0.5	2.5	1.1	3.6
Electrical grid upgrades	2.9	0.5	3.4	1.2	4.6
Expanding high efficiency automobile fleet	0.03	0.01	0.04	0.02	0.06

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

TABLE 14

Annual Job Creation in West Virginia through Energy Efficiency Investments, 2021 – 2030

Job creation through average annual spending of $2.3 billion in efficiency investments

ASSUMPTIONS FOR ENERGY EFFICIENCY INVESTMENTS

- 40% on building retrofits
- 20% on public transportation expansion/upgrades
- 15% on combined heat and power (CHP) and other industrial efficiency measures
- 15% on on electrical grid 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	$920 million	3,680	1,748	5,428	1,656	7,084
Public transportation expansion/upgrades, including rail	$460 million	6,670	552	7,222	1,058	8,280
Industrial efficiency, including combined heat and power	$345 million	690	173	863	380	1,242
Electrical grid upgrades	$345 million	1,001	173	1,173	414	1,587
Expanding high efficiency automobile fleet	$230 million	0	0	0	0	0
TOTALS	**$2.3 billion**	**12,041**	**2,645**	**14,686**	**3,508**	**18,193**

Sources: See Tables 12 and 13.

In Table 14, we show the level of job creation through spending an average of $2.3 billion per year on these efficiency projects in West Virginia between 2021 - 2030. We have assumed that the overall level of funding is channeled into the various energy efficiency areas as follows: 40 percent for building retrofits; 20 percent for public transportation expansion and upgrades; 15 percent for both industrial efficiency and CHP and electrical upgrades; and 10 percent for expanding the fleet of high-efficiency automobiles.

The 10 percent allocation for purchasing high-efficiency automobiles will not generate any jobs within West Virginia. As noted above, all of these vehicles and their components will be manufactured elsewhere, and the vehicles will all be imported from other states or countries. Nevertheless, spending within the state to purchase these vehicles will contribute to raising the state's energy efficiency standards.

Aside from the absence of job creation through spending $230 million per year on purchasing high efficiency-autos, the overall result of $2.3 billion per year in efficiency investments in West Virginia will be the creation of 12,041 direct jobs and 2,645 indirect jobs, for a total of 14,686 direct plus indirect jobs created through this energy efficiency investment program. Including induced jobs adds another 3,508 jobs to the total figure. This brings the total job creation figure for efficiency investments, including induced jobs to 18,193 jobs.

Job Creation through Clean Renewable Energy Investments

In Table 15, we show the job creation figures for our five clean renewable energy categories—solar, geothermal, small-scale hydro, onshore wind, and low-emissions bioenergy. As we see, the extent of direct plus indirect jobs ranges from 1.5 direct plus indirect jobs per $1 million in expenditure for onshore wind projects to 6.4 direct and indirect jobs for investing $1 million in small-scale hydro. Adding induced jobs brings the range to 2.1 jobs for wind, 2.7 for solar, 4.5 for low-emissions bioenergy, 7.8 for geothermal and 8.6 for small-scale hydro.

Based on these proportions, we see in Table 16 the levels of job creation in West Virginia generated by spending an average of $1.3 billion per year between 2021 – 2030 in these areas of clean renewable energy. As we see in Table 16, we have divided total spending levels as follows: 30 percent for solar, 20 percent for geothermal and small-scale hydro; and 15 percent for onshore wind and low-emissions bioenergy respectively.

TABLE 15
Job Creation in West Virginia through Clean Renewable Energy Investments:
Job creation per $1 million in clean renewable investments

	Direct jobs	Indirect jobs	Direct + indirect jobs	Induced jobs	Direct, indirect + induced jobs
Solar	1.5	0.5	2.0	0.7	2.7
Geothermal	4.7	1.2	5.9	1.9	7.8
Small-scale hydro	5.5	0.9	6.4	2.2	8.6
Wind	1.2	0.3	1.5	0.6	2.1
Low-emissions bioenergy	3.0	0.4	3.4	1.1	4.5

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

TABLE 16
Annual Job Creation in West Virginia through Clean Renewable Energy Investments, 2021 – 2030
Job creation through average annual spending of $1.3 billion in clean renewable investments

ASSUMPTIONS FOR CLEAN RENEWABLE INVESTMENTS
- 30% on solar PV energy
- 20% on geothermal energy
- 20% on small-scale hydro
- 15% on onsore wind energy
- 15% on low-emissions bioenergy

	Spending amounts	Direct jobs	Indirect jobs	Direct + indirect jobs	Induced jobs	Direct, indirect + induced jobs
Solar PV	$390 million	585	195	780	273	1,053
Geothermal	$260 million	1,222	312	1,534	494	2,028
Small-scale hydro	$260 million	1,430	234	1,664	572	2,236
Onshore wind	$195 million	234	59	293	117	410
Low-emissions bioenergy	$195 million	585	78	663	215	878
TOTALS	**$1.3 billion**	**4,056**	**878**	**4,934**	**1,671**	**6,604**

Sources: See Tables12 and 15.

Following from these budgetary assumptions, we see in Table 16 that total direct plus indirect job creation generated in West Virginia by this large-scale expansion in the state's clean renewable energy supply will be 4,934 jobs. If we include induced jobs, then the total rises to 6,604 jobs.

Table 17 brings together our job estimates for both energy efficiency and clean renewable energy through spending about $3.6 billion per year on this project in West Virginia 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 17 that total average direct and indirect job creation for 2021 – 2030 is 19,620 jobs and 24,797 jobs when we add induced jobs to the total. As we see in row 13, this level of job creation amounts to between 2.5 and 3.1 percent of the total workforce in West Virginia as of 2019, the range depending on whether we include induced jobs in the total.

Indicators of Job Quality

In Table 18, we provide some basic measures of job quality for the jobs that will be generated through clean energy investments in West Virginia. These basic indicators include: 1) average total compensation (including wages plus benefits); and 2) the percentage that are union members.

We focus here on the *direct* jobs that will be created through clean energy investments in West Virginia. 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

TABLE 17

Annual Job Creation in West Virginia 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
$2.3 billion in energy efficiency		
1) Building retrofits	5,428	7,084
2) Public transportation expansion/ upgrades,including rail	7,222	8,280
3) Industrial efficiency,including combined heat and power	863	1,242
4) Electrical grid upgrades	1,173	1,587
5) Total energy efficiency job creation	*14,686*	*18,193*
$1.3 billion in clean renewables		
6) Solar	780	1,053
7) Geothermal	1,534	2,028
8) Small-scale hydro	1,664	2,326
9) Onshore Wind	293	410
10) Low-emissions bioenergy	663	878
11) Total job creation from clean renewables	*4,934*	*6,604*
12) TOTALS *(= row 5 + row 11)*	**19,620**	**24,797**
13) TOTAL AS SHARE OF 2019 WEST VIRGINIA LABOR FORCE *(Labor force at 796,966)*	**2.5%**	**3.1%**

Sources: Tables 14 and 16.

directly created jobs will most fully reflect the specific range of opportunities that will result through building a clean energy economy in West Virginia. The jobs created through the indirect and induced channels will be more diffuse in their characteristics. Indeed, the characteristics of the induced jobs created will simply reflect the overall characteristics of West Virginia's present-day workforce.

Starting with compensation figures, we see that the averages range widely, between about $26,000 for workers in the mass transit sector to about $91,000 in the industrial efficiency sector. Considering all of the workers in all the efficiency and renewable categories in one pool, the average compensation is $52,200.[37]

Only a minority of workers in the various clean energy sectors are represented by unions, with the figures ranging between 7 and 20 percent of the respective workforces. Nevertheless, the level of union representation in all 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 West Virginia can therefore serve as a foundation for raising job quality standards broadly, as the state's

TABLE 18
Indicators of Job Quality in West Virginia Clean Energy Industries: Direct Jobs Only

	Energy Efficiency Investments				Clean Renewable Energy Investments				
	1. Building retrofits *(3,680 workers)*	**2. Industrial efficiency** *(690 workers)*	**3. Grid upgrades** *(1,001 workers)*	**4. Mass transit** *(6,670 workers)*	**5. Solar** *(585 workers)*	**6. Wind** *(234 workers)*	**7. Low-emissions bioenergy** *(585 workers)*	**8. Geo-thermal** *(1,222 workers)*	**9. Small-scale hydro** *(1,430 workers)*
Average total compensation	$66,400	$91,500	$74,300	$26,500	$76,700	$77,000	$63,000	$68,200	$68,900
Union membership, percentage	19.6%	7.2%	7.5%	20.5%	14.3%	17.0%	19.1%	15.3%	18.6%

Sources: See Appendix 2.

clean energy transformation proceeds. As one feature of the overall clean energy transition project for West Virginia, 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 West Virginia 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 West Virginia'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 West Virginia 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 19, we present data on the educational credentials for workers in jobs that are directly tied to clean energy investment activities in West Virginia 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 West Virginia 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 19 shows, the level of educational credentials are generally similar across most industries. Thus, in 7 of the 9 industries listed, between 57 – 70 percent of the workers have high school degrees or less. The two exceptions are first, industrial efficiency, in which only 29 percent of the workers have high school degrees or less, while 46 percent have Bachelor's degrees or higher; and mass transit, in which 43 percent of workers have high school degrees or less than 26 percent have Bachelor's degrees.

TABLE 19
Educational Credentials and Race/Gender Composition of Workers in West Virginia Clean Energy Industries: Direct Jobs Only

	Energy Efficiency Investments				Clean Renewable Energy Investments				
	1. Building retrofits *(3,680 workers)*	**2. Industrial efficiency** *(690 workers)*	**3. Grid upgrades** *(1,001 workers)*	**4. Mass transit** *(6,670 workers)*	**5. Solar** *(585 workers)*	**6. Wind** *(234 workers)*	**7. Low-emissions bioenergy** *(585 workers)*	**8. Geo-thermal** *(1,222 workers)*	**9.Small-scale hydro** *(1,430 workers)*
Share with high school degree or less	70.4%	29.4%	68.2%	42.9%	57.0%	63.2%	69.9%	61.2%	67.8%
Share with some college or Associate degree	21.3%	25.1%	21.4%	31.1%	23.9%	23.0%	21.0%	23.0%	21.6%
Share with Bachelor's degree or higher	8.2%	45.5%	10.5%	26.0%	19.1%	13.9%	9.0%	15.8%	10.7%
Racial and gender composition of workforce									
Pct. non-white	4.2%	6.0%	3.0%	15.7%	5.2%	4.7%	4.4%	5.1%	4.3%
Pct. female	7.7%	32.7%	6.9%	26.3%	20.0%	14.3%	8.8%	14.9%	8.4%

Sources: See Appendix 2.

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 19 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 3 - 6 percent of the workforce. The one exception is mass transit, in which non-white workers account for 16 percent of the workforce. These figures are somewhat below the non-white share of the West Virginia population is about 8 percent.

The representation of women in the clean energy sectors of West Virginia's economy is proportionally much lower. The share of female employment is between 8 – 33 percent in West Virginia's clean energy economy at present, even while women make up a 47 percent of West Virginia's workforce.

Despite these disparities in the current composition of the workforce associated with clean energy investments in West Virginia, especially with regard to women, the large-scale expansion of these investments provides a major opportunity to increase opportunities for both people of color and female workers if they are combined with an initiative focused on equal opportunity in the growing clean energy investment areas, an initiative that 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 West Virginia through investments in energy efficiency and clean renewable energy, in Tables 20 – 24, we report on the prevalent job types associated with three of the major efficiency and renewable energy activities. Table 20 provides data for investments in building retrofits, our largest category of energy efficiency investments. Table 21 focuses on industrial efficiency, including combined heat and power (CHP), and Table 22 on public transportation. Table 23 then reports these same figures for the largest category of clean renewable energy investments, solar energy. Table 24 shows the employment profile for four areas of clean renewable energy investments combined, i.e. wind, low-emissions bioenergy, geothermal and hydro power. In all cases, we report on the job categories in which we estimate that 5 percent or more of the new jobs will be created through clean energy investments.

TABLE 20
Building Retrofits: Prevalent Job Types in West Virginia Industry
(Job categories with 5 percent or more employment)

Job category	Percentage of direct jobs created	Representative occupations
Construction	61.3%	First-line supervisors; electricians; construction equipment operators
Management	17.8%	Financial managers; general managers; chief executives
Installation and maintenance	5.2%	Machinery maintenance workers; telecommunications line installers; heavy vehicle mechanics

Sources: See Appendix 2.

TABLE 21
Industrial Efficiency, including Combined Heat and Power: Prevalent Job Types in West Virginia Industry
(Job categories with 5 percent or more employment)

Job category	Percentage of direct jobs created	Representative occupations
Business operation specialists	18.6%	Market research analysts; human resource workers; logisticians
Management	17.5%	Training managers; construction managers; chief executives
Construction	13.1%	Operating engineers; carpenters; construction laborers
Office and administrative support	11.9%	Customer service representatives; shipping clerks; first-line supervisors
Architecture and engineering	7.4%	Surveyors; engineering technicians; surveying technicians
Computer and mathematical science	7.1%	Computer network architects; computer systems analysts; computer programmers

Sources: See Appendix 2.

TABLE 22
Public Transportation: Prevalent Job Types in West Virginia Industry
(Job categories with 5 percent or more employment)

Job category	Percentage of direct jobs created	Representative occupations
Transportation	57.3%	Excavating machine operators; crane operators; bus drivers
Office and administrative support	15.6%	Bookkeeping clerks; dispatchers; secretaries
Construction	14.8%	Carpenters; electricians; construction laborers

Sources: See Appendix 2.

TABLE 23
Solar: Prevalent Job Types in West Virginia Industry
(Job categories with 5 percent or more employment)

Job category	Percentage of direct jobs created	Representative occupations
Construction	47.0%	First-line supervisors; construction equipment operators; electricians
Management	17.4%	Operation managers; financial managers; construction managers
Life, physical and social science	9.7%	Material scientists; biological scientists; physical science technicians
Office and administrative support	7.3%	General office clerks; accounting clerks; administrative assistants

Sources: See Appendix 2.

