



Original research article

Necessary, welcome or dreaded? Insights on low-carbon transitions from unionized energy workers in the United States[☆]Diane M. Sicotte^{*}, Kelly A. Joyce, Arielle Hesse

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ABSTRACT

The Green New Deal resolution in 2019 focused the United States on the need to quickly phase out fossil fuel use. Unionized energy workers, important actors in low-carbon energy transition, are theorized as being concerned about the environment and much affected by the energy transition, but US energy workers are understudied and their concerns and needs are not well understood. In this study, part of a larger project on labor and energy, we focus on in-depth interviews conducted in 2019 and 2020 with 48 labor union members and leaders in varied occupations from eight national unions located in New Jersey, New York and Pennsylvania. Energy workers' views on climate change were varied, but contrary to stereotypes about blue-collar workers "climate skeptic" views were held by only a few. Despite political polarization in the US, energy workers' political identity did not seem to be as important regarding what type of energy system they thought the US should adopt. Energy workers' views on how they would be affected by low-carbon energy transition varied according to the degree to which their skills were a good match for skills needed in renewable energy industries and whether their bargaining power was enhanced or disempowered by conditions in renewable energy industries. Our findings emphasize the need for the Multi-Level Perspective to incorporate a way to examine power relations in renewable energy industries. We argue that the needs and opinions of these workers should be central to deliberations and planning for energy transition in the U.S.

1. Introduction

Scientific evidence now indicates that we have entered a climate emergency. If we are to avert catastrophic consequences, coal, natural gas and oil energy sources must be replaced with low-carbon and low-methane fuels as quickly as possible [1]. But fossil fuels are still the primary sources of energy in the US; in 2020, 79% of all energy consumed was fueled by coal, oil or natural gas. Another 9% came from nuclear power, and only about 12% was fueled by renewable sources including hydroelectric, solar and wind power [2].

While urgently needed, proposals to quickly phase out fossil fuel use threaten the livelihoods of at least some whose work involves or is related to fossil fuels. The question of how many in the US will lose employment if fossil fuels are phased out is important, but the answer is complex. The Department of Energy considers "energy employment" to be concentrated in four economic sectors: power generation and fuels; energy transmission, distribution and storage; energy efficiency, and

motor vehicles. They estimate a current workforce of about 4 million involved with "traditional energy" sources such as coal, oil and natural gas in these sectors, but they note that some of the jobs lost will be offset by expanded employment in renewable energy and energy efficiency [3]. The most conservative estimate characterizes as vulnerable only the 582,000 jobs directly involved in coal mining and oil and gas drilling, and the support activities for each [4]. Other researchers estimate that reducing greenhouse gas emissions by 40% over the next 20 years would mean a loss of 1.5 million jobs directly and indirectly related to fossil fuels—a 34% contraction in employment [5], mitigated by the fact that 85% of job losses could occur through retirement at age 65, and also by a shift in employment from fossil fuel jobs to new jobs in energy efficiency and clean energy industries [6].

Labor has been theorized as influential in energy transitions, but unions have taken varied positions on energy transitions [7]. Since 2012, the Laborers International Union of North America (LiUNA), backed by the US's largest umbrella labor organization, AFL-CIO, has

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endorsed the Keystone XL and Dakota Access pipelines and applauded President Trump's lifting of the ban on crude oil exports [8]. In addition to LiUNA, the International Brotherhood of Electrical Workers (IBEW) and United Mine Workers of America (UMWA) strongly opposed the Obama Administration efforts to phase out coal through EPA's Clean Power Plan, a position known in union circles as "the Black-Blue Alliance" [8,9].

Other unions including the Communication Workers of America (CWA) and the United Electric, Radio and Machine Workers of America (UE) opposed the Dakota Access Pipeline [8], citing concerns for drinking water and the human rights of Native Americans [10,11]. Although United Association (UA), a plumbers' and pipefitters' union, represents oil and gas pipeline workers and United Steel Workers (USW) represents refinery workers, both unions are members of the Blue-Green Alliance, an organization that seeks to bring labor unions together with environmentalists to address issues where work and environment intersect [12].

The question of how energy workers view the prospect of an energy transition is a complex one not well understood by researchers. In this study we bring the views of unionized energy workers in the Northeast US into clearer focus by investigating their views on two issues: whether they see a low-carbon energy transition as necessary; and whether they view renewable energy technologies as displacing them from their jobs, bringing precarity into their work lives, or bringing them new opportunities.

