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FRACKING OR NO FRACKING? *HOW A GREEN TRANSITION CAN WORK FOR WORKERS*

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ABSTRACT: *Throughout the 2024 U.S. Presidential campaign, the only climate-related issue to achieve prominence was the question of whether to ban fracking operations in the United States. Donald Trump is a long-time climate denier, and therefore had no qualms in supporting fracking and all other techniques for extracting fossil fuels from the ground. By contrast, Kamala Harris had supported a nationwide ban on fracking during her 2019 presidential campaign. This was due to the severe negative environmental and public health impacts of this natural gas extraction technique and because burning natural gas to produce energy generates CO₂ emissions that cause climate change. But Harris opposed a fracking ban in 2024 on the assumption that the ban would impose major costs to the economy of Pennsylvania, which has the second-largest fracking operations among U.S. states, after Texas only. Such negative economic outcomes in Pennsylvania would indeed result if fracking were banned in the U.S. and no large-scale alternative economic activities were introduced into Pennsylvania's economy. But banning fracking must be understood as one component of a much larger program to advance a viable climate stabilization program, in Pennsylvania, and everywhere else. We find that building a clean energy-dominant infrastructure in Pennsylvania—focused on investments in energy efficiency and renewable energy sources—will generate approximately 160,000 jobs in the state. Meanwhile, phasing down fracking and all other fossil fuel activities by 50 percent between 2026 – 35 will entail job losses in the range of 1,700 per year within the state. We argue that these 1,700 displaced fossil fuel workers should receive just transition policies that include pension, employment and income guarantees, in addition to, as needed, retraining and relocation support. We estimate that such a just transition program for these workers will cost in the range of \$240 million per year. This amounts to about 0.02 percent of Pennsylvania's current GDP. Thus, we show how, between 2026 – 2035, Pennsylvania could phase out 50 percent of all its fossil fuel production activities—including fracking operations—while also providing generous support for workers to transition out of their fossil fuel industry jobs and into activities that both raise public health and environmental standards in the state and contribute toward a viable global climate stabilization project.*

1. INTRODUCTION

The deepening climate crisis was almost entirely ignored as an issue throughout the 2024 U.S. presidential campaign between Donald Trump and Kamala Harris. In fact, only one climate-related issue achieved prominence during the campaign. This was the question of whether to ban fracking operations in the United States (Lefebvre 2024).

“Fracking” is an informal term of reference for hydraulic fracturing. This is a technology used to extract oil and natural gas from underground rock formations, such as sandstone, limestone, or shale rock deposits. Fracking technology is employed as a means of increasing the rate at which oil and gas can be extracted profitably from such rock formations. But fracking operations also generate severe environmental and health impacts through water and soil contamination as well as noise pollution. This is why, as of 2024, five U.S. states had banned fracking, including California, New York, Washington, Maryland, and Vermont.

Donald Trump has long been a rapturous cheerleader in behalf of fossil fuel production in the U.S., regularly invoking the “drill baby drill” slogan first popularized by the 2008 Republican vice-presidential candidate Sarah Palin. It follows that Trump would have no qualms whatsoever in supporting fracking and all other techniques for extracting fossil fuels from the ground. This is the case, even though burning oil, coal, and natural gas to produce energy is, by far, the most significant driver of the climate crisis, because burning fossil fuels releases carbon dioxide (CO₂) emissions into the atmosphere. The accumulated stock of CO₂ emissions in the atmosphere, in turn, is the most important factor producing climate change. Trump, of course, denies these most basic conclusions established by climate science. Since taking office in January 2025, President Trump himself and his administration more generally have reiterated their unqualified support for expanding fossil fuel production within the U.S.—i.e. “drill baby drill”—and their vehement opposition to “green new deal social engineering programs.”¹

Kamala Harris, by contrast, has always made clear that she supports the findings of climate science. She also supported a nationwide ban on fracking during her first presidential campaign in 2019. Harris then dropped her opposition to fracking when she became the vice-presidential candidate in Joe Biden’s 2020 presidential campaign and maintained that position throughout the Biden-Harris administration of 2021 – 2024. Throughout her 2024 presidential campaign, Harris continued to support fracking operations in the U.S. This was true, even while Trump regularly reminded voters of Harris’s earlier opposition to fracking and claimed that Harris would end up banning fracking if she were elected president.

Harris did have an obvious strategic, if unprincipled, motivation for maintaining her support for fracking during the 2024 election campaign. This was due to the centrality of Pennsylvania in determining the election’s outcome. That is, Pennsylvania was, at once, the most important contested state in the 2024 campaign as well as the state with the second-largest fracking operations in the U.S., following Texas only. Thus, supporting a ban on fracking was

¹ <https://www.bbc.com/news/articles/c20px1e05w0o>; <https://www.pbs.org/newshour/politics/trump-orders-temporary-funding-freeze-that-could-affect-trillions-of-dollars>

understood to be a strategic non-starter for Harris’s campaign. The assumption was that a ban on fracking would inflict major damage to Pennsylvania’s economy.

Such negative economic outcomes in Pennsylvania would indeed result if fracking were banned in the U.S. and no large-scale alternative economic activities were introduced into Pennsylvania’s economy. But in fact, banning fracking cannot be understood as an isolated, one-off policy measure. It should rather be recognized as one component of a much larger program to advance a viable climate stabilization program, in Pennsylvania, and everywhere else.

Focusing on Pennsylvania, a fracking ban would be one component of an overall program to achieve zero CO₂ emissions in the state, by phasing out fossil fuel consumption and building a high-efficiency, renewable energy-dominant infrastructure as the alternative to the state’s existing fossil fuel-dominant infrastructure.² The research we review in this paper shows that the investments needed to build this alternative clean energy infrastructure in Pennsylvania will generate far more jobs in the state than the jobs that will be lost through phasing out fracking and all other fossil fuel-based activities. Moreover, we will also show that the most viable clean energy transition program for Pennsylvania is one that incorporates just transition policies for the workers and communities in the state that are currently dependent on the fossil fuel industry for their livelihoods. This overall package of measures could indeed be characterized as major components of a “Green New Deal” program for Pennsylvania in particular, as well as for the U.S. and global economies more generally.³

Specifically, we will discuss here how building a clean energy-dominant infrastructure in Pennsylvania—focused on investments in energy efficiency and renewable energy sources—will generate approximately 160,000 jobs in the state. Meanwhile, phasing out fracking and all other fossil fuel activities will entail job losses in the range of 1,700 per year within the state over a 10-year period, 2026 – 2035, in which fossil fuel consumption would contract by 50 percent. This 50 percent decline in fossil fuel consumption would be matched by a comparable decline in fossil fuel production activity in the state.

Policies will also certainly need to be enacted to provide robust transition support for these 1,700 displaced workers per year—what the late U.S. labor leader and environmentalist Tony Mazzocchi termed “just transition” policies. As early as 1993, Mazzocchi wrote:

Paying people to make the transition from one kind of economy—from one kind of job—to another is not welfare. Those who work with toxic materials on a daily basis...in order to provide the world with the energy and the materials it needs deserve a helping hand to make a new start in life.

The critical point in Mazzocchi’s idea is that providing high-quality adjustment assistance to today’s fossil fuel industry workers will represent a major contribution

² This study summarizes and updates the main findings of Pollin et al. (2021). All statistical results that are not explicitly derived in this paper itself are presented in the 2021 Pollin et al. study.

³ See, e.g., Chomsky and Pollin (2020) for a general overview of Green New Deal policy perspectives and Pollin (2023) for a more formal presentation of this framework.

toward making a global climate stabilization project viable. Without such adjustment assistance programs operating at a major scale, the workers and communities facing retrenchment will, predictably and understandably, fight to defend their communities and livelihoods.

The just transition policies that we propose for Pennsylvania’s fossil fuel industry-based workers includes job guarantees, wage insurance, and pension guarantees, as well as job placement, training and relocation support. We estimate that the costs of providing this level of just transition support will cost about \$240 million per year. This would amount to roughly 0.02 percent of Pennsylvania’s average GDP between 2026 and 2035.