TABLE 24
Wind/Low Emissions Bioenergy/Geothermal/ Small-Scale Hydro: Prevalent Job Types in West Virginia Industry
(Job categories with 5 percent or more employment)

Job category	Percentage of direct jobs created	Representative occupations
Construction	54.5%	First-line supervisors; electricians; operating engineers
Management	18.4%	Financial managers; farmers; chief executives
Office and administrative support	5.5%	General office clerks, auditing clerks; secretaries

Sources: See Appendix 2.

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 construction jobs will be created through all the clean energy investment activities. Of course, this is true with the 61 percent of jobs created through building retrofit investments. But we also find that 47 percent of jobs in the solar sector will be in construction, along with 55 percent of jobs in other areas of renewable energy investments, along with 15 percent in public transportation and 13 percent in industrial efficiency. The specific types of construction 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.

Jobs in management also constitute a large share of overall job creation across all categories, accounting for between 17 – 18 percent in all industries other than public transportation. The share of management positions in public transportation is less than 5 percent. However, office and administrative support jobs make up 16 percent of employment in public transportation. Beyond this, what emerges generally from Tables 20-24 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 West Virginia 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 West Virginia through clean energy investments in the range of $2.6 billion per year, or 4.2 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. The overall average compensation level, at $52,200 is about 20 percent below the average compensation level for U.S. workers overall, which is about $65,000. In addition, as we will review below, this overall average compensation figure in the current clean energy sectors remain below those for workers in West Virginia'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 West Virginia is $8.75. 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).[38] A worker employed full-time year-round at West Virginia's minimum of $8.75 would make about $18,000 per year. 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 30 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, approximately one percent.[39]

By contrast, as we have seen, the level of union membership in West Virginia's clean energy sectors is well above the economywide national average for private sector workers. The expansion of West Virginia'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 West Virginia 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 25 and 26 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 25 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 25 B and C, as well as in the summary Table 26, 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).

It is clear therefore that high-quality and accessible workforce training programs need to be included as an important component of West Virginia'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 West Virginia, and elsewhere, so that women and people of color will have equal opportunities to move into the expanding clean energy economy.

TABLE 25

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 26
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/).

Which Clean Energy Projects Are "Shovel-Ready?"

Given the current recession conditions, it will be a challenge to move roughly $4 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. West Virginia's construction industry has been permitted to operate throughout the COVID pandemic, as Governor Justice deemed construction as an essential business activity. However, the level of activity has been reduced since March. It will certainly pick up once most of the state's population has been inoculated.[40]

As we saw in Table 13, the building retrofits investment program will generate about 8 jobs per $1 million in expenditures within West Virginia. Thus, $920 million in annual energy retrofit investments included in the Table 14 calculations will generate about 7,000 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 4 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.

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

3.1 Features of the Investment Program

West Virginia'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 five 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 roughly 2 percent of West Virginia's 2018 GDP level of $79 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 broad investment areas would receive $800 million 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--$800 million per year

1. Broadband development: $160 million/year
2. Water/wastewater/inland waterways upgrades: $160 million/year
3. Manufacturing R&D: $160 million/year
4. Dams/Levees upgrades: $160 million/year
5. Repairing existing gas distribution pipelines: $160 million/year.

Land Restoration and Agriculture--$800 million per year

1. Regenerative agriculture: $200 million/year
2. Farmland conservation: $200 million/year
3. Plugging orphaned oil and gas wells: $200 million/year
4. Land restoration: $200 million/year

These proposed funding areas and budget allocations broadly 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 2020 assessment of the American Society of Civil Engineers as to the conditions of West Virginia'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.[41]

In the area of "Creating Millions of Good, Safe Jobs with Access to Unions," the THRIVE Agenda includes the following as priorities[42]:

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 West Virginia's public infrastructure.
In 2020, the ASCE provided a detailed study, *Report Card for West Virginia's Infrastructure, 2020.*[43] Their assessment is that West Virginia's infrastructure deserves an overall grade of D. We consider here four of the five areas on which the ASCE has focused: bridges, dams, drinking water, and wastewater. We do not consider here the fifth area analyzed by the ASCE, i.e. roads. For the four areas that we do consider, the ASCE summarized its findings as follows[44]:

1. ***Bridges, D+*:** Over 95% of the state's 7,291 bridges are maintained by the West Virginia Division of Highways (WVDOH). Of those bridges, 21 percent or 1,531 are structurally deficient, a much higher percentage than the national average of 7 percent. Replacing, widening, strengthening, or repairing efforts are estimated to cost the state around $2.9 billion.
2. ***Dams, D:*** Seventy-five percent of the state's dams are classified as high hazard potential, and seventy-five percent of those have current Monitoring and Emergency Action Plans (MEAPs) – essentially tying the national average of seventy-four percent. With ever-rising costs for operation, maintenance, and repair, West Virginia still faces funding needs of more than $900 million and a long road ahead for increasing education and interest for protecting the state's dam infrastructure.
3. ***Drinking Water, D:*** Some drinking water systems in West Virginia are losing more than half of their treated water throughout the distribution systems. This non-revenue (lost) water requires investment in infrastructure replacements and technology improvements to locate and replace sections of the lines associated with the leaks. However, West Virginia has a very rough and rugged topography with many streams and rivers which make locating leaks difficult. This presents a major challenge for improving West Virginia's already

struggling drinking water infrastructure. Currently water utilities are seeking approximately $302 million to address their needs.

4. ***Wastewater, D:*** Many of West Virginia's wastewater utilities have worked diligently to operate and maintain their systems, but only a quarter of these utilities employ asset management to extend the infrastructure's life. Routine rehabilitation, service extensions, and day-to-day operations can overtax some utilities' resources because user rates are too low, the rate-paying population base is dwindling, and existing financing mechanisms are undesirable. Therefore, as of 2020 significant portions of the state's wastewater systems have deteriorated including 59 combined sewer systems requiring $1.2 billion to address state and federal requirements.

Civilian Conservation Corps 2.0 and Regenerative Agriculture and Agro-Forestry.
A 2020 paper by Patricia DeMarco and Sara Nicholas develops an agenda for Reimagine Appalachia that recommends four mutually reinforcing policies[45]:

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 [the] 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 cooperatives 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.

3.2 Job Creation through Investment Programs

Jobs through Manufacturing and Public Infrastructure Investments

In Table 27, we show the job creation figures for our five manufacturing and public infrastructure investment areas: broadband; water/wastewater/inland waterways; manufacturing R&D; dams/levees; and repairing leaky gas distribution pipelines. As we see, the extent of direct plus indirect jobs ranges from 2.2 direct plus indirect jobs per $1 million in expenditure for broadband development to 7.9 direct and indirect jobs for upgrading the state's dams and levees. Adding induced jobs brings the range to 2.9 jobs per $1 million for broadband to 10.5 for dams/levees.

Based on these proportions, we see in Table 28 the levels of job creation in West Virginia generated by spending an average of $800 million per year between 2021 – 2030 in these areas of manufacturing and public infrastructure investments at the levels of $160 million per year in each of the areas.

Following from these budgetary assumptions, we see in Table 28 that total direct plus indirect job creation generated in West Virginia by these investments will be roughly 3,600 direct plus indirect jobs and just under 4,900 jobs total if we include induced jobs.

Jobs through Land Restoration and Agriculture Investments

In Table 29, 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 3.5 per $1 million in expenditure for plugging orphaned wells, 5.8 for farmland

TABLE 27
Job Creation in West Virginia 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	1.4	0.8	2.2	0.7	2.9
Water/wastewater/inland waterways	4.9	1.3	6.2	2.0	8.2
Manufacturing R&D	2.0	1.2	3.2	1.1	4.3
Dams/levees	6.6	1.3	7.9	2.6	10.5
Gas distribution pipelines—repairing leaks	1.4	1.7	3.1	1.4	4.5

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

TABLE 28

Manufacturing and Public Infrastructure Investments for West Virginia, 2021 – 2030

Overall Program at $800 million per year

1 percent of 2019 West Virginia GDP (= $78.8 billion)

	Budget	Direct jobs	Indirect jobs	Direct+ indirect jobs	Induced jobs	Direct, indirect+ induced jobs
Broadband	$160 million	224	128	352	112	464
Water/wastewater/ inland waterways	$160 million	784	208	992	320	1,312
Manufacturing R&D	$160 million	320	192	512	176	688
Dams/levees	$160 million	1,056	208	1,264	416	1,680
Gas distribution pipe-lines—repairing leaks	$160 million	224	272	496	224	720
TOTALS	**$800 million**	2,608	1,008	3,616	1,248	4,864

Source: Table 27.

TABLE 29

Job Creation in West Virginia 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	31.8	2.0	33.8	0.4	34.2
Farmland conservation	4.9	0.9	5.8	1.7	7.5
Plugging orphaned oil and gas wells	1.9	1.6	3.5	1.4	4.9
Land restoration	6.0	1.4	7.4	2.4	9.8

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

conservation, 7.4 for land restoration and up to 33.8 for regenerative agriculture. Adding induced jobs brings the range to 4.9 per $1 million for plugging orphaned wells to 34.2 for regenerative agriculture.

Based on these proportions, we see in Table 30 the levels of job creation in West Virginia generated by spending an average of $800 million per year between 2021 – 2030 in these areas of land restoration and agriculture at the budget of $200 million per year for each project.

TABLE 30
Land Restoration and Agriculture Investment Program for West Virginia, 2021 – 2030
Overall Program at $800 million per year
1 percent of 2019 West Virginia GDP (= $78.8 billion)

	Budget	Direct jobs	Indirect jobs	Direct+ indirect jobs	induced Jobs	Direct, indirect+ Induced jobs
Regenerative agriculture	$200 million	6,360	400	6,760	80	6,840
Farmland conservation	$200 million	980	180	1,160	340	1,500
Plugging orphaned oil and gas wells	$200 million	380	320	700	280	980
Land restoration	$200 million	1,200	280	1,480	480	1,960
TOTALS	**$800 million**	8,920	1,180	10,100	1,180	11,280

Source: Table 29.

Following from these budgetary assumptions, we see that total direct plus indirect job creation generated in West Virginia by these investments will be 10,100 jobs and 11,280 jobs total if we include induced jobs.

Table 31 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 13,716, equal to 1.7 percent of West Virginia's 2019 workforce; and when induced jobs are included, the total comes to roughly 16,144 jobs, equal to 2.0 percent of the 2019 West Virginia workforce.

Indicators of Job Quality

In Table 32, 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 West Virginia. As with our discussion on clean energy investment jobs, the basic indicators again are: 1) average total compensation (including wages plus benefits); and 2) 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 West Virginia.

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 about $66,000 on average. At the high end are the jobs repairing gas pipelines, in which average pay is $128,000.

Average compensation also ranges widely in the areas of land restoration/agriculture. Plugging orphaned wells pays about $100,000 per year on average, while the jobs in farmland conservation and land restoration pay between $60,000 and $66,000. The extremely low figure for regenerative agriculture—an average compensation per year of $1,100, clearly requires some explanation.

TABLE 31

Annual Job Creation in West Virginia through 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
$800 million in manufacturing development and public infrastructure		
1) Broadband	352	464
2) Water/wastewater/inland waterways	992	1,312
3) Manufacturing R&D	512	688
4) Dams/levees	1,264	1,680
5) Gas distribution pipelines-repairing leaks	496	720
6) Total job creation from manufacturing development and public infrastructure	*3,616*	*4,864*
$800 million in land restoration and agriculture		
7) Regenerative agriculture	6,760	6,840
8) Farmland conservation	1,160	1,500
9) Plugging orphaned oil and gas wells	700	980
10) Land restoration	1,480	1,960
11) Total job creation from land restoration/ agriculture	*10,100*	*11,280*
12) TOTALS *(= row 6 + row 11)*	13,716	16,144
13) TOTAL AS SHARE OF 2019 WEST VIRGINIA LABOR FORCE *(Labor force at 796,966)*	**1.7%**	**2.0%**

Sources: See Tables 28 and 30.

This low compensation figure for the jobs created by regenerative agriculture investments reflects the fact that this spending primarily creates employment for farmers and farmers typically receive a low level of income from farming. This is due to the following reasons. First, many farms receive federal government subsidies that are intended to support food production and/or farmland conservation by stabilizing farmers' incomes. However, these subsidies are not counted as income. Second, most farmers use their farms as their residence and the value of the farm residence is also excluded from their compensation figures.[46] These factors can help explain the existence of many small, operating family farms in which farmers report near-zero--or even negative--income amounts from their farming activities.[47]

Putting aside this unique situation with regenerative agriculture, compensation figures are otherwise—at between $60,000 and $128,000—within a high range relative to average pay for all workers in West Virginia, which is about $52,700. This compensation range for

TABLE 32
Indicators of Job Quality in West Virginia Manufacturing/Infrastructure and Land Restoration/Agriculture Industries: *Direct Jobs Only*

	Manufacturing Development/Infrastructure Investments				
	1. Broadband *(224 workers)*	**2. Water/ wastewater** *(784 workers)*	**3. Manufacturing R&D** *(320 workers)*	**4. Dams/levees** *(1,056 workers)*	**5. Gas pipeline repairs** *(224 workers)*
Average total compensation	$80,300	$65,600	$71,700	$66,200	$128,400
Union membership, percentage	23.5%	17.2%	0.0%	16.1%	38.9%

	Land Restoration/Agriculture Investments			
	6. Regenerative agriculture *(6,360 workers)*	**7. Farmland conservation** *(980 workers)*	**8. Plug orphaned wells** *(380 workers)*	**9. Land restoration** *(1,200 workers)*
Average total compensation	$1,100*	$60,100	$101,100	$66,400
Union membership, percentage	1.8%	2.1%	26.3%	2.9%

Note: *See discussion on p. 62 about the compensation figure for regenerative agriculture.
Sources: See Appendix 2.

the infrastructure/public investment and land/restoration also compares well with the figure for fossil fuel based employment in West Virginia. As we will see in Section 5, that figure is $77,327.