2. Theorizing energy workers' views on a possible low-carbon energy transition in the United States

Our work contributes to the interdisciplinary field of "transition management," which focuses on how to manage sustainability transitions and how they should be governed [13]. Low-carbon energy transitions are contested, political undertakings that involve multiple actors and power imbalances [14–18] and tend to yield winners and losers [19–21]. But transition management research has been criticized for not delving deeply enough into issues such as resistance from energy system incumbents [21,22], issues of power and inequality [23], access to transitional assistance [24,25] and access to participation in decisions about how the transition will take place [17].

Low-carbon energy transitions vary a great deal across regions and are context-dependent [26]. Theorizing how US energy workers might view a possible energy transition requires an understanding of the political, economic and social context facing energy workers; the attitudes of labor union members toward environmental issues such as climate change, and the consequences to energy workers of technological shifts in the sociotechnical energy system.

2.1. The Just Transition in the US

The term "just transition" refers to a sustainability transition in which harms to people vulnerable to the social impacts of transition, such as job loss, are mitigated [27]. Discussion of just transition in the US originated in the 1990s with labor leader Tony Mazzocchi's focus on the need for a "Superfund for workers" that would provide income supports and college tuition for workers so that the most hazardous jobs in the most toxic industries could be phased out [28].

Such supports are an important feature of the Ocasio-Cortez/Marky Green New Deal resolution introduced into the United States Congress in 2019. The Green New Deal blends two goals: decarbonizing the economy by 2030 and addressing structural inequalities. US Senator Bernie Sanders then fleshed out the resolution by detailing the cost of initiatives to build out renewable energy and low-carbon transportation and infrastructure, support displaced energy workers, and expand the social safety net [29].

These policy proposals backgrounded interviews with union members, which took place before March 2021 when President Joe Biden

announced his American Jobs Plan initiative, a proposal similar to the Green New Deal that would modernize the power grid to deliver green electricity, retrofit buildings to make them more energy efficient and expand employment in renewable energy. In the proposal, Biden calls on Congress to pass the Protecting the Right to Organize (PRO) act, which would protect workers' right to organize a union [30], signaling a sharp change from both the anti-labor and anti-environmentalist practices of his predecessor, Donald Trump.

In addition to helping craft such government initiatives, labor unions are building state-level coalitions of unions through the Climate Jobs National Resource Center. These coalitions are currently providing training for workers and pushing for the development of renewable energy industries and worker protections such as project labor agreements in these industries [31].

But despite the importance of labor in low-carbon energy transitions, only a small stream of research on this topic has accumulated, most of which focuses on energy workers in Europe [17,25,32–35]. One recent study including US energy workers, the Just Transition Listening Project, revealed that energy workers were concerned about climate change but resisted the idea of low-carbon energy transition due to fear that they would be left to shoulder the burden of job displacement without assistance. Manufacturing workers in this study had already experienced mass layoffs in their industry without assistance, which they considered an unjust transition [36].

Of the remaining studies on US energy workers, nearly all focus on the experience of coal workers [37]. This is not surprising as the US's only significant energy transition to date has involved decreased demand for coal, driven more by the expansion of inexpensive natural gas and less by the Obama administration's environmental reforms aiming to phase out coal use. The diminished profitability of coal has triggered sudden mine and plant closings in Appalachia [38], a "chaotic and unmanaged decline" [39, pg. 3] that has devastated surrounding communities [40] and the United Mine Workers of America [37]. But in the Southwest region, the planned shutdown of the coal-fired Mohave Generating Station went differently. The Mohave Station was supplied by the Black Mesa Coal Mine located on tribal lands of the Hopi and Navajo Nations, and its shutdown would have deprived the tribes of revenue and jobs. Instead, both tribes worked in coalition with environmentalists to use SO2 emissions credits to create dedicated funding for transition assistance [41]. Both shutdowns exemplify why market forces alone are not capable of producing managed declines, which require transitional assistance policies for workers [24] and planned plant closures [39]. Nor are jobs in renewable energy a panacea: it is known in labor circles that some "green jobs" are low-wage jobs in which labor rights and safety standards are violated [42]. Both the issue of job loss and the issue of job quality will have to be addressed to bring about a just transition from fossil fuels in the US.