As such, when included as one component of an overall clean energy and climate stabilization program, banning fracking in Pennsylvania will achieve significant environmental and health benefits for the state’s residents while contributing toward eliminating CO₂ emissions—that is, eliminating the single largest factor causing the global climate crisis. This overall clean energy and climate stabilization program will also become a major engine for expanding job opportunities and increasing living standards throughout the state, generating far greater net benefits than what has been achieved through the state’s fracking operations.

The rest of this paper proceeds as follows. Section 2 reviews the economic, public health and environmental impacts of fracking operations in Pennsylvania. Section 3 then presents an outline of an emissions reduction and clean energy expansion program for the state. We estimate that about 160,000 jobs will be generated within Pennsylvania through a clean energy investment program scaled at about \$26 billion per year, equal to about 2.5 percent of the state’s GDP. Section 4 reviews the clean energy investments that have resulted in Pennsylvania in connection with the two major Biden-era programs, the Inflation Reduction Act (IRA) and the Bipartisan Infrastructure Law (BIL). Investments in Pennsylvania associated with these two programs totaled to about \$9 billion at the end of 2024.

Section 5 then focuses on the job losses that will result in Pennsylvania through the fossil fuel phase out in the state and just transition policies to support the workers who will experience displacement through this phase out. We estimate that about 1.700 fossil-fuel based workers per year will experience displacement through a 10-year program to reduce fossil fuel production and consumption in Pennsylvania by 50 percent. This total figure for displaced workers includes workers engaged in fracking operations as well as all other fossil-fuel-based activities. We propose that support for all these workers should include pension, employment and income guarantees, as well as retraining and relocation assistance as needed. The paper concludes with some general observations on how a green transition program, in Pennsylvania and elsewhere, can support working people—including those now employed in fracking operations and other fossil fuel-based activities—while also driving down CO₂ emissions and thereby advancing a viable climate stabilization project.

2. IMPACTS OF PENNSYLVANIA’S FRACKING OPERATIONS

Pennsylvania is a major supplier of fossil fuel energy in the U.S. As of the most recent 2022 data, it ranks second among U.S. states, behind only Texas, in producing natural gas,

providing 17.5 percent of overall U.S. gas supply. It also ranks third, behind Wyoming and West Virginia, in producing coal, contributing 8.7 percent of overall U.S. production.⁴

The most significant fossil fuel energy source in Pennsylvania is the Marcellus Shale formation. In 2008, natural gas began being extracted from Pennsylvania's Marcellus Shale deposits at a large scale through fracking operations along with horizontal drilling technology. The Marcellus formation extends under three-fifths of Pennsylvania as well as parts of West Virginia, New York, Ohio and Maryland. But most of the gas extraction activity in the Marcellus Shale formation has been concentrated in northeastern and southwestern Pennsylvania. This is both because the gas deposits in these parts of Pennsylvania are relatively accessible through fracking technology and also because the policy framework in Pennsylvania has supported fracking. By contrast, as noted above, New York and Maryland have banned fracking operations to date, even though these states have potentially significant gas reserves to exploit in the portions of the Marcellus Shale that are within their respective borders.

We review here the experience with fracking operations in Pennsylvania since their inception in 2008, in terms of their economic, environmental and public health impacts.

Economic Impacts

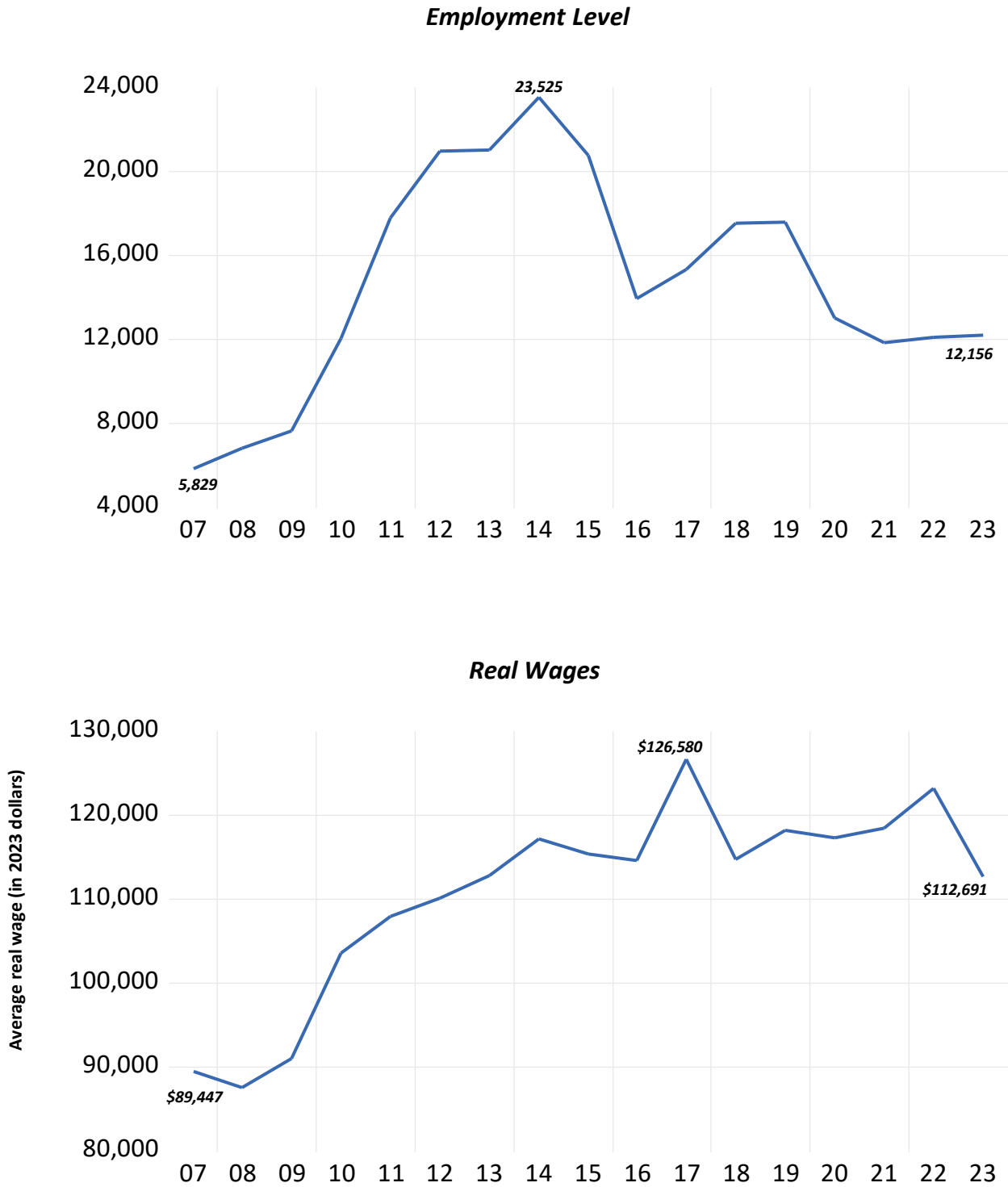
Between 2007 and 2014, employment grew strongly in northeastern and, to a somewhat lesser extent, southwestern Pennsylvania, as a result of the fracking boom. But the employment level peaked in 2014, and has experienced a declining trend subsequently. In Figure 1, we show state-wide employment data for three industries in the state—oil and gas extraction, drilling oil and gas wells, and support activities for oil and gas operations. As we see, employment in these oil and gas industries increased four-fold between 2007 and 2014, from 5,829 to 23,525. The employment level then begins falling off after 2014. As of the most recent 2023 data, statewide employment in these oil and gas sectors was at 12,156, a nearly 50 percent decline relative to the 2014 peak.

Average real wages in oil and gas-related employment also rose sharply in the initial phase of the state's fracking boom, from the 2007 level of about \$90,000 (in 2023 dollars) to about \$127,000 in 2017, a 41 percent increase. But wages then began a general, if uneven, downward trajectory. As of 2023, average real wages were at \$112,691, an 11 percent decline relative to the 2017 peak.

Since 2019, the industry experienced a sharp slump, as reflected especially in the data on employment decline. This decline began prior to the 2020 COVID-induced recession. But the recession deepened the contraction. Fracking operations in the state have not since returned to their 2014 levels.