Unionization rates vary widely by the various specific activities. There is basically no union presence in the area of manufacturing R&D, and very little—between 1.8 and 2.9 percent—in regenerative agriculture, farmland conservation and land restoration. But in the areas of gas pipeline repairs, water management, dams/levees, broadband, and plugging orphaned wells, unionization rates are relatively high, ranging between 16 – 40 percent.

Overall, as indicated by these measures, we see in Table 32 that job quality standards in West Virginia for workers in the areas of manufacturing/infrastructure and land restoration/agriculture are broadly comparable, if not better, than those in the various clean energy activities. The one exception, again, is regenerative agriculture, which operates under a unique situation. Overall, 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, 23 percent pay less than $15.00 per hour. The figure for agriculture/land restoration investments is similar: 25 percent of direct jobs created by such spending pay wage rates below $15.00 per hour. Raising the pay rates of these jobs would entail a modest one percent increase in investment spending.

Educational Credentials and Race/Gender Composition

In Table 33, 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 West Virginia as well as the race and gender composition of these workers.

Educational Credentials

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

As Table 33 shows, there are large disparities in educational attainment levels based on the specific projects we are considering. Not surprisingly, in the area of manufacturing

TABLE 33
Educational Credentials and Race/Gender Composition for West Virginia Manufacturing Development/Infrastructure and Land Restoration/Agriculture Investments:
Direct Jobs Only

	Manufacturing Development/Public Infrastructure Investments				
	1. Broadband *(224 workers)*	**2. Water/ wastewater** *(784 workers)*	**3. Manufacturing R&D** *(320 workers)*	**4. Dams/levees** *(1,056 workers)*	**5. Gas pipeline repairs** *(224 workers)*
Share with high school degree or less	63.3%	62.0%	12.5%	63.9%	52.2%
Share with some college or Associate degree	22.0%	24.2%	32.4%	23.1%	23.2%
Share with Bachelor's degree or higher	14.6%	13.8%	55.2%	13.0%	24.6%
Racial and gender composition of workforce					
Pct. non-white	3.6%	5.1%	8.4%	4.9%	3.4%
Pct. female	15.8%	17.8%	60.5%	12.1%	8.2%

	Land Restoration/Agriculture Investments			
	6. Regenerative agriculture *(6,360 workers)*	**7. Farmland conservation** *(980 workers)*	**8. Plug orphaned wells** *(380 workers)*	**9. Land restoration** *(1,200 workers)*
Share with high school degree or less	63.5%	33.9%	51.6%	48.8%
Share with some college or Associate degree	17.6%	21.4%	23.8%	24.0%
Share with Bachelor's degree or higher	18.9%	44.8%	24.6%	27.2%
Racial and gender composition of workforce				
Pct. non-white	6.5%	3.5%	5.3%	6.7%
Pct. female	23.6%	48.3%	8.6%	23.4%

Sources: See Appendix 2.

R&D, educational attainment levels are high, with 55 percent of workers holding Bachelor's degrees or higher. By contrast, with most of the other activities, 34 percent or more of the workers have lower attainment levels, with high school degrees or less. In four sectors—broadband, water management, dams/levees, and regenerative agriculture—over 60 percent of workers have 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 R&D, fully 61 percent of all jobs are held by women and 8.4 percent are held by people of color, which is comparable to the West Virginia population as a whole. The representation of women is also relatively high, at 48 percent, in farmland conservation, but is lower otherwise, with low figures in the areas of broadband and dams/levees between 12 and 16 percent, water management at 18 percent and repairing gas pipelines at 8 percent. Outside of the manufacturing R&D sector, the share of jobs held by people of color ranges between 3.4 and 6.7 percent, i.e. below the non-white share of West Virginia's population overall, at about 8 percent. Thus, as is the case with West Virginia's clean energy economy, in order for the investments in manufacturing/infrastructure and land restoration/agriculture to create increased opportunities for people of color and women in the state will require a focus on equal opportunity employment policies.

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

Table 34 reports on the prevalent job types associated with investments in manufacturing/infrastructure and Table 35 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, about 36 percent of all employment in manufacturing/infrastructure will be in construction occupations, including jobs for equipment operators, carpenters, and construction laborers. The R&D investment areas will of course create employment for environmental scientists, chemists, and biologists. Jobs will also expand for bookkeeping clerks, customer service representatives, loading machine operators, telecommunication line operators and general maintenance workers. 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 32 – 35 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 West Virginia that will have been displaced by the contraction of the state's fossil fuel industry activities.

TABLES 34

Manufacturing Development and Infrastructure: Prevalent Job Types in West Virginia Industry

(Job categories with 5 percent or more employment)

Job category	Percentage of direct jobs created	Representative occupations
Construction	35.7%	Construction equipment operators; carpenters; construction laborers
Management	14.9%	Financial managers; general managers; construction managers
Office and administrative support	9.8%	Bookkeeping clerks; customer service representatives; administrative assistants
Transportation and material moving	7.4%	Tower operators; loading machine operators; laborers
Production	5.9%	First-line supervisors; inspectors; water treatment plant operators
Installation and maintenance	5.9%	Mobile equipment service technicians; telecommunications line repairers; general maintenance workers
Life, physical and social science	5.6%	Environmental scientists; chemists; biological scientists

Source: See Appendix 2.

TABLES 35

Agriculture and Land Restoration: Prevalent Job Types in West Virginia Industry

(Job categories with 5 percent or more employment)

Job category	Percentage of direct jobs created	Representative occupations
Management	46.1%	Chief executives; community service managers; farmers
Farming, fishing, and forestry	20.7%	Logging workers; conservation workers; agricultural products graders and sorters
Transportation	5.2%	First-line supervisors; recyclable material collectors; freight movers

Source: See Appendix 2.

4. TOTAL JOB CREATION IN WEST VIRGINIA THROUGH COMBINED INVESTMENT PROGRAMS

We include this brief Section 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 Sections 2 and 3. These include:

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

As we have shown in Sections 2 and 3, we have scaled these investment projects at an average of $5.2 billion per year over 2021 – 2030, equal to about 6.1 percent of West Virginia's projected average GDP for 2021 – 2030. The proposed budget allocations include $3.6 billion per year for clean energy, including $2.3 billion per year in efficiency investments and $1.3 billion annually in clean renewable energy. This is the figure that we have estimated will be needed to achieve a 50 percent reduction in West Virginia's CO_2 emissions by 2030. We have also budgeted $800 million per year respectively for manufacturing/public infrastructure and land restoration/agriculture, totaling to $1.6 billion per year in these two areas.

We summarize the impact of these investment projects in Table 36. As the table shows, we estimate that these projects, in combination, will generate about 33,000 direct and indirect jobs per year in West Virginia, amounting to about 4.2 percent of West Virginia's labor

TABLE 36

Annual Job Creation in West Virginia through Combined Investment Programs

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

Estimates are annual averages for 2021 – 2030

Overall Investments at $5.2 billion/year; 6.1% of West Virginia GDP

	Number of direct and indirect jobs created	Number of direct, indirect and induced jobs created
1) $2.3 billion/year in energy efficiency	14,686	18,193
2) $1.3 billion/year in clean renewable energy	4,934	6,604
3) $800 million/year in manufacturing/public infrastructure	3,616	4,864
4) $800 million/year in land restoration/agriculture	10,100	11,280
5) Total for All Investment Areas (= rows 1 – 4)	33,336	40,941
13) TOTAL AS SHARE OF 2019 WEST VIRGINIA LABOR FORCE *(Labor force at 796,966)*	**4.2%**	**5.1%**

Sources: See Tables 17 and 31.

force as of 2019. When we include induced job creation (i.e. "multiplier effects"), total job creation rises to nearly 41,000 jobs, equal to about 5.1 percent of West Virginia's 2019 labor force.

As a simple exercise to illustrate the potential impact of this level of job creation in West Virginia, 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 3 percent. A reduction in West Virginia'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.

5. JUST TRANSITION FOR FOSSIL FUEL INDUSTRY-DEPENDENT WORKERS AND COMMUNITIES

5.1 Employment Levels and Contraction

As we have shown above, in order for West Virginia to bring total CO_2 emissions down from its 2018 level of 90 million tons to no more than about 45 million tons by 2030, we have developed a 10-year program for reducing the consumption of coal, natural gas and oil by 50 percent as of 2030. As we have seen, coal, natural gas, and oil provided 95 percent of West Virginia's overall energy supply in 2018 including electricity exports to other states. That is, these are the predominant sources of energy supply in West Virginia at present.

The issue on which we focus in this section is what the impact will be on workers in industries in West Virginia that are dependent on statewide consumers, along with electricity importers from other states, continuing to purchase fossil fuel energy supply. 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. by 50 percent across-the-board for all fossil fuel sources.[48] In particular, we develop here a just transition program for the workers in these fossil fuel related sectors who will face displacement as a result of the statewide contraction in the consumption of CO_2-producing energy sources.

Our primary concern in this section is on the *direct* jobs that will be lost in West Virginia through the contraction of the state's fossil fuel-based industries. Our reasoning for focusing on the contraction of direct jobs is the same as we discussed above with respect to the job quality issues regarding clean energy investments in the state. That is, the direct jobs that will be lost in West Virginia through the cuts in CO_2-generating energy sources are the jobs that are, at present, most closely associated with the state's fossil fuel-based industry activities. The workers currently employed in these jobs will therefore be the ones that will be most in need of just transition support as West Virginia 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 West Virginia'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 West Virginia 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 37, we show employment levels for the 14 fossil fuel-based industries in West Virginia as of 2018. As we see, as of 2018, there are 40,188 people employed in the fossil fuel and ancillary industries in West Virginia. Of these, 12,793 (32 percent) are employed in coal mining, 10,892 (27 percent) work in oil and gas extraction, and 5,182 (13 percent) are in support activities for oil and gas support activities. Thus, these three sectors—coal mining, oil and gas extraction and support activities for oil and gas—together account for 72 percent of total employment in all of West Virginia's fossil fuel-based industries. The other

TABLE 37
Number of Workers in West Virginia Employed in Fossil Fuel-Based Industries, 2018

Industry	2018 Employment levels	Industry share of total fossil fuel-based employed
Coal mining	12,793	31.8%
Oil and gas extraction	10,892	27.1%
Support activities for oil/gas	5,182	12.9%
Fossil fuel electric power generation	2,851	7.1%
Drilling oil and gas wells	2,178	5.4%
Pipeline construction	1,932	4.8%
Support activities for coal	976	2.4%
Pipeline transport	945	2.4%
Natural gas distribution	798	2.0%
Wholesale -petroleum and petroleum products	723	1.8%
Mining machinery and equipment manufacturing	401	1.0%
Petroleum refining	347	0.9%
All other petroleum and coal products manufacturing	103	0.3%
Oil and gas field machinery and equipment manufacturing	67	0.2%
Fossil fuel industry total	**40,188**	**100%**
TOTAL FOSSIL FUEL EMPLOYMENT AS SHARE OF WEST VIRGINIA STATE EMPLOYMENT *(West Virginia 2018 employment = 744,326)*	**5.4%**	

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

three major sources of fossil fuel industry-based employment in West Virginia are fossil fuel-based power generation, oil and gas drilling, and pipeline construction. Together, these three industries account for another 17 percent of total fossil fuel-based jobs. The six largest industries by employment therefore account for nearly 90 percent of all fossil fuel-based employment in the state.

Characteristics of Fossil Fuel-Based Industry Jobs

Table 38 provides basic figures on the characteristics of the direct jobs in West Virginia for workers in fossil-fuel based sectors. We first see that, on average, these are relatively high-paying jobs. The average overall compensation is $77,327, 32 percent more than the average pay level for full set of energy efficiency and clean renewable energy jobs in the state, which is at $52,200.

Union membership is at 17 percent. This is broadly in line with most of the various clean energy industries, as well as much higher than the figure for the overall U.S. economy of 6.2 percent.

TABLE 38
Characteristics of Workers Employed in West Virginia's Fossil Fuel-Based Sectors

	Fossil fuel-based industries
Average total compensation	$77,327
Union membership coverage	17.0%
Educational credentials	
Share with high school degree or less	57.1%
Share with some college or Associate degree	24.1%
Share with Bachelor's degree or higher	18.8%
Racial and gender composition of workforce	
Pct. non-white workers	4.6%
Pct. female workers	8.5%

Source: See Appendix 2.

Table 38 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, 57 percent of workers have high school degrees or less while 19 percent have BA degrees or higher. Women account for only 8.5 percent of the workforce, and people of color account for 4.6 percent.

In Table 39, we gain further detailed information on workforce and employment conditions for workers in West Virginia'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 West Virginia provide a wide range of employment opportunities for the roughly 40,000 workers currently employed in these industries. As we see, the largest share of jobs, at roughly 28 percent, are in extraction, including earth drillers, derrick operators and roustabouts. Another 17 percent are in construction, including construction laborers, pipelayers, and operating engineers. There are also large numbers of people employed, respectively, in transportation, installation and maintenance, engineering, and office support.

Overall, from the data presented in Table 39, we see that a large number of jobs match up well with new types of employment that will be generated through clean energy investments in West Virginia, 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 West Virginia's fossil fuel-based activities, starting, of course, with extraction. As such, any just transition program to support displaced workers in West Virginia'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 West Virginia transitions out of CO_2-generating energy sources.