2.2. Labor unions and environmentalism

Despite the politically useful stereotype of the anti-environmentalist blue-collar energy worker [43], labor union members in the US are just as concerned about environmental issues as members of the general public [44] and may be more supportive of environmental protection during strong economic times [45]. Union leaders characterized their unions' relationships with environmental groups as good, even when their industry had suffered recent job loss [46]; and even union members in industries such as petroleum refining consistently said that the government was spending "too little" on environmental protection [47]. US labor unions have long been involved in environmental and energy issues [46,48–51] and have supported environmental regulation even when it was directly opposed to their economic self-interest [48]. Union members active in climate change issues have formed new environmental caucuses within their unions and forged new alliances with other unions and environmentalists through important bridging organizations such as the Blue-Green Alliance and the Labor Network for

Sustainability [42].

However, environmental sociologists theorize that workers' interests span both the use value and exchange value of ecosystems disorganized by production. While workers suffer losses from environmental degradation caused by expanding industry, labor occupies the middle ground between environmentalists and fossil fuel energy producers [52]. Although unionized workers were predicted to unite with their employers to resist the phase-out of fossil fuels, workers' material and political interests can affect the politics of production in unpredictable ways [54]. As was true of German workers, unionized energy workers in the US can be either a force for continuing fossil fuel use, a "force for sustainable change" [7, pg. 218] or a force for *both* continuing fossil fuel use and the adoption of renewable energy, which could slow down efforts toward low-carbon energy transition.

2.3. Sociotechnical systems, workers and technological change

A sociotechnical systems approach to low-carbon energy transition highlights social factors such as norms and values, natural resources, science, organizations, laws, policies, financing, industries and user practices that co-constitute the design and use of technologies [15,55,56]. Geels' Multi-Level Perspective (MLP), focusing on the development of new, sustainable technologies as a driver of sociotechnical energy regime change, has become a central heuristic framework in research on sociotechnical systems [17]. The MLP conceptualizes a sociotechnical system made up of niches for the development of sustainable energy technologies, regimes in which dominant energy technologies are institutionalized, and landscapes in which contextual social factors such as energy policy impact the sociotechnical regime [57]. In later work, Geels addresses power relations by pointing to the core alliance between policymakers and incumbent firms, which strengthens energy corporations' ability to resist change [58].

This suggests that in the US, labor, together with boosters of niche technologies, face the "Goliath" of fossil fuel corporations aligned with the state [58, p. 37] but the MLP provides no way to examine power relations within renewable energy industries not yet fully institutionalized into the energy regime. Avelino usefully applies the concept of disempowerment to the MLP framework [59], allowing for a critical examination of labor and power relations in sociotechnical energy regime transition.

Current research on how new technology affects workers is almost entirely focused on technologies such as artificial intelligence and the self-driving car, but it usefully categorizes the impacts of new technologies on workers: *displacing technologies* replace workers, particularly those whose skills are a poor match with the skills demanded by the new technologies. In contrast, *enabling technologies* create new occupations and stimulate demand for employees [60,61]. But the technologies themselves do not determine the outcomes for workers: instead, positive or negative effects on workers are contingent on the skill demands of the technology, labor arrangements and processes of implementation [62], and on the power of labor [61].

2.4. Low-wage and precarious jobs and labor power in the US

In the US the number of low-wage jobs has been growing: between 1979 and 2016 the median wage level for non-college-educated workers has declined as has the proportion of employers providing paid sick leave and vacation time, health insurance and pensions; and the proportion of workers in non-standard work arrangements such as temporary work, work outsourced to contracting companies, and self-employment has increased [63]. These types of work situations have been characterized as low-quality or precarious [64]. Declines in job quality have been most acute among non-college educated men [65], who are a large proportion of the US energy workforce.

The existing US fossil fuel energy system developed in stages during

the 19th and early 20th centuries [66] and was marked by low pay and hazardous working conditions. It was only by organizing unions in the early twentieth century that energy workers were able to win higher pay and safer working conditions [67,68]. Although unionized work in fossil fuel industries is well-paid now, new energy industries such as solar and wind power are developing at a time when the bargaining power of labor is greatly diminished.

As of 2020, only 10.8% of all US workers were union members, and only 6.3% of private sector workers were union members [69]. Declines in union membership have been accelerated by government attacks on unions such as "Right-to-Work" laws passed by state legislatures that prohibit unions from collecting dues from non-members who are represented by the union. In 2018 the US Supreme Court narrowed labor rights and protections under the National Labor Relations Act (NLRA): it upheld right-to-work laws in the *Janus v. AFSCME* decision and ruled in the *Epic Systems Corp. v. Lewis* decision that forcing employees to agree to arbitrate disputes with employers as individuals instead of bargaining collectively through their union does not violate the NLRA [70]. Emboldened by government failure to protect unions, corporations found it increasingly cost-effective to hire "consultants" to prevent unions from being certified, often acting illegally by firing union organizers or sympathizers [71]. These developments underscore the need for more research on employment as an aspect of the sociotechnical energy system.