⁴<https://www.eia.gov/state/seds/>

Figure 1. Employment Level and Real Wages for Pennsylvania Oil and Gas Operations, 2007 - 2023



Source: U.S. Bureau of Labor Statistics, QCEW
Note: Figures are for oil/gas extraction, drilling and support activities.

Public Health and Environmental Impacts

A large number of reports of the negative environmental and public health impacts of fracking operations in Pennsylvania began to emerge soon after these operations expanded to a large scale in the state in 2008. Thus, in June 2020, an Allegheny County grand jury report documented these impacts in detail, based on two years of research and direct testimony.⁵

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

Wells can be drilled as close as 500 feet from your front door. Once construction of a well pad begins, life changes. We heard about the clouds of dust, the grimy film, the booming and the blinding lights, day and night. The construction phase of the process is still just the beginning. Next comes the drilling and the hydraulic fracturing of the wells. These parts of the process bring their own nuisances, some of which are similar to what homeowners experienced during the construction phase. Oftentimes, the noise is far worse than it was during the construction phase and can occur 24 hours a day. Some people had to sleep in a corner of the basement trying to get away from it....

Aside from the nuisances of the process, some people, as we learned from testimony, began to notice changes to their water. In many areas where unconventional oil and gas activity is common, there is no public water line. People rely entirely on water wells drilled on their own property. When the oil and gas operators spilled products used to fracture a well, or the storage facilities that held the waste-water leaked, the chemicals made their way into the aquifers that fed those water wells. The water started smelling like sulfur, or tasting like formaldehyde. It burned the skin....

Then there was the air. The smell from putrefying waste water in open pits was nauseating. Airborne chemicals burned the throat and irritated exposed skin. One witness had a name for it: "frack rash." It felt like having alligator skin. At night, children would get intense, sudden nosebleeds; the blood would just pour out. Many of those living in close proximity to a well pad began to become chronically, and inexplicably, sick. (pp. 3 – 4).

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

⁵ Office of the Attorney General, Commonwealth of Pennsylvania (2020).

The environmental impacts from UNGD [i.e. fracking] include chemical, physical, and psychosocial hazards as well as more general community impacts.By 2017, there were a number of important, peer-reviewed studies published in the scientific literature that raised concern about potential ongoing health impacts. These studies have reported associations between proximity to UNGD and pregnancy and birth outcomes; migraine headache, chronic rhinosinusitis, severe fatigue, and other symptoms; asthma exacerbations; and psychological and stress-related concerns. Beyond its direct health impacts, UNGD may be substantially contributing to climate change (due to fugitive emissions of methane, a powerful greenhouse gas), which has further health impacts. Certain health outcomes, such as cancer and neurodegenerative diseases, cannot yet be studied because insufficient time has passed in most regions since the expansion of UNGD to allow for latency considerations (p. 1).

More recent research, including that focused on health impacts in Pennsylvania, have corroborated the findings from Gorski and Schwartz's 2019 survey. Thus, a 2023 study from the University of Pittsburgh found that children living near gas wells in heavily drilled parts of the state were more likely to develop a relatively rare form of lymphoma, and that nearby residents of all ages had an increased chance of incidents of severe asthma.⁶

3. A PENNSYLVANIA EMISSIONS REDUCTION AND CLEAN ENERGY PROGRAM

We describe here a 10-year program through which CO₂ emissions in Pennsylvania will fall by approximately 50 percent. This will enable the state to be in rough alignment with the IPCC's intermediate emissions reduction target of reducing global emissions by 45 percent as of 2030. As of the most recent 2022 data, overall CO₂ emissions in Pennsylvania from burning fossil fuels to produce energy were 214 million metric tons (mmt).⁷ A 50 percent emissions decline would therefore entail the level of emissions to be no higher than 107 mmt as of 2034. The state did reduce emissions by a significant 23 percent between 2005 – 2016, from 281 to 217 mmt. But the state has not achieved further significant cuts since then.

For emissions in the state to fall by 50 percent over a 10-year period will require that fossil fuel energy consumption in the state will also fall by 50 percent within 10 years. In addition, Pennsylvania exports fossil fuels to other U.S. states as well as, to a lesser extent, other countries. We assume that Pennsylvania's domestic and international fossil fuel export markets will also decline by 50 percent over this 10-year period. This assumption is consistent with the idea that these other regions will also be moving into alignment with the IPCC's emissions reduction targets.

⁶ Buchanich et al. (2023)

⁷ <https://www.eia.gov/state/seds/> An additional source of CO₂ emissions in Pennsylvania, as elsewhere, is generated through combusting wood, plants, and waste materials to produce bioenergy. This additional source of CO₂ emissions from consuming bioenergy constitutes a negligible share of the state's overall CO₂ emissions. For simplicity, we therefore do not include bioenergy emissions in our estimates of total CO₂ emissions in the state, or in our calculations for moving Pennsylvania onto a zero emissions trajectory.

Based on these assumptions, it follows that over the 10-year period we are considering, production activity and employment in Pennsylvania’s fossil fuel industries will decline at the same rate at which energy consumption is declining in Pennsylvania itself as well as in its export markets—i.e. by 50 percent across-the-board for all fossil fuel sources. The just transition program will cover the workers in Pennsylvania employed in all of the state’s fossil fuel-related sectors, all of which will be phasing down their production activity by 50 percent over the 10-year period.

Concurrent Job Creation through Clean Energy Investments

This phase-down of Pennsylvania’s fossil fuel production activity will, of course, need to occur in conjunction with the building of a new clean energy infrastructure in the state. The program we developed for Pennsylvania is designed to produce sufficient clean energy supply in the state that will enable the state to maintain a healthy economic growth path while still reducing its consumption of fossil fuel energy by 50 percent within 10 years. We assume that there will be two areas of large-scale clean energy investments over this 10-year period. They are:

- *Energy efficiency.* Dramatically improving energy efficiency standards in Pennsylvania’s stock of buildings, automobiles and public transportation systems, and industrial production processes; and
- *Clean renewable energy.* Dramatically expanding the supply of renewable sources, primarily solar and wind, but also, as supplemental sources, geothermal, small-scale hydro, and low-emissions bioenergy available at competitive prices to all sectors of Pennsylvania’s economy.

We estimate that the level of investment needed to achieve Pennsylvania’s energy goals will average roughly \$26 billion per year (in 2023 dollars) over 10 years, with most of the funding being provided by private investors.⁸ This estimate assumes that Pennsylvania’s economic growth proceeds at an average rate of 1.5 percent per year. Clean energy investments—from both public and private funding sources combined—will amount to about 2.5 percent of Pennsylvania’s average annual GDP over this 10-year period.

We estimated that investing an average of \$26 billion per year in clean energy projects in Pennsylvania over 10 years will generate an average of about 162,000 jobs per year in the state. This includes the three channels through which clean energy investments—as with any investments in all economic activities—generates new employment, i.e. the direct, indirect and induced employment creation channels. The direct channel refers to the jobs created within a sector itself. Mounting solar panels on rooftops is one clear example. The indirect channel refers to jobs created within a given sector’s supply chain. An example here would be truck drivers delivering solar panels to a construction site. Induced jobs are those generated by

⁸ This \$26 billion per year investment figure is expressed in 2023 dollars, whereas, in our 2021 study (Pollin et al. 2021), the overall clean energy investment figure we reported was \$22.6 billion per year. That figure is in 2018 dollars.

multiplier effects—i.e. the job creation generated by increases in consumption spending resulting from the increased incomes provided by newly created jobs.

We estimate that of the 162,000 jobs generated by \$26 billion in annual clean energy investments in Pennsylvania, about 107,000 will be generated through either the direct or indirect channels within the various clean energy investment projects. This amounts to about 1.6 percent of Pennsylvania’s overall 2024 labor force of 6.5 million people. The remaining 55,000 jobs will be induced through the increased overall spending levels in the state resulting from the direct and indirect growth in employment. The 162,000 in overall employment expansion through Pennsylvania’s clean energy investments would represent about 2.5 percent of the state’s workforce.