TABLES 39
Prevalent Job Types in West Virginia's Fossil Fuel-Based Sectors
(Job categories with 5 percent or more employment)

Job category	Percentage of direct jobs lost	Representative occupations
Extraction	27.6%	Earth drillers; derrick operators; roustabouts
Construction	17.2%	Construction laborers; pipelayers; operating engineers
Management	10.6%	Construction managers; property managers; general managers
Transportation	10.1%	Hoist operators; pumping station operators; freight movers
Installation and maintenance	7.2%	Refractory machinery mechanics; electrical power-line installers; heavy vehicle service technicians
Architecture and engineering	7.2%	Electrical engineers; mining safety engineers; industrial engineers
Office and administrative support	5.9%	Utilities meter readers; customer service representatives; administrative assistants

Source: See Appendix 2.

5.2 Features of a Just Transition Program

We present here a just transition program for workers who face job losses through direct channels from the 50 percent contraction of the state's coal, natural gas and oil industries. 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 40.

As we see in Table 40, 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.

TABLE 40
Policy Package for Displaced Workers in West Virginia's Fossil Fuel-Based Industries

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

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 West Virginia. Specifically, the scope and cost of any set of just transition policies will depend substantially on whether the contraction is steady or episodic.

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

The costs of a 10-year just transition will be much lower if the transition is able to proceed smoothly rather than through a series of episodes. One reason is that, under a smooth transition, the proportion of workers who will retire voluntarily in any given year will be substantially greater than if several large businesses were to shut down abruptly and lay off their full workforce 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 West Virginia will successfully implement a relatively steady contraction of its fossil fuel sectors. As we will see, a steady 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 41, we show figures on annual employment reductions in West Virginia's fossil-fuel based industries over 2021 – 30 that would result from a steady contraction of these industries.

We also then show the proportion of workers who will move into voluntary retirement at age 65 by 2030. Once we know the share of workers who will move into voluntary retirement at age 65, we can then estimate the number of workers who will be displaced through the 50 percent contraction of the fossil fuel industries. As described above, the just transition program will provide support for all displaced workers through a re-employment guarantee along with wage insurance, retraining, and relocation support.

All forms of just transition support will also be fully available to those workers 65 and over who choose to continue working. We therefore need to estimate how many workers 65 and older are likely to choose to remain employed. For the fossil fuel sector taken as a whole, we approximate that about 20 percent of workers who are 65 and over choose to continue on their jobs.[49] 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 41 an estimate that, of the total number of workers reaching age 65 in any given year, 80 percent will retire voluntarily while 20 percent will choose to continue working.

TABLE 41
Attrition by Retirement and Job Displacement for Fossil Fuel Sector Workers in West Virginia

	Fossil fuel workers
1) Total workforce as of 2018	40,188
2) Job losses over 10-year transition, 2021 – 2030	20,094
3) Average annual job loss over 10-year production decline *(= row 2/10)*	2,009
4) Number of workers reaching 65 over 2021 – 2030 *(=row 1 x % of workers 54 and over in 2019)*	8,078 *(20.1% of all workers)*
5) Number of workers per year reaching 65 during 10-year transition period *(=row 4/10)*	808
6) Number of workers per year retiring voluntarily	646 *(80% of 65+ workers)*
7) Number of workers requiring re-employment *(= row 3 - row 6)*	1,363

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

We can see, step-by-step, how these various considerations come into play through the figures we show in Table 41. As we again see in column 2 of Table 41, there were, as of the most recent 2018 figures, 40,188 workers in West Virginia employed in all fossil fuel-based industries. We assume that all the fossil fuel-based industries will contract by 50 percent. As we see in row 2 of the table, this means that total employment in these sectors will fall by exactly half as of 2030, to 20,094. This which means that there will be another 20,094 jobs retained. If we then assume that the contraction in these industries proceeds at a steady rate between 2021 – 2030, this means that 2,009 jobs in these industries will be lost each year, as we see in row 3 (i.e. 20,094 job losses in total/10 years of industry contraction = 2,009 job losses per year).

We see in row 4 that, of the workers presently employed in these sectors in West Virginia, 8,078, or 20 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 808 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 646 workers employed in these sectors will retire voluntarily every year between 2021 – 2030.

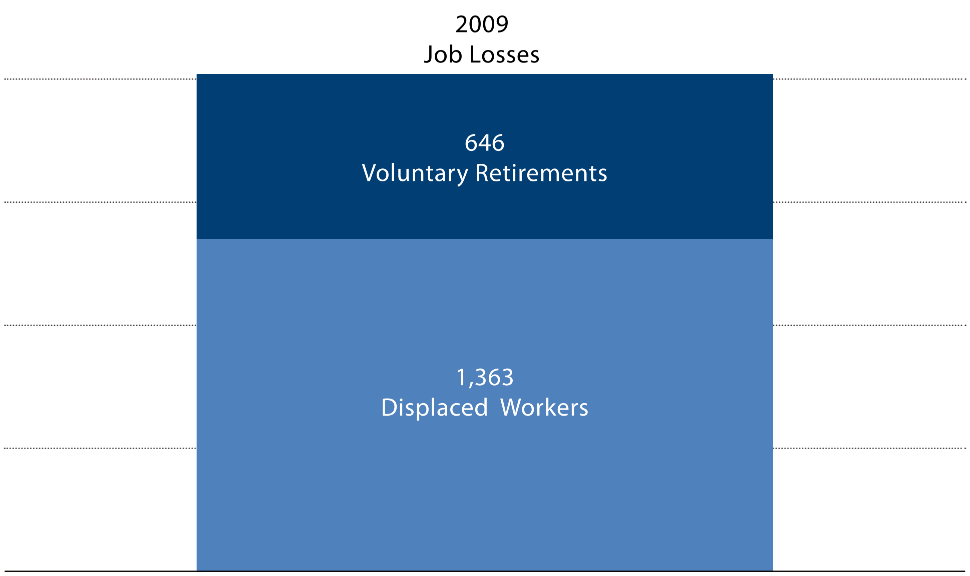
Given that total job losses each year will average 2,009 over the 2021 – 2030 period, that in turn means that the total number of workers currently employed in West Virginia's fossil fuel-based sectors that will require re-employment will be 1,363 per year. We show this figure in row 7 of Table 41.

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 646 workers per year moving into voluntary retirement; and 2) Providing all the forms of re-employment support, including the re-employment guarantee, for the 1,363 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 West Virginia who are likely to experience job displacement through the state's transitioning away from CO_2-generating energy sources will be small—indeed, the number of workers facing displacement should be in the range of 1,400 per year. Given that there are over 40,000 people employed presently in West Virginia's fossil fuel-based industries, we acknowledge that it may appear implausible that there should be only about 1,400 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 41, this finding is not due to any kind of unreasonable assumptions or incomprehensible mathematical manipulations.

In Figure 1, we illustrate the main results of our calculations in Table 41.

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



Source: See Table 41.

5.3 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 West Virginia'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 West Virginia 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.[50]

Guaranteed Re-employment

New employment opportunities will certainly open up in the expanding clean energy sectors, with approximately 25,000 jobs created per year in West Virginia through clean energy investments at the level of $3.6 billion per year (see Table 17).[51] We estimate that the investments in manufacturing/infrastructure and land restoration/agriculture, financed at $1.6 billion per year, will generate another roughly 16,000 jobs.

Overall then, these investment projects are capable of generating roughly 40,000 new jobs in West Virginia. These projects will also be financed substantially through public-sector funding. Given such public sector funding, the state could require job preference provisions for the displaced workers. Again, our estimate of the number of displaced workers that will need re-employment is about 1,400 in total. Within the overall pool of 40,000 jobs being generated through the clean energy, infrastructure/manufacturing and land restoration/agriculture investments, it will not be difficult for the state to set aside 1,400 guaranteed jobs for these displaced workers, or, for that matter, even, say, 5,000 jobs, as needed for this purpose.

Income Support through Wage Insurance

Though it will not be difficult to find new employment opportunities for the 1,400-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 West Virginia at present is about $77,000. This compares with the average compensation in the clean energy areas

TABLE 42
Estimating Costs of 100 Percent Compensation Insurance for Displaced Workers in West Virginia's Fossil-Fuel Based Sectors

1. Number of fossil fuel-based displaced workers per year requiring re-employment	1,363
2. Average compensation for displaced workers	$77,300
3. Average compensation for clean energy sector jobs	$52,200
4. Average compensation difference between fossil fuel-based and clean energy jobs *(= row 2 - row 3)*	$25,100
5. Annual cost of compensation insurance for 1,363 workers *(= row 4 x row 1)*	$34.2 million
6. Total cost of compensation insurance for 3 years *(= row 5 x 3)*	$102.7 million

Source: See Tables 18, 38, and 41.

of $52,000, though, as we saw in Table 18, the pay range is wide in the clean energy sectors, between $27,000 and $92,000. In all cases, it will, in any case, 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 42 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 41 on the number of displaced workers in the fossil-fuel based sectors—i.e. 1,363 workers per year. Row 2 then shows their average compensation level of $77,300. In row 3, we show the mean compensation level for all of West Virginia's clean energy sectors, as reported in Table 18, which is $52,200. From this difference in average compensation levels, we then calculate that the annual cost of compensation insurance for 1,363 workers will be about $25,000 per worker, totaling to about $34 million. The total spending amount for 3 years of support for each displaced worker would be about $103 million.

Retraining Support

As we have seen above (Tables 19 – 24), 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 working in extraction. This is why a just transition program must include a provision for retraining for the displaced fossil fuel-based industry workers. The just transition program will also need to serve as a job placement clearinghouse for all displaced workers.

There will be two components of this job retraining program for displaced workers. The first will be to finance the actual training programs themselves. We can estimate this with reference to the overall costs of providing community college education. An average figure for annual non-housing costs for community college in West Virginia is around $$4,313.[52] We then also allow an additional $2,157 per year per worker—50 percent of the non-housing costs—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 1,363 workers would be about $16 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 1,363 displaced workers per year will need relocation allowances, at an average of $75,000 per displaced worker.[53] That would bring the annual relocation budget to about $51.2 million for 682 workers each year.

Overall Costs for Supporting Displaced Workers

In Table 43, we show estimates of the full costs of providing this set of wage insurance, retraining and relocation support for 1,363 workers per year. As Table 43 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 1,363 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 $94.2 million in 2021. Costs increase in 2022, since we now have two cohorts of displaced workers receiving income and retraining support, as well as one cohort receiving relocation support. Thus, total costs in 2022 rise to $137.2 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 $171.5 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 $77.3 million, then to $34.2 million.

In total over the full period 2021 – 2032, just transition benefits provided to 1,363 displaced workers in West Virginia will total to $1.7 billion, or an average of $142.9 million per year over 12 years. The total costs per worker will amount to about $42,000 per year and about $126,000 per worker in total over three years.

TABLE 43
Total and Annual Average Costs for Just Transition Support for Displaced Fossil Fuel-Based Workers in West Virginia, 2021 – 2030

Year	Income support *(3 years of support for 1,363 workers)*	Retraining support *(2 years of support for 1,363 workers)*	Relocation support *(1 year of support for 682 workers)*	Total *(cols. 1+2+3)*
2021	$34.2 million (1 cohort)	$8.8 million (1 cohort)	$51.2 million	$94.2 million
2022	$68.4 million (2 cohorts)	$17.6 million (2 cohorts)	$51.2 million	$137.2 million
2023	$102.7 million (3 cohorts)	$17.6 million (2 cohorts)	$51.2 million	$171.5 million
2024	$102.7 million (3 cohorts)	$17.6 million (2 cohorts)	$51.2 million	$171.5 million
2025	$102.7 million (3 cohorts)	$17.6 million (2 cohorts)	$51.2 million	$171.5 million
2026	$102.7 million (3 cohorts)	$17.6 million (2 cohorts)	$51.2 million	$171.5 million
2027	$102.7 million (3 cohorts)	$17.6 million (2 cohorts)	$51.2 million	$171.5 million
2028	$102.7 million (3 cohorts)	$17.6 million (2 cohorts)	$51.2 million	$171.5 million
2029	$102.7 million (3 cohorts)	$17.6 million (2 cohorts)	$51.2 million	$171.5 million
2030	$102.7 million (3 cohorts)	$17.6 million (2 cohorts)	$51.2 million	$171.5 million
2031	$68.4 million (2 cohorts)	$8.8 million (1 cohort)		$77.3 million
2032	$34.2 million (1 cohort)			$34.2 million
Total	**$1.0 billion**	**$176.4 million**	**$511.5 million**	**$1.7 billion**
Average annual costs	**$85.6 million** *(12 years of support)*	**$16.0 million** *(11 years of support)*	**$51.2 million** *(10 years of support)*	**$142.9 million** *(12 years of support)*

Sources: See Tables 40–42.

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 West Virginia 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 West Virginia even as the fossil fuel-based industries themselves contract.

5.4 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 West Virginia is relatively high, at about at about 40,000 jobs. This is equal to 5.4 percent of overall employment in the state. After Wyoming and North Dakota, West Virginia's share of employment for all fossil fuel-based workers is the third highest in the United States.[54]

It is critical to recognize here that the decline of West Virginia's fossil fuel industry will be occurring in conjunction with the rapid expansion of its clean energy economy, along with parallel investment programs 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.[55]

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.[56] 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.[57] 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.[58] 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.[59] 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.[60] 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.[61] 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.[62]

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.[63] 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.[64]

An example of the type of community transition projects that could be viable in West Virginia has been outlined for Colstrip, Montana in a 2018 study *Doing It Right: Colstrip's Bright Future with Cleanup*.[65] This study is authored jointly by the Northern Plains Resource Council and the International Brotherhood of Electrical Workers (Local 1638). As the study documents, the Colstrip Steam Electricity Station, owned by Talen Energy, contains 4 electricity generating units that supply the region with electricity. The plant employs 388 workers. Moreover, coal for the plant is supplied by the nearby Rosebud mine, which employs another 373 workers. However, two of the four units are scheduled to close by July 2022.