3. Methods

As part of a larger project that included collecting and analyzing data from union websites, we conducted 101 in-depth interviews with members and leaders from ten labor unions located in New Jersey, New York or Pennsylvania from September 2019 to December 2020. We sought to understand how unions and unionized workers viewed energy technologies, and what kind of energy system they wanted to see in the future. We chose the Mid-Atlantic region for its union-rich environment and for contrasting state-level policies on low-carbon transition. Compared with New York and New Jersey, Pennsylvania legislators have made more modest commitments to increasing the proportion of energy sourced from renewable technologies. Pennsylvania also lacks the policies aimed at social justice and employment growth in renewable energy industries adopted by New Jersey and New York [72].

This study focuses on 48 interviews with energy workers. The energy workers interviewed were not selected for any particular occupation, but with the aim of reaching saturation for each union.

They included electric power plant workers from the International Brotherhood of Boilermakers (IBB); electricians who work in power plants and install solar arrays from the International Brotherhood of Electrical Workers (IBEW); heavy construction workers who build pipelines, power plants, dams for hydropower, and wind turbines from the International Union of Operating Engineers (IUOE); construction workers who install solar panels from the Laborers International Union of North America (LiUNA); plumbers, pipefitters and steamfitters who install natural gas pipelines from United Association (UA); auto manufacturing workers from United Auto Workers (UAW); workers who manufacture locomotives and offshore drilling machinery from United Electrical, Radio and Machine Workers of America (UE); and petroleum refinery workers from United Steel Workers (USW). Energy workers worked in many different occupations (see Table 1).

As was true of energy workers in the US overall [73], a majority of our interview participants were white and male. Thirty-nine (or 85%) self-identified as white while six (12.5%) self-identified as African American or Black. More of our interview participants were male than was true of energy workers in the US overall: 46 (96%) identified as male and two (4%) identified as female. Twelve (25%) described themselves as "Conservative-Leaning," "Conservative," or "Very Conservative," while 14 (29%) described themselves as "Moderate" and 13 (27%) described themselves as "Liberal-Leaning," "Liberal," or "Very Liberal."

Table 1
Occupation within industry of energy workers interviewed.

Industry	Occupation
Automobile manufacturing	Production worker
Automobile parts manufacturing	Driver (in-plant distributor of supplies)
Coal-fired electric power generation	Boilermaker
	Certified welder
	Control-room operator
	Electrician
	Emissions technician
	Pipefitter
	Union staffer
Construction (general, hydroelectric, power plants, refineries)	Water utility operator
	Electrician
	Laborer
	Operating engineer
	Operating engineer (pipelines)
Electric power distribution	Plumber and pipefitter
	Union leader
	Diesel technician
	Facilities drafter
	Industrial meter technician
	Lineman
	Outside field plant technician
Gas- and oil-fired electric power generation	Boilermaker
	Pipefitter
Institutional building maintenance	Stationary engineer
Locomotive/offshore drilling machinery manufacturing	Assembly machinist
Natural gas distribution	Union leader
	Industrial meter technician
	Natural gas mechanic
	Natural gas technician
Natural gas-fired electric power generation	Plumber
Nuclear electric power generation	Operator
Petroleum refining	Pipefitter
	Union leader
	Boilermaker
	Construction/demolition laborer
	Lab technologist
	Laborer (environmental remediation)
	Operator
	Refinery mechanic
	Water operator
Industry	Occupation
Steel manufacturing	Union official
Various (by project)	Business manager (union)
	Laborer
	Plumber and pipefitter
	Steamfitter
	Union staffer

In the US registration is required to vote in any election, and party registration is required to vote in primary elections that decide which of that party's candidates will run for President. Thirty-one energy workers (65%) were registered Democrats, four (8%) were Independents, eleven (23%) were Republicans, and two were not registered to vote.

Interviews with energy workers were 1 h long. Interview participants were asked open-ended questions about their views on the top energy issues facing US, the strengths and weaknesses of fossil fuels and renewable energy sources, and what kind of energy system they would like to see the US adopt (see Appendix for Interview Schedule for Energy Workers).