Focusing on the direct employment channel, the clean energy investments will produce new job opportunities in a wide range of areas, including construction, sales, management, production, engineering and office support. As of the 2023 Pennsylvania labor market, the average pay in most sectors ranges between about \$80,000 and \$95,000. The weighted average pay level for the full set of clean energy related jobs in Pennsylvania is \$81,033. This includes jobs in retrofitting buildings, industrial efficiency, electrical grid upgrades and building out the state’s solar and wind energy sectors. The one area where pay is significantly lower is mass transit, where average pay is about \$40,000. Average pay is highest in industrial efficiency, at about \$108,000.⁹

4. CLEAN ENERGY INVESTMENTS IN PENNSYLVANIA THROUGH BIDEN-ERA PROGRAMS

The enactment under the Biden Administration of the Bipartisan Infrastructure Law (BIL) in November 2021 and the Inflation Reduction Act (IRA) in August 2022 created a major new pool of available funding for advancing a viable clean energy transition program, in the U.S overall, and in Pennsylvania specifically. The BIL consists of a wide range of public programs in the areas of manufacturing, infrastructure as well as clean energy, with a total annual budget for the U.S. economy overall of \$170 billion per year over five years. Roughly one-third of this total funding level, or roughly \$60 billion per year—are designated for programs that, in broad terms, support energy efficiency and renewable energy projects.¹⁰

The IRA also includes a wide range of specific programs, again with about one-third of these projects broadly aimed at supporting energy efficiency and renewable energy investments. But funding through the IRA is distinct, in that it mostly consists of subsidies for private investments, either in the form of tax credits or loan guarantees. Moreover, with a high proportion of the individual IRA programs, the availability of subsidy support is uncapped—i.e. support for individual private investment projects is available without specified limits in the aggregate. As such, the total amount of clean energy investment financing that could result through the IRA could potentially reach very high levels, depending on the take-up rate by private investors and consumers. A midrange estimate for IRA-funded clean energy for the

⁹ See appendix for the derivation of these figures.

¹⁰ See Pollin et al. (2023)

overall U.S. economy is about \$30 billion per year over 10 years. But credible higher-end estimates are 3-4 times higher, ranging up to \$120 billion per year over a decade.¹¹

Of course, as of this writing in January 2025, it is uncertain as to how much of the BIL and IRA will survive under the Trump Administration. Consistent with his general climate denialism, Trump has never expressed support for any clean energy investment programs. But he could potentially alter his position during his second presidential term, given the benefits that have resulted to date, and would be ongoing, from these programs in terms of job creation and community development.

For our present discussion, our focus is to estimate the extent of funding that the IRA and BIL have provided to date in Pennsylvania and the prospects for further support if these programs are maintained going forward. According to a website that was maintained by the Biden White House, *Invest.gov*, total funding commitments in Pennsylvania since the IRA and BIL programs were enacted, including both private and public investments, amounted to about \$18 billion. Of this total funding level, roughly half of the reported total, i.e. about \$9 billion, could be categorized as clean energy investments. Of this \$9 billion in funding announcements, about \$7 billion are private investment projects subsidized in part by IRA funds. The remaining \$2 billion are public-sector projects supported by both BIL and IRA programs.

From the information provided at *Invest.gov*, it is not possible to establish with confidence the expected time frame over which these \$9 billion in clean energy investment commitments will flow into the Pennsylvania economy. As a rough approximation, we estimate that, on average, spending per project will occur over a 3-year period. This suggests that approximately \$3 billion per year would be spent in Pennsylvania on clean energy investments through projects that have been announced to date at *Invest.gov*. This level of annual clean energy investment spending is, of course, significant. But it is also not close to sufficient relative to the \$26 billion per year in spending that we estimate is necessary for Pennsylvania to build out a clean-energy dominant energy infrastructure within 10 years. This, again, is the clean energy infrastructure that would be capable within 10 years of providing a sufficient supply of clean energy in Pennsylvania that would substitute for the 50 percent reduction in fossil fuel energy consumption in the state.

A major challenge for Pennsylvania, as elsewhere, is, therefore, how to dramatically scale up clean energy investments in the state. Addressing this question is beyond the scope of this paper.¹² For our present discussion, what is most critical is to be able to understand the scale at which clean energy investments in Pennsylvania will be needed, and how this project, operating at this requisite scale, will expand new job opportunities that are more than sufficient to offset the job losses that will result through the phase out of fossil fuel production in the state.

As another rough approximation, derived from our estimate that \$26 billion per year in clean energy investments would generate about 160,000 new jobs in Pennsylvania, it follows that

¹¹ For example, Bistline et al. (2023), Penn Wharton Budget Model (2023).

¹² See Pollin et al. (2021) for an extended analysis of this topic.

the roughly \$3 billion per year allocated to date for Pennsylvania through the IRA and BIL would generate about 20,000 jobs per year in the state.¹³

5. FOSSIL FUEL PHASE OUT AND JUST TRANSITION

The issue on which we focus in this section is what the impact will be on workers employed in Pennsylvania’s fossil fuel-based industries. We assume that, over the 10-year period 2026 – 2035, production activity and employment in all of Pennsylvania’s fossil fuel-based industries will decline at approximately the same 50 percent rate as energy consumption in the state. In particular, we develop here a just transition program for the workers in these fossil fuel sectors who will face displacement as a result of this contraction in the state’s fossil fuel-based sectors.

Our primary focus in this section is on the *direct* jobs that will be lost in Pennsylvania through the contraction of the state’s fossil fuel-based industries. The workers currently employed in these jobs will be the ones that will be most in need of just transition support as Pennsylvania phases out these CO₂-generating activities. The jobs that will be lost through the indirect and induced channels will be more diffuse in their characteristics. A high proportion of the jobs lost through the indirect channels are likely to match up reasonably well with those in the clean energy economy, including in areas such as administration, clerical, professional services, and transportation services. The characteristics of the induced jobs created will simply reflect the overall characteristics of Pennsylvania’s present-day workforce. The job losses that will result through the indirect and induced channels can therefore be appropriately managed through the same set of policies that are available to all workers in Pennsylvania who experience unemployment.

Measuring Direct Employment Levels

In Table 1, we show employment levels for the 14 fossil-fuel and ancillary industries in Pennsylvania as of 2023. As we see, as of 2023, there are 48,293 people employed in the fossil fuel and ancillary industries in Pennsylvania. Of these, 12,375 (26 percent) are employed in oil and gas extraction, 8,416 (17 percent) work in oil and gas support activities, and 5,306 are in natural gas distribution (11 percent). Thus, these three sectors—extraction, support activities and natural gas distribution together account for 54 percent of total employment in all of Pennsylvania’s fossil fuel-based industries. The other major employment category is coal mining, with 7,292 jobs, AT 15 percent of the total.

¹³ That is, \$3 billion per year in clean energy investments in Pennsylvania is equal to approximately 12 percent of \$26 billion. Correspondingly, 20,000 jobs generated by \$3 billion in investments is roughly 12 percent of 160,000 jobs generated by \$26 billion in investments in the state.

TABLE 1
Number of Workers in Pennsylvania Employed in Fossil Fuel-Based Industries, 2023

Industry	2023 Employment Levels	Industry share of total fossil fuel-based employment
<i>Fossil Fuel Industry Total</i>	<i>48,293</i>	<i>100.0%</i>
Oil and Gas Extraction	12,375	25.6%
Support Activities for Oil/Gas	8,416	17.4%
Coal Mining	7,292	15.1%
Natural Gas Distribution	5,306	11.0%
Wholesale -Petroleum and petroleum products	3,447	7.1%
Fossil Fuel Electric Power Generation	2,647	5.5%
Pipeline Transport	2,542	5.3%
All other petroleum and coal products manufacturing	1,729	3.6%
Drilling Oil and Gas Wells	1,273	2.6%
Pipeline Construction	1,123	2.3%
Petroleum Refining	1,107	2.3%
Mining Machinery and Equipment Manufacturing	600	1.2%
Support Activities for Coal	311	0.6%
Oil and Gas Field Machinery and Equipment Manufacturing	125	0.3%
TOTAL FOSSIL FUEL EMPLOYMENT AS SHARE OF PENNSYLVANIA EMPLOYMENT <i>(Pennsylvania 2023 employment = 6,295,653)</i>		0.8%

Source: IMPLAN (<https://implan.com/>); Pennsylvania employment is from the BLS Local Area Unemployment Statistics program (<https://www.bls.gov/lau/>).