The coal ash generated by these 2 plants are disposed of in ash ponds spread over 278 acres in the area. The ash ponds have produced serious contamination of the local groundwater. As a result of a series of lawsuits, Talen Energy has been required to remediate the groundwater contamination, with the completion of the project to occur no later than 2049.

Doing it Right documents the types of jobs that would be created by this remediation project. They include: heavy equipment operator, electrician, environmental engineer, groundwater sampling technician, septic system operator, as well as more generic occupations such as mechanic, fence erector, truck driver, security guard, and construction crews.

The authors of the study acknowledge that their estimate as to the number of jobs that will be generated by the remediation project is still preliminary. But the evidence they provide suggests that the number of jobs created is likely to be in the range of 200, i.e. about half of the nearly 400 jobs that currently exist at the two power plants. The remediation project would therefore not provide a full one-for-one replacement in terms of total employment in the area relative to the job losses resulting from the closing of the two power plants. But the remediation project will provide an alternative foundation on which to maintain a healthy local economy. Jobs created through building a new clean energy infrastructure in the area will expand opportunities further off of this new foundation. The study does also point out that, in general, remediation of brownfield sites throughout the U.S has lead to increases in property values while, not surprisingly, allowing sites to remain contaminated greatly detracts from their commercial value.

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.[66] As one important example of this repurposing project in the Ruhr region, RAG AG, a German coal-mining firm, is in the process of converting its Prosper-Haniel coal mine into a 200 megawatt pumped-storage hydroelectric reservoir that acts like a giant battery. The capacity is enough to power more than 400,000 homes in North-Rhine Westphalia.[67] 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 West Virginia will be to effectively integrate transition programs with the coming wave of public and private investments in energy efficiency and clean renewable energy as well as in manufacturing development, public infrastructure, land restoration and agriculture. As we have seen, we estimate that, in combination, these new investment projects in West Virginia are capable of generating more than 40,000 new jobs in the state, equal to roughly 5 percent of the state's 2019 workforce.

6. FINANCING WEST VIRGINIA'S RECOVERY AND SUSTAINABLE TRANSITION PROJECTS

In Sections 2 – 5 of this study, we presented proposed investments and just transition programs for West Virginia whose total costs come to an average of $5.3 billion per year between 2021 – 2030. These overall costs include the following:

- $3.6 billion per year for clean energy and energy efficiency;
- $1.6 billion per year for public investment/manufacturing and land reclamation/agriculture;
- $143 million per year in just transition support for displaced workers in fossil fuel-based industries.

However, as we discussed in Section 2, of this $5.3 billion total, we assume that more than half of the funds would be provided by private investors. Specifically, we assume that with the clean energy program, $1 dollar of public funds would be capable of leveraging $9 in private investment. Based on this assumption, it follows that annual *public spending* on clean energy and energy efficiency will amount to $360 million per year while private investment spending will total to about $3.2 billion.

Thus, the total annual public sector budget for these programs would be $2.1 billion, including:

- $1.6 billion per year for public infrastructure/manufacturing and land reclamation/agriculture
- $360 million per year for public funding of clean energy investments
- $143 million per year for just transition support

This $2.1 billion overall public spending figure would amount to an average of 2.4 percent of West Virginia's average GDP between 2021 – 2030, assuming the economy grows at an average rate of 1 percent per year.

Federal Stimulus Support

How would a spending program at this level be financed in West Virginia? We can begin by considering funds that would be available from the federal government. In December 2020, the federal government, still under former President Trump, passed a $900 billion economic recovery bill, the COVID-19 Economic Relief Bill. Most of the funds provided in this bill are targeted to provide various forms of short-term support over the remaining course of the COVID-induced recession. This includes $600 in direct payments for individuals earning less than $75,000 per year, $300 a week in supplemental unemployment insurance benefits, $285 billion for small business loans, $82 billion for public education, $70 billion for production and distribution of vaccines, and smaller amounts for child-care workers, rental assistance, and food security. The overall package does also allocate a relatively small but still significant amount, $35 billion, to fund wind, solar and other clean energy projects.[68]

In addition to these already allocated funds from the federal government, the Biden administration introduced in mid-January 2021 the American Rescue Plan. This is an additional short-term recovery proposal, budgeted now at $1.9 trillion beyond the $900 billion already allocated through the December bill. Most of the funding priorities in Biden's proposed American Rescue Plan are similar to those included in the December measure, but with higher levels of spending attached. These include an additional $1,400 in direct payments to individuals, $400 per week in additional supplemental unemployment insurance, along with major support for state and local governments, a major increase in spending for distributing COVID vaccines and expanding the tax credit for families with children.[69]

These funds will provide an important short-term boost to the West Virginia economy as well as to the U.S. economy overall. If West Virginia were allocated a share of the overall funds equal to its 0.5 percent share of the U.S. population, the state would be receiving a $4.5 billion injection from the December bill. The state would receive an additional $9.5 billion in support from Biden's proposed American Rescue Plan.

In combination then, the December COVID-19 Economic Relief Bill and the proposed American Rescue Plan would deliver $14 billion to West Virginia. This amount is 7 times greater than the annual figure we are proposing for the clean energy, infrastructure/manufacturing and land restoration/agriculture investment programs and the just transition support for displaced fossil fuel industry workers. However, almost none of the funds from these two measures will have been allocated to directly support the investment and just transition programs we have proposed here. For example, of the $35 billion total allocated for clean energy investments in the December bill, West Virginia would receive $175 million, assuming funds are allocated based on relative population size. Nevertheless, these stimulus funds will certainly provide indirect support through strengthening the economic recovery.[70]

Federal Public Investment Initiatives: "Build Back Better" and "THRIVE"

A central policy proposal during President Biden's campaign was his "Build Back Better" infrastructure and clean energy investment program. This campaign proposal was for $2 trillion in federal funds to be spent over Biden's first term in office—i.e. at an average rate of $500 billion per year for four years. The overall Build Back Better campaign proposal included the following investment areas:

> Building and repairing roads and bridges, ports, airports, water systems, electric grids and broadband; investing in the automotive sector from parts to materials to electric vehicle charging stations; building and upgrading rail networks and working towards zero-emission public transportation; investing in green power (solar, wind); upgrading 4 million buildings and "weatherizing" 2 million homes to make them more energy efficient; constructing 1.5 million sustainable housing units; and investing in clean energy technologies such as battery storage, emissions technology, green hydrogen and advanced nuclear.[71]

This Biden campaign proposal is similar in its aims to the "THRIVE Agenda" which we have summarized in Section 3. In September 2020, before becoming Senate Majority Leader in January 2021, Senator Chuck Schumer pledged to establish THRIVE as a "top priority" for 2021.[72]

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

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

These budget allocations total to $864 billion per year.[73] Thus, the THRIVE Agenda allocates roughly $360 billion more—i.e. about 70 percent more—in annual investment spending in these areas than the amounts provided in Biden's Build Back Better campaign proposal.

As of this writing, we do not know what will be the final proposal introduced by the Biden administration. But even after the Biden proposal is publicly presented, it will, of course, require weeks and perhaps months before a final version of the measure is enacted in Congress and signed into law by Biden.

Recognizing these uncertainties, it will be useful to consider here a range of possibilities as to the level of support West Virginia could receive through the final version of Biden's Build Back Better program or any similar federal initiative. For purposes of illustration, let us assume, initially, that whatever are the final national funding allocations of this bill, West Virginia's share of the total allocation will be proportional to its 0.5 percent share of the U.S. population. Under the $500 billion per year Biden campaign proposal, West Virginia would then receive $2.5 billion per year. Under the THRIVE program, West Virginia's allocation would rise to $4.4 billion per year.

However, it would be also reasonable to allow that West Virginia should receive a larger share of the overall funding budget. This larger share for West Virginia would reflect the fact that West Virginia's economy is much more dependent on the fossil fuel industries than most U.S. states. West Virgina will correspondingly face much more significant challenges than most other states in moving onto a clean energy transition path.

But even if we assume that federal funding support will be at the lower-end Biden Build Back Better campaign proposal, as opposed to the Congressional THRIVE Agenda, and that West Virginia's share of total funding is only equal to its 0.5 percent population share, the state would still end up receiving $2.5 billion per year in funding to support public investment and infrastructure programs similar to those that we have presented here. More specifically, the $2.5 billion Biden Build Back level of funding would more than fully cover the total $2.1 billion annual public spending budget that we have proposed for the full set of clean energy, infrastructure/manufacturing, and land restoration/agriculture investments, along with the just transition program for displaced fossil fuel industry workers. In short, the prospects are favorable that the public funding to support the full set of initiatives that we have introduced will be financed in total by the federal government.

State Government Support for Capital Investment Projects

In addition to this potential federal funding support, the West Virginia state government is also capable of making supplemental contributions to the public investment, infrastructure and just transition programs. By statute, the West Virginia state government does have the capacity to issue bonds to support certain types of capital projects which have been authorized by constitutional amendments approved by voters.[74] Historically, such capital projects have typically been in the area of transport infrastructure such as roads and bridges, such as those authorized by the 2017 Roads to Prosperity Amendment to the West Virginia Constitution. As of June 30, about $200 million in bonds were still left to be issued under the Roads to Prosperity Amendment, which must be issued before July 2021.[75]

If approved by voters, future capital projects could also include public-sector led clean energy investments to, for example, raise energy efficiency standards in public buildings through retrofitting. Financing of such capital projects is limited by the amounts prescribed in the constitutional amendments. To authorize new levels of financing to support investments, for example, in clean energy and land restoration, another constitutional amendment would need to be initiated by a two-thirds majority in the West Virginia legislature, and brought before voters. This process would take no less than four months due to consultation times built into the amendment process.[76]

While these legal requirements would be cumbersome, it is important to recognize that, at present, bonds issued by the state and municipalities in West Virginia are being marketed at very low rates. As of 2/3/21, the yield on West Virginia state and municipal bonds ranged narrowly between 0.9 and 1.1 percent.[77] Depending on Federal Reserve policy over the coming year, these rates could remain very low and perhaps even fall further, i.e. to near-zero.[78] With West Virginia's state and municipal governments being able to borrow at such low rates, the prospects will remain highly favorable for the state to provide supplemental funding in behalf of moving West Virginia onto a robust economic recovery path and a sustainable long-term growth trajectory.

Appendix 1
Employment Estimating Methodology

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

One important point to note here is that I-O models to date do not identify, for example, renewable energy industries such as wind, solar, or geothermal, or energy efficiency industries such as building retrofits, industrial efficiency, or grid upgrades.[79] 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 existing industries in the I-O model. By identifying the relevant industries and assigning weights to each, we can create "synthetic" industries representing each of the renewable energy and energy efficiency industries within the model, as well as the manufacturing/infrastructure and land restoration/agriculture industries. 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 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 relatively rapidly. While it may be possible for construction and service activities to keep pace with the rapid scaling up of clean energy consumption in West Virginia, we assume that manufacturing facilities will take longer to develop. While manufacturing activity will expand within the state, some clean energy manufacturing will develop out of state in the first ten years of clean energy expansion. Here we make the conservative assumption that all sectors will expand at their existing domestic content. Thus, the employment multipliers will be lower in this constrained case than if we assume that all sectors, including manufacturing, will be produced domestically. In the IMPLAN model, we reduce the regional purchasing content to the existing levels to incorporate this change.

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

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

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

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

Industries	Composition and Weights of Industries within the I-O Model
Broadband	10% cable subscription programming, 25% construction of new power structures, 20% wired telecommunication services, 20% wireless telecommunication services, 10% fiber optic cable manufacturing, 15% miscellaneous electrical equipment.
Water and wastewater infrastructure	30% water and sewage, 25% construction of other new nonresidential structure, 10% plastic pipe, 5% concrete pipe, 5% iron and steel pipe, 5% fabricated pipe, 10% other support services, 10% waste management.
Manufacturing 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 crops, 20% animal production, 10% beef cattle ranching, 5% labor and civic organizations, 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: Clean Renewable Energy Sectors

	Direct, indirect, and induced jobs per $1 million	
	If all sectors expanded 100 percent	Constrained: all sectors expand at existing domestic content
Wind (onshore)	3.4	2.1
Solar PV	4.6	2.7
Geothermal	10.4	7.8
Small-scale hydro	9.5	8.6

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 the over 500 industries through our input-output model (IMPLAN) as explained in Appendix 1.

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

Our information about the workers currently employed in the industrial mix of jobs created by an investment comes from the Current Population Survey (CPS). The CPS is a household survey administered by the U.S. Census Bureau, on behalf of the Bureau of Labor Statistics of the U.S. Labor Department. The basic monthly survey of the CPS collects information from about 60,000 households every month on a wide range of topics including basic demographic characteristics, educational attainment, and employment status. Among a subset of its monthly sample—referred to as the outgoing rotation group (ORG)—respondents are asked more detailed employment-related questions, including about their wages and union status. We pool data from 2015-2019 for our analyses.[80]

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 nation and state. We adjust the CPS-provided sampling weights by multiplying each individual worker's sampling weight with the following:

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

where S is a scalar equal to the number of direct jobs produced overall by the level of investment being considered. For example, say West Virginia's investment in solar power of $400 million would generate 600 direct jobs, then S is equal to 600.

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

We use these adjusted sampling weights to estimate the 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.

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.

We can therefore use IMPLAN to model the industry distribution of the jobs that will be lost as the fossil fuel related sectors in West Virginia 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.

There is one analysis in which we use the QCEW wage and salary employment data as opposed to the IMPLAN employment data. This is in our analysis of the share of fossil fuel-based employment across states discussed in Section 5 of the main text and presented in the following Appendix 3.