Interviews were verified and transcribed. Transcripts were coded into themes in NVivo by the three-person research team, who developed a set of 31 codes including "Climate Change," and "Imagining Energy Futures." All members of the three-person research team coded the interview data, and a merged file with all coding was used for the analysis.

4. Results: energy workers making sense of a possible low-carbon energy transition

4.1. Necessity of the transition from fossil fuels: climate change

We did not ask their views on climate change, but 29 of the 48 energy workers we interviewed, unprompted, used language that indicated they saw fossil fuel use as a problem because climate change was occurring, and its consequences were significant. Many used phrases such as "carbon footprint," and said that "our climate is definitely changing," described carbon as "a huge deal," said that "global warming is real," or said we needed an energy system that was "carbon-neutral," "low carbon" or "zero carbon-emitting." Other energy workers did not use words related to climate change, but instead referred to "pollution" or their impact on "the atmosphere" as a weakness of fossil fuels.

Members of four different unions (IBEW, IUOE, UE and USW) expressed very strong concern about climate change, using phrases such as "killing our environment," "we don't want to kill ourselves for the fossil fuel," and "we're killing our planet." Another called climate change "an existential crisis." In more than a few interviews with members of different unions, men mentioned their concern about climate change and its impacts on their children, grandchildren and future generations:

"You know, I'm 61 years old and I've got five kids. I want to see the world still be there for them and their grandkids and their ki- you know, on and on." (White man, nuclear power industry supplier worker, age range 60-69, IBEW, Pennsylvania.)

Another, when asked at the end of the interview if there was anything more he wanted us to know, said:

"We've got to stop [burning fossil fuels] because we're running out of time. They're just saying that we've got a 17-year window of fixing this, and if we don't, God knows what's going to happen." (Mixed-race man, union staffer, age range 60-69, USW, Pennsylvania.)

But concern about climate change was not unanimous: one energy worker said, "I don't know if I can go as far as saying 'contributing to global warming'" which indicated he was uncertain about climate change, while three others expressed views consistent with "climate skepticism," most strongly expressed by this boilermaker:

"Well, I think the renewable side of it, the clean and green part of it, I mean, they totally have demonized us and are telling us that we are going to end the world. I think that they've brainwashed our youth into thinking the world's going to come to an end in 12 years. And I think they're completely wrong and they're misguided." (White man, boilermaker, age range 50-59, IBB, Pennsylvania.)

While 16 out of 48 energy workers expressed no concern about air emissions from fossil fuels, the three who expressed a climate skeptic position viewed the push to get rid of fossil fuels as motivated by a "political agenda" rather than real-world effects of climate change. This illustrated political polarization around climate change in the US in 2019 and 2020. Two of the three energy workers who expressed a climate skeptic position described themselves as "Conservative-Leaning," while the other's chosen label was "Moderate/Middle-of-the-Road." The strongest concern about climate change was expressed mostly by energy workers who described themselves as "Liberal," "Very Liberal," or "Socialist" (but one energy worker who expressed strong and urgent concerns about climate change described himself as a "Conservative" Republican).

4.2. Necessity of the transition from fossil fuels: what kind of energy system should exist in the US?

When asked what kind of energy system they wanted to see in the US, energy workers' answers fell into three categories. The most prevalent,

expressed by 22 out of 48 energy workers from all eight unions, was the desire for an energy system based either solely on renewables, or predominantly renewables with fossil fuels used only as backup sources. When asked about the top energy issues in the US, this stationary engineer said:

"I think I would say transferring from fossil fuel to renewable energy is probably our primary concern, to switch over. You know, become more energy efficient, and now it's taking off more with solar." (White man, stationary engineer, age range 30- 39, IUOE, Pennsylvania.)

A natural gas technician expressed a preference for renewable energy, as opposed to natural gas:

"Well, what I would like is some type of renewable energy system that's not going to damage the environment ... Solar's great. I mean, solar's terrific. The fracking industry, to be completely and totally honest with you, is a huge stain on us. And it's just so bad. I would like to see us stop being so dependent on fossil fuels. Absolutely. And I would like us to get to renewable energy resources." (White man, natural gas technician, age range 40-49, IBEW, Pennsylvania.)

Surprisingly, among energy workers who wanted an energy system based primarily or exclusively on renewables equal numbers described their political identity as conservative, liberal or moderate.