Characteristics of Fossil Fuel-Based Industry Jobs

Table 2 provides basic figures on the characteristics of the direct jobs in Pennsylvania for workers in fossil-fuel based sectors. We first see that, on average, these are relatively high-paying jobs. The average overall compensation is roughly \$118,000. This is nearly 50 percent more than the \$81,033 average pay level for jobs in Pennsylvania's various clean energy sectors. It is also about 9 percent more than the \$108,000 average pay level for workers in the industrial efficiency sector who are, on average, the highest paid workers employed in Pennsylvania's clean energy sectors.

In terms of private health insurance coverage, the fossil fuel industries are, for the most part, providing coverage for their workers, with about 75 percent of workers receiving employer-based insurance. This level of health insurance coverage is significantly higher than the 60.4 percent of U.S. workers overall who receive health insurance through their employer. Union membership is at about 15 percent for Pennsylvania's fossil fuel based workers. This is much higher than the figure for the overall U.S. private sector, of 5.9 percent.¹⁴

Table 2
Characteristics of Workers Employed in Pennsylvania's Fossil Fuel-Based Sectors

	Fossil Fuel-Based industries
Average total compensation (2023 dollars)	\$118,083
Health insurance coverage	74.7%
Retirement benefits	54.2%
Union membership coverage	14.6%
Educational credentials	
Share with high school degree or less	37.7%
Share with some college or Associate degree	22.4%
Share with Bachelor's degree or higher	40.0%
Racial and gender composition of workforce	
Pct. non-White workers	13.6%
Pct. female workers	19.0%

Source: IMPLAN; Current Population Survey data files 2022-2024. See Appendix for details.

¹⁴ Private health insurance coverage figures are here: <https://www.kff.org/health-policy-101-employer-sponsored-health-insurance/>. Private sector unionization rates figures are here: <chrome-extension://efaidnbmninnkcepbpcjpclefindmkaj/https://www.bls.gov/news.release/pdf/union2.pdf>

Table 2 also reports figures on educational credential levels for workers in the fossil fuel-based sectors, as well the percentages of workers who are women and people of color. With respect to educational credentials, the overall level of attainment is relatively high, with about 40 percent having a Bachelor’s degree or higher, and another 22 percent have some college or an Associate degree. The remaining 38 percent have high school degrees only or less. Women account for only 19 percent of the workforce, and non-White workers account for roughly 14 percent of the total workforce.

In Table 3, we gain further detailed information on workforce and employment conditions for workers in Pennsylvania’s fossil fuel-based industries. We show the most prevalent job categories and the representative occupations in each job category.

Table 3
Prevalent Job Types in Pennsylvania’s Fossil Fuel-Based Industries
(Job categories with 5 percent or more employment)

Job Category	Percentage of Direct Jobs Lost	Representative Occupations
Management	18.3%	Marketing managers; computer and information systems managers, general and operations managers
Transportation and material movers	16.4%	Supervisors of transportation and material moving workers; pumping station operators; hand laborers and freight, stock and material movers
Office and administrative support	15.1%	Customer service representatives; bookkeeping, accounting, and auditing clerks; secretaries
Business operations specialists	9.1%	Market research analysts and marketing specialists; project management specialists; human resource workers
Extraction	8.6%	Derrick, rotary drill, and service unit operators in oil, gas, and mining; earth drillers; explosives workers, ordnance handling experts, and blasters
Production	6.4%	Plant and system operators, first-line supervisors of production and operating workers; inspectors

Source: Current Population Survey data files 2022-2024.

Note: Due to small sample sizes, these estimates are based on the mid-Atlantic region which includes Pennsylvania, New York and New Jersey, rather than Pennsylvania only.

The key finding that emerges from these tables is that Pennsylvania's fossil fuel-based industries provide a wide range of employment opportunities for the nearly 50,000 workers currently employed in these industries. As we see, the largest share of jobs, at roughly 18 percent, are in management. The next largest category, at roughly 16 percent, is "transportation and material movers." Office and administrative support is the next largest category, at about 15 percent, followed by market research and human resources, at about 9 percent. In combination, these four job categories account for nearly 60 percent of total employment in Pennsylvania's fossil fuel-based industries. It is important to note with this 60 percent figure for total fossil fuel-based employment, most of the occupations in these job categories—in management, transportation, office support, and business operations—require skills that are specific to the activities of the fossil fuel industries per se. Rather, these job categories mostly require skills that are transferable to other economic sectors.

With the other two fossil fuel-based job categories employing more than 5 percent of workers shown in Table 3—i.e. extraction at 8.6 percent and production at 6.4 percent respectively of total employment—the skill requirements will be more specific to the fossil fuel activities themselves. For this roughly 15 percent of Pennsylvania's fossil fuel-based industries' workforce, the challenge will therefore be greater to transition these workers into new employment situations as their fossil fuel-based jobs are phased out. More generally, what these employment figures underscore is that any just transition program to support displaced workers in Pennsylvania's fossil fuel related industries will need to be focused on the specific background and skills of each of the impacted workers.

Features of a Just Transition Program

We outline here a just transition program for workers who face job losses through direct channels from the 50 percent contraction of the state's fossil fuel 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 2035;
- 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.

The detailed policy package includes five components. These are:

1. Pension guarantees for retired workers who are covered by employer-financed pensions, starting at age 65;
2. Re-employment for displaced workers through an employment guarantee, with 100 percent wage insurance. With wage insurance, workers are guaranteed that their total compensation in their new job will be supplemented to reduce any losses relative to the compensation they received working in the fossil fuel-based industry;

3. Retraining, as needed, to assist displaced workers to obtain the skills required for a new job;
4. Relocation support for 50 percent of displaced workers, assuming only 50 percent will need to relocate; and
5. Full just transition support for workers 65 and over who choose not to retire.

Steady versus Episodic Industry Contraction

Before presenting the cost estimate calculations, it is critical to note how any such policy measures will be affected by the conditions under which the fossil fuel-based industries contraction occurs in Pennsylvania. Specifically, the scope and cost of any set of just transition policies will depend substantially on whether the contraction is steady or episodic.

Under a pattern of steady contraction, there will be uniform annual employment losses over the 10-year period in the affected industries. But it is not realistic to assume that the pattern of industry contraction will necessarily proceed at a steady rate. An alternative pattern would entail relatively large episodes of employment contraction, followed by periods in which no further employment losses are experienced. This type of pattern would occur if, for example, one or more relatively large firms were to undergo large-scale cutbacks at one point in time as the industry overall contracts, or even for such firms to shut down altogether.

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

We proceed here by assuming that Pennsylvania will successfully implement a relatively steady contraction of its fossil fuel sectors. This should be realistic as long as the relevant policymakers remain focused on that goal.

Estimating Attrition by Retirement and Job Displacement Rates

In Table 4, we show figures on annual employment reductions in Pennsylvania's fossil-fuel based industries over 2026 – 35 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 2035. 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 fossil fuel production in the state. As described above, the just transition program will provide support for all displaced workers through a re-employment guarantee along with wage insurance, retraining, and relocation support.

Table 4.
Attrition by Retirement and Job Displacement for Fossil Fuel Workers in Pennsylvania

	Fossil Fuel Workers
1) Total workforce as of 2023	48,293
2) Job losses over 10-year transition, 2026-2035	24,147
3) Average annual job loss over 10-year production decline (= row 2/10)	2,415
4) Number of workers reaching 65 over 2026-2035 (=row 1 x % of workers 55 and over in 2025)	9,176 (20.9% of all workers)
5) Number of workers per year reaching 65 during 10-year transition period (=row 4/10)	918
6) Number of workers per year retiring voluntarily	734 (80% of 65+ workers)
7) Number of workers requiring re-employment (= row 3 – row 6)	1,681

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

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.¹⁵ 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 2026 and 2035. Specifically, we incorporate into our calculations in Table 4 an estimate that, of the total number of workers reaching age 65 in any given year, 80 percent will retire voluntarily while 20 percent will choose to continue working.