Appendix 3
Fossil Fuel-Based Industry Employment by State

Table A3.1 presents shares of fossil fuel-based industry employment for all 50 U.S. states. These figures are for private sector wage and salary employment only, as reported by the Department of Labor's Quarterly Census of Employment and Wages (QCEW). As noted in the main text, these QCEW employment figures vary somewhat from the IMPLAN employment figures we discuss in the main report and related studies. This is because the IMPLAN employment figures include all proprietors employment in addition to wage and salary workers (see discussion in Appendix 2). However, we do not have a full set of IMPLAN employment figures for all 50 states. In order to make a consistent comparison in fossil fuel-based employment across all 50 states, we use the QCEW figures as a proxy for providing these state-by-state comparative figures.

TABLE A3.1
Share of 2018 Employment in Fossil Fuel-Related Industries, by State

State	1. Wage and Salary Private Sector Employment in Fossil Fuel Related Industries	2. Total Wage and Salary Private Sector Employment	3. Fossil fuel employment as % of state employment (col. 1/col. 2)
U.S. TOTAL	1,188,144	124,551,838	1.0%
1. Wyoming	24,512	207,335	11.8%
2. North Dakota	26,901	346,756	7.8%
3. West Virginia	35,991	559,118	6.4%
4. Oklahoma	74,131	1,285,704	5.8%
5. Alaska	12,125	246,319	4.9%
6. Louisiana	70,388	1,612,079	4.4%
7. New Mexico	27,838	645,435	4.3%
8. Texas	382,383	10,429,485	3.7%
9. Colorado	35,493	2,255,703	1.6%
10. Montana	5,879	381,664	1.5%
11. Kansas	14,022	1,139,242	1.2%
12. Mississippi	9,629	897,893	1.1%
13. Pennsylvania	53,831	5,193,979	1.0%
14. Kentucky	15,538	1,592,256	1.0%
15. Utah	10,646	1,247,220	0.9%
16. Alabama	13,107	1,598,129	0.8%
17. Arkansas	6,988	1,014,114	0.7%
18. Ohio	31,934	4,687,246	0.7%
19. Indiana	17,547	2,659,130	0.7%
20. Hawaii	3,316	536,370	0.6%

TABLE A3.1 *(cont.)*
Share of 2018 Employment in Fossil Fuel-Related Industries, by State

State	1. Wage and Salary Private Sector Employment in Fossil Fuel Related Industries	2. Total Wage and Salary Private Sector Employment	3. Fossil fuel employment as % of state employment (col. 1/col. 2)
21. Michigan	18,256	3,776,481	0.5%
22. Illinois	22,646	5,193,821	0.4%
23. Virginia	12,894	3,188,362	0.4%
24. New Jersey	13,345	3,472,611	0.4%
25. Minnesota	9,297	2,498,328	0.4%
26. Iowa	4,438	1,309,819	0.3%
27. California	48,886	14,876,010	0.3%
28. South Dakota	1,150	352,997	0.3%
29. Massachusetts	8,973	3,156,298	0.3%
30. Wisconsin	6,899	2,497,801	0.3%
31. Delaware	1,046	384,332	0.3%
32. Missouri	6,335	2,381,261	0.3%
33. Maryland	5,711	2,188,298	0.3%
34. Washington	7,161	2,810,692	0.3%
35. Nebraska	1,814	816,876	0.2%
36. Maine	1,147	518,990	0.2%
37. Florida	16,485	7,635,037	0.2%
38. North Carolina	7,879	3,710,090	0.2%
39. New Hampshire	1,204	574,083	0.2%
40. Tennessee	5,247	2,560,978	0.2%
41. New York	15,080	8,017,398	0.2%
42. Georgia	7,027	3,777,824	0.2%
43. Nevada	2,172	1,216,080	0.2%
44. Connecticut	2,416	1,449,072	0.2%
45. Vermont	409	257,141	0.2%
46. South Carolina	2,572	1,743,243	0.1%
47. Oregon	2,374	1,648,323	0.1%
48. Idaho	862	611,396	0.1%
49. Arizona	2,861	2,436,592	0.1%
50. Rhode Island	316	421,767	0.1%

Source: 2018 annual average data from the Quarterly Census of Employment and Wages (QCEW) of the Department of Labor.

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://energy.law.wvu.edu/files/d/b1ff1183-e9ae-4ad0-93bf-aa3afa1da785/wv-s-energy-future-wvu-col-cesd-final.pdf.

3 https://www.nytimes.com/2021/01/24/us/west-virginia-vaccine.html.

4 https://covidactnow.org/us/west_virginia-wv/?s=1568508. The figures on infection and death rates are also from the COVID Act Now website.

5 https://governor.wv.gov/Pages/The-Comeback.aspx.

6 https://wvde.us/wp-content/uploads/2021/01/Roadmap-to-Recovery-v4.pdf.

7 https://www.wvnews.com/news/wvnews/west-virginia-education-unions-files-legal-action-sayreopening-orders-unsafe/article_15c7472b-7560-59a3-ba75-5062ddd5255b.html.

8 Formally, the figures reported in Table 3 are derived by multiplying the industry-specific employment loss figures shown in Table 2 by the percent of overall employment—in West Virginia and the U.S. overall—as shown in the "industry job loss as % of total state employment loss" columns in Table 3.

9 https://www.wvnews.com/statejournal/news/west-virginia-economy-recovering-ahead-of-national-average-during-pandemic-but-full-recovery-not-expected/article_cc45cb2b-0b90-50d0-b06c-a5891c73ae09.html.

10 https://wvpolicy.org/west-virginia-has-a-long-road-ahead-to-full-recovery/.

11 https://www.c2es.org/document/climate-action-plans/; https://www.c2es.org/document/greenhouse-gas-emissions-targets/; https://www.c2es.org/document/climate-action-plans/; https://www.c2es.org/document/energy-efficiency-standards-and-targets/; https://www.c2es.org/document/us-state-clean-vehicle-policies-and-incentives/.

12 https://www.wvlegislature.gov/Bill_Status/bills_history.cfm?INPUT=583&year=2020&sessiontype=RS .

13 https://www.bowlesrice.com/in-focus-blog/utility-scale-solar-projects-in-west-virginia.

14 https://programs.dsireusa.org/system/program/detail/104; https://programs.dsireusa.org/system/program/detail/561.

15 https://www.energycodes.gov/adoption/states/west-virginia .

16 https://programs.dsireusa.org/system/program/detail/4835; https://programs.dsireusa.org/system/program/detail/4834; https://programs.dsireusa.org/system/program/detail/5491.

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); Romm (2014); Howarth (2015); and Peischl (2015).

19 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.

20 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. https://www.documentcloud.org/documents/6889670-Scientist-Letter-to-Congress-8May20.html.

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

22 https://www.fs.fed.us/nrs/pubs/rb/rb_nrs105.pdf.

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

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

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

26 See the discussion and references in Pollin et al. (2015), pp. 92 – 96. We note there that average rebound effects are likely to be significantly larger in developing economies.

27 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.

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

29 https://energy.law.wvu.edu/files/d/b1ff1183-e9ae-4ad0-93bf-aa3afa1da785/wv-s-energy-future-wvu-col-cesd-final.pdf, p. 8

30 Douglas G. Hall, Kelly S. Reeves, Julie Brizzee, Randy D. Lee, Gregory R. Carroll, and Garold L. Sommers, "Feasibility Assessment of the Water Energy Resources of the United States for New Low Power and Small Hydro Classes of Hydroelectric Plants," (Idaho Falls: Idaho National Laboratory, 2006), p. v, available at: http://www1.eere.energy.gov/water/pdfs/doewater-11263.pdf.

31 Lea Kosnik, "The Potential for Small Scale Hydropower Development in the U.S.," *Energy Policy* 38 (10) (2010): 5512–5519, p. 5512.

32 See Chomsky and Pollin (2020) pp. 78 – 79 for further details and references on these issues.

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 We do not include in these calculations the small additional emissions generated through consuming high-emissions bioenergy. But, as we discuss more below, we assume that high-emissions bioenergy is phased out entirely in West Virginia as of 2030, while low-emissions bioenergy sources become a significant energy source as of 2030.

36 https://wvpress.org/breaking-news/governors-flat-state-budget-plan-for-w-va-includes-no-pay-raises-or-major-new-initiatives/.

37 This figure is equal to the average compensation from each clean energy sector weighted by number of direct jobs created.

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

39 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 30 percent of workers in direct, clean energy jobs would earn less than $15.00 per hour, or 4,829 direct jobs (16,097 direct jobs x 30 percent). These workers earn, on average, $11.90 and work 35 hours weekly. We then assume these workers work 50 weeks over the year. Therefore, raising these workers' wages by $3.10 per hour to $15.00 would sum to just over $26 million ($3.10/hr. x 35 hrs./wk. x 50 wks. x 4,829 direct jobs = $26.2 million). $26 million is equal to 0.7 percent of the annual clean energy investment figure of $3.6 billion.

40 https://www.timeswv.com/covid-19/construction-industry-works-through-coronavirus/article_5592f466-a13e-11ea-af42-2f006039a9ca.html. /

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

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

43 https://www.infrastructurereportcard.org/state-item/west-virginia/.

44 The quotes are from the Executive Summary of the full study, which can be found here: https://www.infrastructurereportcard.org/wp-content/uploads/2020/12/ASCE_BrochureWV2020_final.pdf.

45 Patricia DeMarco and Sara Nicholas (2020) "Heal our Land and our People—Civilian Conservation Corps 2.0 and Regenerative Agriculture and Agro-Forestry," https://reimagineappalachia.org/wp-content/uploads/2020/10/Reimagine-Appalachia-Regenerative-Ag-CCC-Whitepaper-10-28-2020.pdf.

46 https://www.nass.usda.gov/Publications/AgCensus/2017/Full_Report/Volume_1,_Chapter_1_US/st99_1_0052_0052.pdf; https://www.ers.usda.gov/topics/farm-economy/farm-household-well-being/glossary/#income.

47 https://www.ers.usda.gov/webdocs/publications/95547/eib-214.pdf?v=9906.4.

48 We emphasize that this assumption of a 50 percent decline in production and employment in West Virginia's fossil fuel industries by 2030 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 West Virginia's fossil fuel related businesses will find it profitable to maintain a disproportionately large workforce even while overall demand declines because doing so maintains their operations at the most effective level. By contrast, it could also follow with some firms that the decline in demand for their products will encourage them to lay off workers by a more than proportional extent—i.e. to reorganize production with a higher level of capital intensity. Some firms could also shut down altogether due to the steady decline in demand (Pollin and Callaci (2018) discuss this latter prospect more fully). Given this range of possibilities—some of which are counteracting—on balance, we conclude, again, that the most reasonable working assumption for our purposes is that the decline in production and employment in West Virginia's fossil fuel related industries will be commensurate with the decline in statewide consumption as well as electricity exports.

49 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.

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

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

52 https://www.univstats.com/community-colleges/?state=WV.

53 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.

54 We present shares of fossil fuel-based industry employment for all U.S. states in Appendix 3. However, the figures we report in Appendix 3 are for wage and salary employment only, as reported by the Department of Labor's Quarterly Census of Employment and Wages (QCEW). These figures vary somewhat from the employment figures we discuss in the body of this and related studies provided by IMPLAN. The IMPLAN figures include proprietors in its employment pool in addition to wage and salary workers. But because we do not have a full set of IMPLAN employment figures for all 50 states, we use the QCEW figures as a proxy for providing these state-by-state comparative figures.

55 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/.

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

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

58 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) reviews these issues in detail.

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

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

61 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/.

62 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).

63 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.

64 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.

65 https://mtstandard.com/news/state-and-regional/doing-it-right-colstrip-s-bright-future-with-cleanup/pdf_378a5b32-d4e0-504c-982d-bd230ab7ea5a.html.

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

67 See, for example, Chow (2017).

68 https://www.nytimes.com/2020/12/28/business/economy/second-stimulus-package.html.

69 https://www.whitehouse.gov/briefing-room/legislation/2021/01/20/president-biden-announces-american-rescue-plan/.

70 https://www.whitehouse.gov/briefing-room/blog/2021/02/03/the-economics-of-the-american-rescue-plan/?fbclid=IwAR3bynaZYWNYreHUwzgm3zgT9kK4GoShKCqeoXHlLYBBXONna9RvuDBWzZE.

71 https://www.icis.com/explore/resources/news/2021/01/15/10595873/us-infrastructure-plan-to-be-unveiled-in-february-in-2nd-step-of-massive-stimulus.

72 https://www.sierraclub.org/sites/www.sierraclub.org/files/THRIVE_%20A%20Bold%20Plan%20for%20Economic%20Renewal.pdf.

73 https://www.sierraclub.org/sites/www.sierraclub.org/files/THRIVE-jobs.pdf.

74 West Virginia Constitution, various Amendments: http://wvlegislature.gov/WVCODE/WV_CON.cfm.

75 https://www.wvlegislature.gov/legisdocs/reports/agency/T03_FY_2020_14832.pdf.

76 West Virginia Constitution, Article 14: http://wvlegislature.gov/WVCODE/WV_CON.cfm.

77 https://westvirginia.municipalbonds.com/bonds/recent/.

78 https://www.brookings.edu/research/fed-response-to-covid19/.

79 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.

80 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.

References

Ackerman, Frank, Pat Knight, and Bruce Biewald. 2016. "Estimating the Cost of Saved Energy," December. www.synapse-energy.com/sites/default/files/COSE-EIA-861-Database-66-017.pdf.

Alston & Bird, Jamie Furst, and Andrew Howard. August 13, 2020. "The Moving America Forward Act: If Passed, Will Result in Increased Opportunities for Infrastructure Work and Contracting With the Federal Government." JD Supra. https://www.jdsupra.com/legalnews/the-moving-america-forward-act-if-66813/.

Alvarez, Ramón A., Stephen W. Pacala, James J. Winebrake, William L. Chameides, and Steven P. Hamburg. 2012. "Greater Focus Needed on Methane Leakage from Natural Gas Infrastructure." *Proceedings of the National Academy of Sciences* 109 (17): 6435–40. https://doi.org/10.1073/pnas.1202407109.