The second most frequently desired type of energy system was a "diverse," "balanced," or "all-of-the-above" mix of energy technologies. The 10 energy workers who expressed this view cited concerns about reliability, either because of the intermittency of renewable sources such as wind and solar, or because they felt renewable energy technologies were "not yet proven." This natural gas power plant worker thought we should have "a little bit of everything":

"... I still don't believe that doing away with coal completely is the right answer for our country. We're going to have to have a little bit of everything. I believe in the wind, and solar, and the renewables, but they've got their place, and technology hasn't proven to me yet that their place is to take the place of the other ones yet. It's to come alongside, come in, cut back on those things." (White man, natural gas power plant operator, age range 50-59, IBEW, Pennsylvania.)

Finally, four energy workers wanted to see natural gas use expand rather than be curtailed. This position seemed based on economic self-interest, but also on environmental concerns: one also favored the expansion of solar energy, while another also favored the expansion of nuclear power. As this labor leader indicated, they seemed to feel that natural gas was cleaner than coal or oil:

"Well, in Pennsylvania we've been blessed with the Marcellus Shale gas...It's clean energy, it's great energy. I can't understand why there isn't more fuel pumps and more natural gas cars; you can convert a car over quite easily [from gasoline to natural gas], which is abundantly cleaner." (White man, labor leader, age range 60-69, IUOE, Pennsylvania.)

Unlike the energy workers who wanted an energy system based on renewables or on "all of the above," those who advocated natural gas expansion tended to be registered Independents or Republicans rather than Democrats.

Considering the prevalence of concern about climate change among energy workers, combined with energy workers' most prevalent preference for an energy system based on renewable energy technologies, most of the energy workers we interviewed indicated that a transition away from fossil fuels and toward renewables is necessary.

4.3. *Imagining renewable energy jobs*

Interview participants were well aware that the renewable energy

sector is growing. But while some participants saw renewable energy as an opportunity for new work, others saw it as a source of job loss; or as a source of low paying, low-skill, temporary jobs. Their responses indicated that a blanket policy promoting the development of renewable energy will not solve employment issues for all energy workers.

4.3.1. *Renewable energy technologies as replacing technologies: mismatch of skills*

Energy workers in three unions (IBB, UA and USW) mentioned concerns about the mismatch of skills they would face if fossil fuel use were phased out. Energy workers in one union (IBB) clearly viewed renewable energy technologies as replacing technologies and were pessimistic about the prospect of work in renewable energy. As this boilermaker put it:

"I would think I would need to be retrained. For what we do [work in renewable energy is] nonexistent in boiler-making, beyond the one job that I know of that we had exposure in was when we were doing the windmills, because there's a turbine and there's housing and stuff like that." (White man, boilermaker, age range 40-49, IBB, Pennsylvania.)

This steamfitter was a bit more optimistic about the prospect of work in sectors other than energy:

"Right now, we are going through the desire to transition from oil and gas, which is where a bunch of our work is, into the green energy, to your windmills and solar, different moratoriums on gas piping, and pipelines being shut down and different projects getting canceled, and it's affecting our industry, this transition... Maybe we're going to get into more medical gas piping." (White man, union business manager, age range 50-59, UA, New Jersey.)

For some of the Steel Workers we interviewed, the prospect of job loss was more than hypothetical: after an explosion and massive fire on June 21, 2019, the Philadelphia Energy Solutions refinery was permanently shut down, throwing about 1000 employees out of work. The shutdown was due to a business decision by the banks that owned the refinery rather a step toward phasing out fossil fuel use, but the impact on these refinery workers was similar to the impact of unmanaged decline on coal workers: a difficult shift from high-paying work to uncertainty. When asked his union's stance on renewable energy technologies, one steelworker said:

"If you're an oil worker, you're an oil worker. And they don't see any transition. And that's, to me, the biggest hurdle. There's no easy transition for us."

But he said he disagrees with this stance, and went on to say:

"I think eventually, if we did the right things, green is jobs. Good jobs." (White man, refinery lead operator, age range 40-49, USW, Pennsylvania.)