We can see, step-by-step, how these various considerations come into play through the figures we show in Table 4. As we again see in column 2 of Table 4, there were, as of the most recent 2023 figures, 48,293 workers in Pennsylvania employed in all fossil fuel-based industries. Given the 50 percent contraction in all fossil fuel-based industries in the state, this means that total employment in these sectors will fall by 24,147 as of 2035. It therefore also means that the same number of jobs, 24,147, will be retained. If we then assume that the contraction in these

¹⁵ 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>.

industries proceeds at a steady rate between 2026 and 2035, this means that 2,415 jobs in these industries will be lost each year, as we see in row 3 (i.e. 24,147 job losses in total/10 years of industry contraction = 2,415 job losses per year).

We see in row 4 that, of the workers presently employed in these sectors in Pennsylvania, 9,176, or 21 percent, will be between 55 and 65 years old over 2026 - 2035. If all these workers were to voluntarily retire at a steady rate over 2026 - 35, this would mean that 918 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 734 workers employed in these sectors will retire voluntarily every year between 2026 and 2035.

Given that total job losses each year will average 2,415 over the 2026 - 35 period, that in turn means that the total number of workers currently employed in Pennsylvania's fossil fuel-based sectors that will require re-employment will be 1,681 per year. We show this figure in row 7 of Table 4.

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 734 workers per year moving into voluntary retirement; and 2) Providing all the forms of re-employment support, including the re-employment guarantee, for the 1,681 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 steady as is being assumed in our calculations.

Nevertheless, precise details aside, it is the overall finding that these results firmly establish that is most central: that the number of workers in Pennsylvania who are likely to experience job displacement through the state's transitioning away from CO₂-generating energy sources will be small—indeed, the number of workers facing displacement, if not exactly 1,681 per year, should be, under most circumstances, below 2,000 per year.

Cost Estimates for a Just Transition Program

Pension Guarantees for Retiring Workers

What becomes clear from the evidence on the steady rate of contraction for Pennsylvania's fossil fuel related industries is that guaranteeing workers' pension funds must be a centerpiece of the state's overall just transition program. This is especially important, given that the fossil fuel-based enterprises will likely face major financial challenges through experiencing sharp contractions between 2026 and 2035. Under these circumstances, these firms may not consider their pension fund commitments to be a top financial priority. Despite this, guaranteeing workers' pensions as a first-tier financial obligation for employers can be established through regulatory policies. For example, the State of Pennsylvania could work in coordination with federal regulators, at the Pension Benefit Guarantee Corporation (PBGC) to place liens on company assets when pension funds are underfunded. Through such measures, the

pension funds for most of the affected workers can be protected through regulatory intervention alone, without the government having to provide financial infusions to sustain the funds.¹⁶

Guaranteed re-employment

New employment opportunities will certainly open up in the expanding clean energy sectors, with approximately 107,000 new direct plus indirect jobs created per year in Pennsylvania through clean energy investments at the level of \$26 billion per year (see Table 2.16). An additional 55,000 jobs will also likely be generated through induced job creation channel—i.e. multiplier effects resulting from the 107,000 new jobs generated through the direct and indirect employment channels. A high proportion of the new state clean energy projects are likely to be financed at least partially through public-sector funding. Given such public sector funding, the state could require job preference provisions for the displaced workers. Again, our estimate of the number of displaced workers per year that will need re-employment is about 1,700 in total. It will not be difficult for the state to set aside 1,700 – 2,000 guaranteed jobs for these displaced workers, or, for that matter, even, say, 10,000 jobs, as needed for this purpose.

This remains true even if we assume that the level of clean energy investments in Pennsylvania were much more modest than the \$26 billion per year figure we have projected as necessary for achieving the 50 percent CO₂ reduction target by 2035. Thus, as we discussed above, the level of IRA/BIL-supported investments for Pennsylvania had totaled to about \$9 billion by the end of the Biden administration. We roughly assumed above that this \$9 billion total would be allocated over three years, at \$3 billion per year. That level of clean energy investments, while not close to adequate for sufficiently expanding the state's clean energy infrastructure, would nevertheless generate about 20,000 new jobs in Pennsylvania. This level of job creation would be approximately 10 times more than the number of workers who would be displaced through the state's 50 percent fossil fuel phase out through 2035.

Income Support through Wage Insurance

Though it will not be difficult to find new employment opportunities for the roughly 1,700 fossil fuel-based workers that will be displaced annually on average, there is a high likelihood that, for workers currently employed in the fossil fuel-based industries and re-employed in clean energy activities, their new jobs will be at lower pay levels than their previous jobs. As we have seen, the average compensation for fossil fuel-based workers in Pennsylvania at present is \$118,083. This compares with the average compensation in the clean energy areas, ranging for the most part, as noted above, between about \$80,000 and \$95,000 in the various specific sectors. The average weighted compensation figure for the full set of direct jobs generated by clean energy investments is, again, \$81,035. It will therefore be necessary for the fossil fuel-based sector workers to be provided with wage insurance so that they experience no income losses in their transition from fossil fuel industry jobs into new positions.

To provide some initial specifics on the costs of providing wage insurance for displaced workers who move into jobs at lower pay levels, we propose that all displaced workers facing

¹⁶ See more detailed discussions on these pension fund policies in, for example, Pollin et al. (2019).

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 5 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 4 on the number of displaced workers in the fossil-fuel based sectors—i.e. 1,681 workers per year. Row 2 then shows their average compensation level of \$118,083. In row 3, we show the weighted average compensation level for all of Pennsylvania’s clean energy sectors, which, as noted above is \$81,033. From this difference in average compensation levels, we then calculate that the annual cost of compensation insurance for 1,681 workers will be about \$62 million.

Table 5.
Estimating Costs of 100 Percent Compensation Insurance for Displaced Workers in Pennsylvania’s Fossil-Fuel Based Sectors

1. Number of Fossil Fuel-Based displaced workers per year requiring re-employment	1,681
2. Average compensation for displaced workers (2023 dollars)	\$118,083
3. Average compensation for clean energy sector jobs (2023 dollars)	\$81,033
4. Average Compensation difference between fossil fuel-based and clean energy jobs (= row 2 – row 3)	\$37,050
5. Annual cost of compensation insurance for 1,681 workers (= row 4 x row 1)	\$62.3 million
6. Total Cost of compensation insurance for 3 years (= row 5 x 3)	\$186.8 million

Source: See Tables 2 and 4.

Retraining Support

As we have discussed above, 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. A majority 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 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 obviously distinct from laying oil and gas pipelines. This is why a just transition program must include a provision for retraining for the displaced fossil fuel-based industry workers whose skills do not transfer readily into the state’s other areas of employment, in clean energy or otherwise. For this discussion, we assume, as a high-end figure, that 50 percent of the 1,681 displaced workers per year—i.e. 840 workers per year—will need access to significant retraining opportunities after experiencing displacement from their fossil fuel industry-based jobs.

There will be two components of this job retraining program for these 840 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. The average figure for in-state tuition for community college in Pennsylvania is around \$11,000.¹⁷ We then also allow an additional \$3,000 per year per worker to cover other expenses during their training program, such as purchases of textbooks and equipment. We assume that workers would require the equivalent of two full years of training, which they would most likely spread out on a part-time basis, as they move into their guaranteed jobs. By this measure, the average costs of the training program for 840 workers would be about \$12 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 again assume that half of the 1,681 displaced workers per year will need relocation allowances, at an average of \$75,000 per displaced worker.¹⁸ That would bring the annual relocation budget to about \$63 million for 840 workers each year.

Overall Costs for Supporting Displaced Workers

In Table 6, we show estimates of the full costs of providing this set of wage insurance, retraining and relocation support for 1,681 workers per year. As Table 6 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.

¹⁷ <https://www.communitycollegereview.com/tuition-stats/Pennsylvania#:~:text=For%20Pennsylvania%20community%20colleges%2C%20the,is%20approximately%20%2413%2C841%20per%20year.>

¹⁸ According to the 2023 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.