American Society of Civil Engineers (ASCE). n.d. "West Virginia Infrastructure Overview." ASVE's 2018 Infrastructure Report Card. https://www.infrastructurereportcard.org/state-item/west-virginia/. Accessed February 11, 2021.

———. n.d. "Report Card for West Virginia's Infrastructure." ASVE's 2020 Infrastructure Report Card. https://www.infrastructurereportcard.org/wp-content/uploads/2020/12/ASCE_BrochureWV2020_final.pdf. Accessed February 11, 2021.

Appel, Sam. 2018. *Building a Skilled and Equitable Energy Efficiency Workforce in California*. San Francisco: Blue/Green Alliance of California.

Biven, Megan Milliken. 2020. "The Abandoned Well Administration: Putting Oil and Gas Workers Back to Work Protecting American Communities." In Progress Manuscript, August.

Booth, Mary S. "Not Carbon Neutral: Assessing the Net Emissions Impact of Residues Burned for Bioenergy." *Environmental Research Letters*, vol. 13, no. 3, February 2018, p. 035001. *Institute of Physics*, doi: 10.1088/1748-9326/aaac88.

Browning, Lexi. May 29, 2020. "Construction Industry Works through Coronavirus." *Times West Virginian*, https://www.timeswv.com/covid-19/construction-industry-works-through-coronavirus/article_5592f466-a13e-11ea-af42-2f006039a9ca.html.

Center for Climate and Energy Solutions (C2ES). January 7, 2019. "U.S. State Clean Vehicle Policies and Incentives." https://www.c2es.org/document/us-state-clean-vehicle-policies-and-incentives/.

———. March 2019. "Energy Efficiency Standards and Targets." https://www.c2es.org/document/energy-efficiency-standards-and-targets/.

———. September 28, 2020. "U.S. State Climate Action Plans." https://www.c2es.org/document/climate-action-plans/.

———. January 15, 2021. "U.S. State Greenhouse Gas Emissions Targets." https://www.c2es.org/document/greenhouse-gas-emissions-targets/.

Center for Energy and Sustainable Development, West Virginia University College of Law. 2020. "West Virginia's Energy Future: Ramping Up Renewable Energy to Decrease Costs, Reduce Risks, and Strengthen Economic Opportunities in West Virginia." https://energy.law.wvu.edu/files/d/b1ff1183-e9ae-4ad0-93bf-aa3afa1da785/wv-s-energy-future-wvu-col-cesd-final.pdf.

Chang, Joseph. January 15, 2021. "US Infrastructure Plan to Be Unveiled in February in 2nd Step of Massive Stimulus." *ICIS Explore*, Independent Commodity Intelligence Services, www.icis.com/explore/resources/news/2021/01/15/10595873/us-infrastructure-plan-to-be-unveiled-in-february-in-2nd-step-of-massive-stimulus.

Chomsky, Noam, Robert Pollin, and C. J. Polychroniou. 2020. *Climate Crisis and the Global Green New Deal: The Political Economy of Saving the Planet*. Brooklyn, NY: Verso.

Chow, Lorraine. March 20, 2017. "Germany Converts Coal Mine into Giant Battery Storage for Surplus Solar and Wind Power," *EcoWatch*, https://www.ecowatch.com/coal-mine-hydroelectric-2321724350.html.

Common Dreams. September 10, 2020. "THRIVE Agenda Creates Millions of New Jobs While Addressing Intersecting Crises of Climate Change, Racial Injustice, and Economic Inequity," https://www.commondreams.org/newswire/2020/09/10/thrive-agenda-creates-millions-new-jobs-while-addressing-intersecting-crises.

Covid Act Now. n.d. "America's COVID Warning System." https://covidactnow.org/us/west_virginia-wv/?s=1587527. Accessed February 10, 2021.

DeMarco, Patricia, and Sara Nicholas. 2020. "Heal Our Land and Our People — Civilian Conservation Corps 2.0 and Regenerative Agriculture and Agro-Forestry." ReimagineAppalachia.org.

Development, United States Congress House Committee on Appropriations Subcommittee on Energy and Water. 2003. *Energy and Water Development Appropriations for 2004: Department of Energy Fiscal Year 2004 Budget Justifications*. Washington DC: U.S. Government Printing Office.

Dixon, Eric and Kendall Bilbrey, 2015. "Abandoned Mine Land Program: A Policy Analysis for Central Appalachia and the Nation." AML Policy Priorities Group, Appalachian Citizens' Law Center, The Alliance for Appalachia.

Dohmen, Frank, and Barbara Schmid. 2011. "Mining Green Energy: A Coal Region's Quest to Switch to Renewables - DER SPIEGEL - International." SPIEGEL International. September 11, 2011. https://www.spiegel.de/international/business/mining-green-energy-a-coal-region-s-quest-to-switch-to-renewables-a-796399.html.

Flood, Sarah, Miriam King, Renae Rodgers, Steven Ruggles, and J. Robert Warren. 2020. "Integrated Public Use Microdata Series, Current Population Survey: Version 7.0." Minneapolis, MN: IPUMS. https://doi.org/10.18128/D030.V7.0.

Galgóczi, Béla. 2014. "The Long and Winding Road from Black to Green: Decades of Structural Change in the Ruhr Region." *International Journal of Labour Research* 6 (2): 217.

Garrett-Peltier, Heidi. 2017. "Green versus Brown: Comparing the Employment Impacts of Energy Efficiency, Renewable Energy, and Fossil Fuels Using an Input-Output Model." *Economic Modelling* 61 (February): 439–47. https://doi.org/10.1016/j.econmod.2016.11.012.

Hall, Douglas G., Kelly S. Reeves, Julie Brizzee, Randy D. Lee, Gregory R. Carroll, and Garold L. Sommers, "Feasibility Assessment of the Water Energy Resources of the United States for New Low Power and Small Hydro Classes of Hydroelectric Plants" (Idaho Falls: Idaho National Laboratory, 2006), p. v, available at http://www1.eere.energy.gov/water/pdfs/doewater-11263.pdf.

Hendren, Sam. May 11, 2015. "Slow Paced Clean Up of Cold War Era Atomic Plant Frustrates Piketon Area Residents". WSOU Radio. https://radio.wosu.org/post/slow-paced-clean-cold-war-era-atomic-plantfrustrates-piketon-area-residents.

Higdon, James. 2017. "The Obama Idea to Save Coal Country." *POLITICO Magazine*, March 8, 2017. https://www.politico.com/magazine/story/2017/03/the-obama-administration-idea-to-save-coal-country-214885.

Howarth, Robert W. 2015. "Methane Emissions and Climatic Warming Risk from Hydraulic Fracturing and Shale Gas Development: Implications for Policy." *Energy and Emission Control Technologies* 3 (October): 45–54. https://doi.org/10.2147/EECT.S61539.

International Energy Agency (IEA). 2019. "World Energy Outlook 2019.". https://www.iea.org/reports/ world-energy-outlook-2019.

———. n.d. "India - Countries & Regions." https://www.iea.org/countries/india. Accessed 11 Oct. 2020.

International Renewable Energy Agency (IRENA). 2020. "Renewable Power Generation Costs in 2019." Abu Dhabi. https://www.irena.org/publications/2020/Jun/Renewable-Power-Costs-in2019#:~:text=Electricity%20costs%20from%20utility%2Dscale,respectively%2C%20for%20newly%20commissioned%20projects.

Jaffe, Mark. 2020. "Environmentalists Worry Colorado Will See a Surge of Abandoned Oil and Gas Wells as Industry Tanks." *The Colorado Sun*, May 12, 2020. https://coloradosun.com/2020/05/12/fracking-oil-price-colorado-abandoned-wells/.

Kabler, Phil. 2020. "Governor's 'Flat' State Budget Plan for W.Va. Includes No Pay Raises or Major New Initiatives." *West Virginia Press Association*, January 9, 2020, https://wvpress.org/breaking-news/governors-flat-state-budget-plan-for-w-va-includes-no-pay-raises-or-major-new-initiatives/.

Kelsh, James V. November 17, 2020. "Utility-Scale Solar Projects Accelerating Rapidly in West Virginia." *In Focus: A Views and Visions Blog*. BowlesRice, LLP. https://www.bowlesrice.com/in-focus-blog/utility-scale-solar-projects-in-west-virginia, Accessed February 11, 2021.

Kosnik, L., 2010. The potential for small scale hydropower development in the US. *Energy Policy*, *38*(10), pp.5512-5519.

Lawrence, Mark G., Stefan Schäfer, Helene Muri, Vivian Scott, Andreas Oschlies, Naomi E. Vaughan, Olivier Boucher, Hauke Schmidt, Jim Haywood, and Jürgen Scheffran. 2018. "Evaluating Climate Geoengineering Proposals in the Context of the Paris Agreement Temperature Goals." *Nature Communications* 9 (1): 3734. https://doi.org/10.1038/s41467-018-05938-3.

Lieberman, Bruce. July 7, 2016. "Pros and Cons: Promise, Pitfalls of Natural Gas." Yale Climate Connections. https://www.yaleclimateconnections.org/2016/07/pros-and-cons-the-promise-and-pitfalls-of-naturalgas/.

Lowrie, Karen, Michael Greenberg, and Michael Frisch. 1999. "Economic Fallout." *Forum for Applied Research and Public Policy*; Knoxville 14 (2): 119–25.

Lynch, John, and Seth Kirshenberg. 2000. *Economic Transition by the Energy-Impacted Communities*. Sacramento, CA: California Energy Commission.

McKinsey & Company. 2010. *Energy Efficiency: A Compelling Global Resource*, New York, NY: McKinsey & Company.

Mervosh, Sarah. 2021. "How West Virginia Became a U.S. Leader in Vaccine Rollout." *The New York Times*, January 25, 2021. https://www.nytimes.com/2021/01/24/us/west-virginia-vaccine.html.

Molina, Maggie. 2014. "The Best Value for America's Energy Dollar: A National Review of the Cost of Utility Energy Efficiency Programs." U1402. American Council for an Energy-Efficient Economy (ACEEE). https://www2.aceee.org/l/310911/2018-01-26/mdjth.

Money-Zine. 2020. "Job Relocation Expenses." https://www.money-zine.com/career-development/finding-a-job/job-relocation-expenses/.

Montague, Zach. 2020. "A Look at What's in the Stimulus Package Trump Signed." *The New York Times*, December 28, 2020, https://www.nytimes.com/2020/12/28/business/economy/second-stimulus-package.html.

Montana Standard. August 1, 2018. "Doing It Right: Colstrip's Bright Future with Cleanup," Northern Plains Resource Council. mtstandard.com/news/state-and-regional/doing-it-right-colstrip-s-bright-future-with-cleanup/pdf_378a5b32-d4e0-504c-982d-bd230ab7ea5a.html.

Moomaw, William R., Paul R. Ehrlich, Dominick A. DellaSala, Beverly Law, George M. Woodwell, Mark E. Harmon, James E. Hansen, et al. May 8, 2020. "Scientist Letter to Congress," https://www.documentcloud.org/documents/6889670-Scientist-Letter-to-Congress-8May20.html.

MunicipalBonds.com. n.d. "West Virginia Municipal Bonds," www.municipalbonds.com. Accessed February 10, 2021.

NASA Langley Research Center Aerosol Research Branch. June 15, 2001. "Global Effects of Mount Pinatubo." NASA Earth Observatory. https://earthobservatory.nasa.gov/images/1510/global-effects-of-mount-pinatubo.

N.C. Clean Energy Technology Center. n.d. "AEP Appalachian Power – Non-Residential Custom Rebate Program," DSIRE, https://programs.dsireusa.org/system/program/detail/5491. Accessed February10, 2021.

———. n.d. "AEP Appalachian Power – Non-Residential Prescriptive Rebate Program," DSIRE, https://programs.dsireusa.org/system/program/detail/4834. Accessed February 10, 2021.

———. n.d. "AEP Appalachian Power – Residential Energy Efficiency Rebate Program," DSIRE, https://programs.dsireusa.org/system/program/detail/4835. Accessed February 10, 2021.

———. n.d. "Special Assessment for Wind Energy Systems." DSIRE, https://programs.dsireusa.org/system/program/detail/561. Accessed February 10, 2021.

———. n.d. "Tax Exemption for Wind Energy Generation." DSIRE, https://programs.dsireusa.org/system/program/detail/104. Accessed February 10, 2021.

National Association of State Energy Officials (NASEO) and Energy Futures Initiative (EFI). 2019. *2019 U.S. Energy and Employment Report*. https://www.usenergyjobs.org/. Accessed February 11, 2021.

National Academy of Sciences, National Academy of Engineering, and National Research Council. 2010. *Real Prospects for Energy Efficiency in the United States*. Washington, DC: The National Academies Press. https://doi.org/10.17226/12621.

Office of the Governor Jim Justice. "West Virginia Strong – The Comeback." https://governor.wv.gov/Pages/The-Comeback.aspx. Accessed February 10, 2021.

Office of Surface Mining Reclamation and Enforcement (OSMRE). n.d. "Reclaiming Abandoned Mine Lands." https://www.osmre.gov/programs/aml.shtm. Accessed September 6, 2020.

O'Leary, Sean. November 11, 2020. "West Virginia Has a Long Road Ahead to Full Recovery." *West Virginia Center on Budget & Policy*. wvpolicy.org/west-virginia-has-a-long-road-ahead-to-full-recovery/.

Olalde, Mark. June 23, 2020. "Support Grows for Taxpayer-Funded Oil Well Cleanup as an Economic Stimulus." *Energy News Network*, https://energynews.us/2020/06/23/national/support-grows-for-taxpayer-funded-oil-well-cleanup-as-an-economic-stimulus/.