Some union members saw the security of their jobs in fossil fuels as waning but were uncertain or pessimistic about the prospect of jobs in renewables. This was particularly true for union members whose work involved generating power from coal: they were concerned about job security and did not see a future in their present occupation. They saw coal technology as dirty, outmoded, "a dying industry," and under attack from environmentalists and politicians. As this power plant worker put it:

"[N]ow it's kind of like still good jobs, still pay as well, not sure where I'm going to be five years from now or ten years from now. Most likely my plant might not be there, so that part's a little worrisome, but I still got a pension. I look around like other jobs: you don't find pensions. You don't find, you know, over \$30 an hour. You don't find any of that local, near here, so [this is] definitely the best working

environment I've ever had." (White man, coal-fired power plant employee, age range 30-39, IBEW, Pennsylvania.)

When asked his impression of jobs in fossil fuel industries, this diesel technician said:

"My impression of jobs in the fossil fuel energy sector is that, if you have a job in the fossil fuel energy sector, you should really start thinking about going into another sector. In ten or fifteen years, a diesel technician, at least in the energy industry, is probably not going to be very valuable; however, a hybrid technician, somebody who can work on the electric equipment, will be." (White man, diesel technician, age range 30-39, IBEW, Pennsylvania.)

4.3.2. Will the renewable energy sector provide good jobs?

Other union members were apprehensive about aspects of work in renewable energy technologies that could transform their present, relatively secure employment situations into precarious situations. We heard many different energy workers say that once built, wind and solar energy installations needed far fewer workers to run and maintain them. Some energy workers also felt that work in renewables paid less because, in their occupation, it required less skill. As a boilermaker put it:

"Well, I can tell you, I met a few weeks ago with [a company that invests in solar energy]. So they're saying that every one of these plants that they have, they probably got five people that work there. Okay? Three of them monitor the electricity and two of them are basically washing and squeegeeing solar panels. I don't see the pay being even close to what a pay scale of like, just say for my trade, a boilermaker, makes." (White man, boilermaker, age range 50-59, IBB, Pennsylvania.)

The issue of precarity is particularly acute for less-skilled laborers in the construction industry, who face wage exploitation and unsafe conditions in the solar energy industry. A union leader with the Laborers International Union of America (LiUNA) viewed the need for unskilled work in solar energy as a situation that generated exploitation:

"The problem with the renewable fields [is] there's no prevailing wage rate attached to this work. And for instance, like solar farms, it doesn't really take a really skilled person to build these solar farms. There's not a lot of welding. Not to be out of line, but we call it 'monkey work,' after a week, anybody knows how to install solar panels. So what happened in our industry is, you're taking away a lot of good paying jobs in the fossil fuel industry and power plants and replacing a lot of this work with solar panel work, which a lot of times you'll get crews from Texas or crews down South who will come up here and work for 40 percent of what the prevailing wage rate is." (White man, union business manager, age range 50-59, LiUNA, New York.)

But the Operating Engineers (IUOE), who do highly skilled heavy construction work building power plants and installing pipelines, also worry about being thrown out of work when construction projects fall through or change:

"We put maybe 200,000 man-hours in every year in gas infrastructure, whether it be replacement or new stuff. If we lost all of it, it would be definitely a big dent. When you have a private funded job like a hotel or a building, things can change day to day. The jobs could be slowed down, shut, changed, whatever. But when it comes to an infrastructure job, you know it's going to be done and completed and there's a need for it. Once you shut down a gas line to replace it, it's got to be put back in service. It's a good job." (White man, union business agent, age range 40-49, IUOE, New York.)

An energy worker recently laid off from a gasoline refinery liked the idea of working in renewables, but balked at the low pay offered:

"Some organization in [...] has a solar panel installation training program. I saw it last year, then looked at the pay. I'm like, 'Yeah, that's cool if you're younger, really young,' but if you've already got a family, you're established, you're at the refinery, you wouldn't take that right now. So, it has to be enticing. That doesn't look enticing right now. I don't want to go back to refining. I will never do that again. But I would want to be a part of [solar energy]. But I don't see it." (Black man, former refinery worker, age range 30-39, USW, Pennsylvania.)

Although for the most part safer than jobs in fossil fuels, some jobs in renewable energy present safety hazards such as working at heights on windmills. Hazards would be more acute for non-union energy workers, who may not have any power to resist unsafe working conditions. As this power plant worker explained:

"I've never worked [a wind turbine job], so I don't really know. I have a couple friends that went to that. They seem to be happy. So as long as you're not afraid of heights, you seem to do okay. They seem to be equally paid, and a lot of times, they're not all union, though, so they feel like they have to do stuff even if the conditions aren't really favorable. I've seen pictures of guys up in storms and stuff and it's just like, 'Why are you even up there?' 'Have to get this job done.' So, I don't like that part of it." (White man, coal-fired power plant worker, age range 30-39, IBEW, Pennsylvania.)