Table 6.
Total and Annual Average Costs for Just Transition Support for Displaced Fossil Fuel-Based Workers in Pennsylvania, 2026 – 2035

Year	Income support <i>(3 years of support for 1,681 workers)</i>	Retraining support <i>(2 years of support for 840 workers)</i>	Relocation support <i>(1 year of support for 840 workers)</i>	Total (Cols. 1+2+3)
2026	\$62.3 million	\$12 million	\$63.0 million	\$137.3 million
	(1 cohort)	(1 cohort)		
2027	\$124.6 million	\$24 million	\$63.0 million	\$211.6 million
	(2 cohorts)	(2 cohorts)		
2028	\$186.9 million	\$24 million	\$63.0 million	\$273.9 million
	(3 cohorts)	(2 cohorts)		
2029	\$186.9 million	\$24 million	\$63.0 million	\$273.9 million
	(3 cohorts)	(2 cohorts)		
2030	\$186.9 million	\$24 million	\$63.0 million	\$273.9 million
	(3 cohorts)	(2 cohorts)		
2031	\$186.9 million	\$24 million	\$63.0 million	\$273.9 million
	(3 cohorts)	(2 cohorts)		
2032	\$186.9 million	\$24 million	\$63.0 million	\$273.9 million
	(3 cohorts)	(2 cohorts)		
2033	\$186.9 million	\$24 million	\$63.0 million	\$273.9 million
	(3 cohorts)	(2 cohorts)		
2034	\$186.9 million	\$24 million	\$63.0 million	\$273.9 million
	(3 cohorts)	(2 cohorts)		
2035	\$186.9 million	\$24 million	\$63.0 million	\$273.9 million
	(3 cohorts)	(2 cohorts)		
2036	\$124.6 million	\$12 million	---	\$136.6 million
	(2 cohorts)	(1 cohort)	---	
2037	\$62.3 million	---	---	\$62.3 million
	(1 cohort)	---	---	
Total	\$1.9 billion	\$240 million	\$630 million	\$2.7 billion
Average Annual Costs	\$155.7 million <i>(12 years of support)</i>	\$21.8 million <i>(11 years of support)</i>	\$63.0 million <i>(10 years of support)</i>	\$240.5 million <i>(12 years of support)</i>

Source: Tables 4-5. All figures are in 2023 dollars.

For example, in 2026, the first cohort of 1,681 displaced workers will receive support through the just transition program, including wage insurance, retraining and relocation support, as needed. As we can see in column 4, these full costs will amount to \$137.3 million in 2026. Costs increase in 2027, 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 2026 rise to \$211.6 million. In 2027, 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 \$273.9 million, the figure that then prevails through 2036. In 2036 and 2037, with smaller cohorts eligible for income and retraining support, and no further cohorts receiving relocation support, the costs of the program fall correspondingly, to \$136.6 million, then to \$62.3 million.

In total, just transition benefits provided to 1,683 displaced workers per year in Pennsylvania will total to \$2.7 billion, or an average of \$240.5 million per year over 12 years, in total costs and about \$167,000 per worker.

Transitional Support for Workers Facing Indirect and Induced Job Losses

It should not be a challenge, either administratively or financially, to provide transition support for the relatively small number of workers facing displacement through indirect and induced job channels. This is especially the case because, on balance, there should be no jobs lost in Pennsylvania through the induced employment channel after we take account of the just transition program for workers who experience displacement through the direct employment channel. This is because, as we have described above, induced employment effects refer to the expansion of employment that results when people in any given industry—such as clean energy or fossil fuels—spend money and buy products. This increases overall demand in the economy, which means more people are hired into jobs to meet this increased demand. It follows that the loss of incomes through a contraction of employment will create a reverse induced employment effect. People will have less money to spend, overall demand for goods and services will contract, and therefore the demand for employees will decline correspondingly. However, our proposed just transition program provides that workers facing displacement through the direct jobs channel will be guaranteed re-employment at a compensation level equal to what they were earning before they became displaced. It follows that implementing the just transition program will mean that there will also be no reverse induced employment effects in Pennsylvania even as the fossil fuel-based industries themselves contract.

6. CONCLUSION

The extraction of natural gas from the Pennsylvania expanse of the Marcellus Shale deposit through fracking operations, which began in 2008, has delivered some economic benefits to working people and communities in Pennsylvania. As we have seen, at their respective peak levels in 2014 and 2017, roughly 24,000 people in Pennsylvania were employed in fracking operations and average pay reached \$127,000. At the same time, fracking in Pennsylvania has generated severe public health and environmental impacts, including groundwater contamination, and a range of chemical, physical and psychological hazards.

The negative impacts of fracking operations in Pennsylvania also extend well beyond the state's borders. This is because burning fossil fuels to produce energy—including natural gas extracted from the earth through fracking operations—is, by far, the most important driver generating the global climate crisis. Phasing out all fossil fuel consumption is therefore a first-order priority for moving onto a viable climate stabilization path, in Pennsylvania and throughout the global economy.

At the same time, people do still need to consume energy to light, heat and cool buildings, to power cars, buses, trains, and airplanes, and to operate computers and industrial machinery, among other uses. As such, to make progress towards climate stabilization requires building, throughout the global economy, a new energy infrastructure whose foundations are high efficiency and clean renewable energy sources.

As we have reviewed, the project of building a clean energy infrastructure in Pennsylvania, capable of providing the state with roughly half of its energy needs as of 2035 while fossil fuel consumption declines by a corresponding 50 percent, would generate far more jobs in the state than have been created through fracking. By our estimate, investing about \$26 billion per year in clean energy investments in the state, roughly equal to 2.5 percent of the state's GDP, would deliver sufficient energy to supply the state with 50 percent of its energy needs. These clean energy investments would generate roughly 160,000 jobs in the state, in a wide range of occupations.

Nevertheless, it is still the case that the phase out of fracking and other fossil fuel production will entail job losses and displacement for workers that are now employed in the fossil fuel industry. As we show, after taking account of voluntary retirements, the number of fossil fuel sector-based workers who would face displacement would be roughly 1,700 per year though the 10-year phase down of the state's fossil fuel production activity between 2026 and 2035.

It will not be a major challenge to find new jobs for these 1,700 workers per year, given the 160,000 jobs that will be generated concurrently through clean energy investments in the state as well as, more generally, an overall employment level in Pennsylvania 6.2 million people. The 1,700 displaced workers per year would thus constitute 1.1 percent of the jobs generated by Pennsylvania's clean energy investments and 0.03 percent of overall employment in the state. hard to

Nevertheless, these 1,700 workers per year facing displacement deserve generous transition support policies—what we have termed, following Tony Mazzochi, a just transition. These just transition policies should include pension, employment and income guarantees, in addition to, as needed, retraining and relocation support. We estimated that a just transition program for these workers, including wage insurance, retraining, and relocation programs, will cost in the range of \$240 million per year. This amounts to about 0.02 percent of Pennsylvania's current GDP.

In short, our paper shows how, between 2026 and 2035, Pennsylvania could phase out 50 percent of all its fossil fuel production activities—including its fracking operations—while also providing generous support for the working people to transition out of their fossil fuel industry jobs and into activities that both raise public health and environmental standards in the state and contribute significantly toward a viable global climate stabilization project.

Appendix

Estimating Worker Characteristics

Our estimates of worker characteristics, presented in Tables 2-4, are based on data from the U.S. Labor Department household survey, the Current Population Survey (CPS), administered by the U.S. Census Bureau for the Bureau of Labor Statistics (see: www.bls.gov/cps/). For a full discussion of the measures we use and how we identify workers in the fossil fuel sectors using IMPLAN and CPS combined, see Appendix 2 of Pollin et al. (2021). For this chapter, we use the most up-to-date, post-COVID recovery, CPS data files available (i.e., 2022-2024) as well as the 2023 IMPLAN data on fossil fuel sector employment. The one exception to this is that, as we discuss below, we use different data sources for our compensation figures.

As with the Pollin et al. (2021) study, we need to pool CPS data across years (2022 to 2024) in order to achieve adequate sample sizes to generate reasonable estimates of worker characteristics. We also need to pool, in most cases, across geographic units beyond Pennsylvania. Except for our estimates of the percentage of fossil fuel sector workers who are age 55 years old and over in 2024 (Table 4) and the compensation figures, these estimates are based on the mid-Atlantic region which includes Pennsylvania, New York and New Jersey, rather than Pennsylvania only.