Peischl, J., T. B. Ryerson, K. C. Aikin, J. A. de Gouw, J. B. Gilman, J. S. Holloway, B. M. Lerner, R. Nadkarni, J. A. Neuman, J. B. Nowak, M. Trainer, C. Warneke, D. D. Parrish. 2015. "Quantifying Atmospheric Methane Emissions from the Haynesville, Fayetteville, and Northeastern Marcellus Shale Gas Production Regions." *Journal of Geophysical Research: Atmospheres* 120 (5): 2119–39. https://doi. org/10.1002/2014JD022697.

Philips, P., 2014. *Environmental and Economic Benefits of Building Solar in California*. Berkeley, CA: University of California Berkeley.

Pollin, Robert, and Brian Callaci. 2019. "The Economics of Just Transition: A Framework for Supporting Fossil Fuel–Dependent Workers and Communities in the United States." *Labor Studies Journal* 44 (2): 93–138. https://doi.org/10.1177/0160449X18787051.

Pollin, Robert, Heidi Garrett-Peltier, James Heintz, and Bracken Hendricks. 2014. *Green Growth: A U.S. Program for Controlling Climate Change and Expanding Job Opportunities*. Washington DC: Center for American Progress. https://cdn.americanprogress.org/wp-content/uploads/2014/09/PERI.pdf.

Pollin, Robert, Heidi Garrett-Peltier, James Heintz, and Shouvik Chakraborty. 2015. *Global Green Growth: Clean Energy Industrial Investments and Expanding Job Opportunities*. Amherst, MA: Political Economy Research Institute. https://www.peri.umass.edu/ publication/item/689-global-green-growth-clean-energy-industrial-investments-and-expanding-job-opportunities.

Pollin, Robert, and Shouvik Chakraborty. 2020. "Job Creation Estimates Through Proposed Economic Stimulus Measures: Modeling Proposals by Various U.S. Civil Society Groups." Sierra Club. www.sierraclub.org/sites/www.sierraclub.org/files/THRIVE-jobs.pdf.

Prentiss, Mara. 2015. *Energy Revolution: The Physics and the Promise of Efficient Technology*. Cambridge, MA: The Belknap Press of Harvard University Press.

"Recognizing the Duty of the Federal Government to Implement an Agenda to Transform, Heal, and Renew by Investing in a Vibrant Economy (THRIVE)." n.d. https://static1.squarespace.com/static/5f53b5996b708446acb296c5/t/5f596f847cd042259067e795/1599696773913/THRIVE+resolution+CLEAN.pdf.

Romm, Joe. 2015. "How The EPA And New York Times Are Getting Methane All Wrong." Think Progress. https://thinkprogress.org/how-the-epa-and-new-york-times-are-getting-methane-all-wrong-eba3397ce9e5/.

Rosenow, Jan, and Edith Bayer. 2016. "Costs and Benefits of Energy Efficiency Obligation Schemes." The Regulatory Assistance Project (RAP). http://www.raponline.org/wp-content/uploads/2016/11/rap-rosenowbayer-costs-benefits-energy-efficiency-obligation-schemes-2016.pdf.

Reclaiming Appalachia Coalition. 2019. "New 2019 Report – A New Horizon." https://reclaimingappalachia.org/new-2019-report-a-new-horizon/.

Schleifstein, Mark. April 19, 2020. "Number of 'orphaned' Wells Increased by 50 Percent, Could Cost State Millions: Audit." NOLA.Com. 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%E2%80%99s%20Office.

Schlesinger, William H. "Are Wood Pellets a Green Fuel?" *Science*, vol. 359, no. 6382, Mar. 2018, pp. 1328–29. *science.sciencemag.org*, doi:10.1126/science.aat2305.

Senator Rob Portman. May 12, 2016. "Senate Passes Portman Priority to Fund Cleanup of Portsmouth Gaseous Diffusion Plant." https://www.portman.senate.gov/newsroom/press-releases/senate-passes-portman-priority-fund-cleanup-portsmouth-gaseous-diffusion.

Sierra Club. n.d. *THRIVE: A Bold Plan for Economic Renewal*, www.sierraclub.org/sites/www.sierraclub.org/files/THRIVE_%20A%20Bold%20Plan%20for%20Economic%20Renewal.pdf.

Sterman, John D., et al. "Does Replacing Coal with Wood Lower CO2 Emissions? Dynamic Lifecycle Analysis of Wood Bioenergy." *Environmental Research Letters*, vol. 13, no. 1, Jan. 2018, p. 015007. *iopscience.iop.org*, doi:10.1088/1748-9326/aaa512.

Slater, Chris. January 11, 2021 "West Virginia Economy Recovering Ahead of National Average during Pandemic, but Full Recovery Not Expected until 2022." *WV News*, www.wvnews.com/statejournal/news/west-virginia-economy-recovering-ahead-of-national-average-during-pandemic-but-full-recovery-not-expected/article_cc45cb2b-0b90-50d0-b06c-a5891c73ae09.html.

Taylor, Robert P., Chandrasekar Govindarajalu, Jeremy Levin, Anke S. Meyer, and William A. Ward. 2008. "Financing Energy Efficiency: Lessons from Brazil, China, India, and Beyond." Energy Sector Management Assistance Program (ESMAP). Washington DC: World Bank. https://openknowledge.worldbank.org/handle/10986/6349 License: CC BY 3.0 IGO.

United States Bureau of Labor Statistics. 2019. "Labor Force Statistics from the Current Population Survey." https://www.bls.gov/cps/cpsaat03.htm.

United States Census Bureau. "Poverty Thresholds." https://www.census.gov/data/tables/ time-series/demo/income-poverty/historical-poverty-thresholds.html. Accessed December 11, 2020.

United States Department of Agriculture, Economic Research Service. 2019. *America's Diverse Family Farms*, Economic Information Bulletin Number 214, December 2019. https://www.ers.usda.gov/webdocs/publications/95547/eib-214.pdf?v=9906.4.

———. 2020. "Glossary, Farm Operator Household Income," https://www.ers.usda.gov/topics/farm-economy/farm-household-well-being/glossary/#income. Last updated: December 2, 2020.

United States Department of Agriculture, National Agriculture Statistics Service. 2017. "Selected Producer Characteristics: 2017 and 2012," www.nass.usda.gov/Publications/AgCensus/2017/Full_Report/Volume_1,_Chapter_1_US/st99_1_0052_0052.pdf.

United States Department of Agriculture, Northern Research Station. 2016. *West Virginia Forests 2013*, Newton Square, PA: US Forest Service. www.fs.fed.us/nrs/pubs/rb/rb_nrs105.pdf.

United States Department of Energy. July 8, 2010. "U.S. Departments of Energy and Interior Announce Site for Solar Energy Demonstration Projects in the Nevada Desert." https://www.energy.gov/articles/us-departments-energy-and-interior-announce-site-solar-energy-demonstration-projects-nevada.

———. 2020. "West Virginia Building Energy Codes Program," https://www.energycodes.gov/adoption/states/west-virginia. Last Updated: Monday, March 16, 2020.

United States Employment and Training Administration, Initial Claims [ICSA], retrieved from FRED, Federal Reserve Bank of St. Louis; https://fred.stlouisfed.org/series/ICSA, Accessed February 11, 2021.

———. Initial Claims in West Virginia [WVICLAIMS], retrieved from FRED, Federal Reserve Bank of St. Louis; https://fred.stlouisfed.org/series/WVICLAIMS, Accessed February 11, 2021.

United States Environmental Protection Agency. 2018. "Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990- 2016." Reports and Assessments, January 30, 2018. https://www.epa.gov/ghgemissions/inventory-usgreenhouse-gas-emissions-and-sinks-1990-2016.

United States Energy Information Administration (EIA). 2019. "State-Level Energy-Related Carbon Dioxide Emissions, 2005-2016." Last updated: February 27, 2019. Accessed February 9, 2021. https://www.eia.gov/environment/emissions/state/analysis/.

———. 2020a. "Levelized Costs and Levelized Avoided Cost of New Generation Resources in the Annual Energy Outlook 2020." https://www.eia.gov/outlooks/aeo/electricity_generation.php.

———. 2020b. "Nuclear Power and the Environment." Last updated: January 15, 2020. Accessed 9 February 9, 2021. https://www.eia.gov/energyexplained/nuclear/nuclear-power-and-the-environment.php.

———. 2020c. "State Energy Data System (SEDS): 1960-2018," Last updated: June 26, 2020. https://www.eia.gov/state/seds/seds-data-complete.php?sid=WV.

———. 2020d. "West Virginia - State Energy Profile Overview." Last Updated: October 15, 2020. https://www.eia.gov/state/index.php?sid=WV.

UNIVSTATS. n.d. "Community Colleges In West Virginia." https://www.univstats.com/community-colleges/?state=WV. Accessed February 9, 2021.

WV News. January 21, 2021. "West Virginia Education Unions Files Legal Action, Say Reopening Orders Unsafe," https://www.wvnews.com/news/wvnews/west-virginia-education-unions-files-legal-action-say-reopening-orders-unsafe/article_15c7472b-7560-59a3-ba75-5062ddd5255b.html.

Wessel, Jeffrey Cheng, Tyler Powell, Dave Skidmore, and David. January 25, 2021 "What's the Fed Doing in Response to the COVID-19 Crisis? What More Could It Do?" Brookings, https://www.brookings.edu/research/fed-response-to-covid19/.

West Virginia Board of Education. 2020. West Virginia Schools' Roadmap to Recovery. wvde.us/wp-content/uploads/2021/01/Roadmap-to-Recovery-v4.pdf. Accessed February 11, 2021.

West Virginia State Legislature. n.d. "Constitution of West Virginia." http://wvlegislature.gov/WVCODE/WV_CON.cfm. Accessed February 10, 2021.

———. n.d. "Constitution of West Virginia - Article 14." http://wvlegislature.gov/WVCODE/WV_CON.cfm. Accessed February 10, 2021.

———. n.d. "Senate Bill 583." https://www.wvlegislature.gov/Bill_Status/bills_history.cfm?INPUT=583&year=2020&sessiontype=RS. Accessed February 10, 2021.

West Virginia State Treasurer's Office. 2020. "Debt Position Report, June 30, 2020." https://www.wvlegislature.gov/legisdocs/reports/agency/T03_FY_2020_14832.pdf.

West Virginia University College of Law, 2020, *West Virginia's Energy Future*, energy.law.wvu.edu/files/d/b1ff1183-e9ae-4ad0-93bf-aa3afa1da785/wv-s-energy-future-wvu-col-cesd-final.pdf. Accessed February 10, 2021.

The White House. January 29, 2021. "President Biden Announces American Rescue Plan," www.whitehouse.gov/briefing-room/legislation/2021/01/20/president-biden-announces-american-rescue-plan/.

———. February 5, 2021. "The Economics of the American Rescue Plan," www.whitehouse.gov/briefing-room/blog/2021/02/03/the-economics-of-the-american-rescue-plan/?fbclid=IwAR3bynaZYWNYreHUwzgm3zgT9kK4GoShKCqeoXHlLYBBXONna9RvuDBWzZE.

ABOUT THE AUTHORS

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

Jeannette Wicks-Lim is an Associate Research Professor at the Political Economy Research Institute at the University of Massachusetts Amherst, where she also earned her Ph.D. in economics. Wicks-Lim specializes in labor economics with an emphasis on the low-wage labor market, the political economy of racism, and the intersection of income, employment, health and health care. She is co-author of *A Measure of Fairness: The Economics of Living Wages and Minimum Wages in the United States* (2008) and co-editor of *Capitalism on Trial: Explorations in the Tradition of Thomas E. Weisskopf* (2013). She also co-authored *Economic Analysis of Medicare for All* (2018). Her journal articles and policy studies cover a wide range of topics, including the economics of minimum wage and living wage laws; the effectiveness of affirmative action policies; the impact of Social Security on child poverty; the role of the Earned Income Tax Credit on improving population health outcomes; the economics of single-payer programs; and the employment-related impacts of clean energy policies. Wicks-Lim regularly contributes to the magazine *Dollars & Sense*. She frequently serves as an economic policy consultant for non-governmental organizations as well as state and municipal legislative committees in her areas of research expertise.

Shouvik Chakraborty is a Research Assistant Professor at the Political Economy Research Institute at the University of Massachusetts Amherst. His research focuses on the employment impacts of investment in the green energy program. This work also examines issues at the intersection of inequality, climate change and environmental justice, especially with respect to developing countries. Separately, he researches subjects related to international trade between advanced countries and developing countries. He is the co-author of the 2015 study *Global Green Growth: Clean Energy Industrial Investments and Expanding Job Opportunities*. In 2019, he co-edited a broad-ranging book on the current political economic situation in India, *A Quantum Leap in the Wrong Direction?* He is a member of the UNESCO Inclusive Policy Lab, a global initiative dedicated to knowledge crowdsourcing and its translation into policy. He is also a contributor to the blog of the International Growth Centre, a research organization affiliated with the London School of Economics and the Institute for New Economic Thinking (INET). He is a member of the Indian Society of Ecological Economics (INSEE), the International Society for Ecological Economics (ISEE), and the Eastern Economic Association (EEA).

Gregor Semieniuk (Ph.D., Economics, New School for Social Research, 2015) is Assistant Research Professor at PERI and the Department of Economics at the University of Massachusetts Amherst. His research focuses on the energy and resource requirements of global economic growth and on the political economy of rapid, policy-induced structural change that is required for the transition to a low carbon economy. Semieniuk has consulted for the United Nations Environment Program and the UK Government on policies spurring low-carbon innovation, and has won grants to study these matters as well as transition risks for finance. He is also affiliated with the Department of Economics at SOAS University of London, the Institute of Innovation and Public Policy Purpose at University College London and the Science Policy Research Unit (SPRU) of the University of Sussex.

POLITICAL ECONOMY RESEARCH INSTITUTE

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

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

POLITICAL ECONOMY RESEARCH INSTITUTE

PERI

University of Massachusetts Amherst

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