Compensation Estimates

The compensation figures for fossil fuel sector jobs in this chapter are based on the U.S. Labor Departments Quarterly Census on Employment and Wages (QCEW). The QCEW is the BLS’ establishment-based survey and is a near census of all jobs in the U.S., with estimates available at the national, state, MSA, and county levels (see: <https://www.bls.gov/cew/>). This departs from our method of using IMPLAN compensation figures in our 2021 report. We changed our data source for our fossil fuel sector earnings estimates due to the unusual—and implausible—volatility in the IMPLAN compensation data for Pennsylvania’s the oil and gas extraction industry from 2018 through 2023. The oil and gas extraction industry comprises a quarter of Pennsylvania’s fossil fuel sector jobs (see Table 1) so that any volatility in the data for this sector significantly impacts our measures for the overall fossil fuel sector in Pennsylvania.

Specifically, IMPLAN provides employment and compensation data for wage and salary workers as well as proprietors (see Appendix 2 of Pollin et al. 2021 for discussion as IMPLAN data). We show in Table A.1, average annual compensation figures of oil and gas extraction industry wage/salary workers and proprietors separately (cols. 1-2) and then combined (col. 3). Wage and salary workers make up between 21 percent and 33 percent of total employment in this sector.

Table A.1 Compensation Estimates for the Oil and Gas Extraction Industry (2023 dollars), 2018-2023

Year	IMPLAN: Average Annual Compensation			BLS QCEW: Average Annual Wages
	Wage/Salary Employees	Proprietors	Wage/Salary Employees and Proprietors, combined	Wage/Salary Employees
2018	\$196,701	\$28,163	\$52,119	\$148,903
2019	\$260,197	\$179,687	\$168,932	\$154,574
2023	\$456,171	\$65,620	\$160,213	\$144,116

The IMPLAN estimates indicate that wage and salary workers' earnings more than doubles between 2018 and 2023. This contrasts sharply with the wage trends indicated by the BLS' QCEW data (col. 4, also see Figure 1). The BLS QCEW data indicate that wage and salary workers' earnings rose between 2018 and 2019 and then fell below 2018 levels in 2023. Although the QCEW data are for wages only whereas the IMPLAN data include wages and benefits, these trends should nevertheless be similar as they are both measures of compensation for wage-earning workers.¹⁹

The IMPLAN proprietor compensation figures (col. 2) are even more volatile than the IMPLAN wage and salary figures. However, this may be explained by the fact that proprietors' compensation reflect earnings from self-employment or other types of business income and therefore includes both earnings gains and losses. Additionally, these figures may reflect other year-to-year accounting differences that are not applicable to wages.

It is unclear what is the source of these implausible trends in IMPLAN earnings, particularly for wage and salary earners. As a result, we do not view the IMPLAN compensation estimates to be reliable for our current analysis. We instead use the average annual wage estimates from the BLS' QCEW. Moreover, we use the average data from 2019 (just prior to the COVID pandemic) and 2023 in order to smooth out the shock to the economy of the COVID pandemic that may linger in the 2023 data and thereby better reflect the conditions of today's fully recovered economy.

We do not observe the same type of volatility in the IMPLAN earnings data for the clean energy sector jobs. Therefore, we continue to use IMPLAN data for the clean energy sector compensation estimates and use the average of the 2019 and 2023 figures. We present these figures in Table A.2.

¹⁹ For information about IMPLAN compensation data, see: <https://support.implan.com/hc/en-us/articles/115009666268-Employee-Compensation>). For information about BLS QCEW compensation data, see: <https://www.bls.gov/cew/publications/employment-and-wages-annual-averages/current/home.htm#wages>.

Table A.2. Compensation Estimates for Clean Energy Sectors (2023 dollars)

Year	1. Building retrofits (10,120 workers)	2. Industrial efficiency (2,880 workers)	3. Grid upgrades (2,610 workers)	4. Mass transit (12,006 workers)	5. Solar (17,640 workers)	6. Wind (5,780 workers)	7. Low emissions bioenergy (8,250 workers)	8. Geothermal (6,300 workers)	9. Small scale hydro (7,686 workers)	Total Weighted Average
2019	\$88,196	\$115,132	\$101,187	\$39,092	\$102,021	\$98,446	\$83,905	\$100,591	\$92,129	\$86,766
2023	\$73,100	\$100,000	\$87,700	\$39,800	\$88,400	\$85,700	\$72,300	\$84,300	\$78,100	\$75,300
Average	\$80,648	\$107,566	\$94,444	\$39,446	\$95,211	\$92,073	\$78,103	\$92,446	\$85,115	\$81,033

REFERENCES

- Bistline, J., N. and Wolfram C. Mehrotra (2023) *Economic Implications of the Climate Provisions of the Inflation Reduction Act*. Brookings Papers on Economic Activity, March, <https://www.brookings.edu/articles/economic-implications-of-the-climate-provisions-of-the-inflation-reduction-act/> <https://www.brookings.edu/articles/economic-implications-of-the-climate-provisions-of-the-inflation-reduction-act/>
- Buchanich, Jeanine M., Evelyn O. Talbott, Vincent Arena, Todd M. Bear, James P. Fabisiak, Sally E. Wenzel, Ada O. Youk, and Jjian-Min Yuan (2023) *Hydraulic Fracturing Epidemiology Research Studies: Asthma Outcomes*, School of Public Health, University of Pittsburgh, July, chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/https://paenv.pitt.edu/assets/Report_Asthma_outcomes_revised_2023_July.pdf
- Chomsky, Noam and Robert Pollin (2020) *Climate Crisis and the Global Green New Deal: The Political Economy of Saving the Planet*, London: Verso.
- Gorski, Irena, and Brian S. Schwartz (2019) “Environmental Health Concerns From Unconventional Natural Gas Development.” *Oxford Research Encyclopedia of Global Public Health*, 25, doi:10.1093/acrefore/9780190632366.013.44.
- Lefebvre, Ben (2024) “Why Harris and Trump are Debating the F-word,” *Politico*, 9/9, <https://www.politico.com/news/2024/09/09/trump-harris-fracking-feud-explained-00177583>
- Mazzocchi, Tony (1993) “A Superfund for Workers,” *Earth Island Journal*, 9(1), pp. 40-41.
- Office of the Attorney General, Commonwealth of Pennsylvania (2020) *Report 1 of the Forty-Third Statewide Investigating Grand Jury*, <https://www.attorneygeneral.gov/wp-content/uploads/2020/06/FINAL-fracking-report-w-responses-with-page-number-V2.pdf>
- Penn Wharton (2023) “Update: Budgetary Cost of Climate and energy provisions in the Inflation Reduction Act.” Available at: <https://budgetmodel.wharton.upenn.edu/estimates/2023/4/27/update-cost-climate-and-energy-inflation-reduction-act>.
- Pollin, Robert (2023) “The Political Economy of Saving the Planet,” *The Japanese Political Economy*, Vol 49, 2-3, <https://doi.org/10.1080/2329194X.2023.2262531>, pp. 141 – 168.
- Pollin, Robert, Jeannette Wicks-Lim, Shouvik Chakraborty, and Tyler Hansen. 2019. “A Green Growth Program for Colorado.” <https://www.peri.umass.edu/publication/item/1168-a-green-growth-program-for-colorado>.
- Pollin, Robert, Jeannette Wicks-Lim, Shouvik Chakraborty and Gregor Semieniuk (2021) *Impacts of the Reimagine Appalachia & Clean Energy Transition Programs for Pennsylvania: Job Creation, Economic Recovery and Long-Term Sustainability*, Political Economy Research Institute, <https://peri.umass.edu/?view=article&id=1026:green-economy-transition-programs-for-u-s-states&catid=143:environmental-and-energy-economics-1>
- Pollin, Robert, Jeannette Wicks-Lim, Shouvik Chakraborty, Gregor Semieniuk, and Chirag Lana (2023) *Employment Impacts of New U.S. Clean Energy, Manufacturing, and Infrastructure Laws*, Political Economy Research Institute, <https://peri.umass.edu/?view=article&id=1749:employment-impacts-of-new-u-s-clean-energy-manufacturing-and-infrastructure-laws&catid=12>