As a LiUNA union leader put it, "All jobs are not created equal." Precarity can be introduced by the simplicity of the renewable energy technology itself, which requires less-skilled labor, or by business practices in renewable energy industries and the legal and political context that shapes these practices.

4.3.3. Renewable energy technologies as enabling technologies

While some union members were apprehensive about the possibility of an energy transition, others were enthusiastic about the possibility of work in renewable energy. Several said they thought the US was lagging in developing renewable energy technologies. They described renewables as "the wave of the future," "advancement," and a way of "moving forward," and said that renewable energy industries are "prospering," and "a growing source of work." When asked his union's stance on renewable energy, a steamfitter said:

"I would guess they're all for it. We're not going to go against the grain and pretend that we're dinosaurs or prehistoric and we only go backwards. We're all for any advancement especially if it has to do with keeping it clean and keeping it safe." (White man, steamfitter, age range 60-69, UA, Pennsylvania.)

For some energy workers, the newer renewable energy technologies such as solar and wind open new possibilities for employment because new infrastructures must be built in order to utilize these technologies. When asked his impression of jobs in renewable energy, a business agent for the IUOE had a favorable impression of jobs in wind power:

"Very good, yeah. Every wind farm that's been put up around here has added seven, ten, fifteen jobs that are well paid between \$60,000 and \$100,000 a year, to maintain these wind farms." (White man, union business agent, age range 40-49, IUOE, New York.)

A man employed at a factory that produces auto parts thought expansion of the use of electric cars would stimulate demand for the products his employer manufactures:

"I definitely think [renewable energy technologies are] prospering. I have a friend that works at Tesla. As far as my job, a lot of the auto parts we supply to a new factory just had almost a \$2 billion investment for electric vehicles." (White man, automotive production worker, age range 20-29, UAW, New York.)

Others see the transition to renewable energy technologies as entirely compatible with their present employment, as did this union leader who works in locomotive manufacturing:

"We have a lot of conversations with [politicians] about this. And we express our concerns. I've had people ask me flat out, 'Well, you're in the locomotive business, wouldn't that be counterproductive to be discussing renewable energy?' And I don't think it is. I think the company we work for we're at the forefront of trying to reduce the emissions of our locomotives and we're working with the state of California right now to figure out how we get to zero emission." (White man, union leader, age range 50-59, UE, Pennsylvania.)

Some energy workers were optimistic about the prospect of work in renewable energy, but were aware that the expansion of the renewable energy industry requires a shift in energy policy:

"So, if there was an opportunity for the energy policies in the United States to change, I would wholeheartedly support it and I would follow it. If tomorrow I showed up to work and [they] say, 'Hey, bad news guys, we shut off all the gas pipelines. We're all working at the solar.' I'd be like, 'Hell yeah, let's go!' Seriously, let's go. Yeah. I don't like heights, so don't make me climb a windmill, but I'll work on solar all day long." (white man, natural gas technician, age range 40-49, IBEW, Pennsylvania.)

5. Discussion

This paper contributes to environmental sociology and the interdisciplinary fields of transition management and science and technology studies by examining how US energy workers view the prospect of a low-carbon energy transition. Despite political rhetoric to the contrary, our research supports the theory that unionized energy workers in the US tend to be pro-environment. We found that many US energy workers were deeply concerned about the severe impacts of unchecked climate change, and the most commonly desired energy system by this group of energy workers was one based on renewable energy sources. Nearly all agree that low-carbon energy infrastructures should be built in the US, and that government and business should focus on creating new high-quality jobs in renewable energy industries.

But four of the 48 energy workers took an obstructionist stance, advocating for technologies such as carbon capture and sequestration, which allow continued coal use. Ten others embraced an "all-of-the-above" stance on energy transition. Both stances could contribute to delaying low-carbon energy transition until it is too late.

Despite their concerns about climate change, many energy workers were apprehensive about the quality of jobs in renewable energy industries. Winning the support of energy workers and unions would help the US to advance energy policies that could accomplish swift decarbonization. This analysis demonstrates that there are ways to gain their support, particularly if training, family sustaining wages and benefits, and location are integrated into transitions. Our analysis shows that these provisions are particularly important for oil workers, pipeliners and boilermakers with skills that are not in demand in wind and solar power, and energy workers who live in areas where there is demand for fossil fuel workers but renewable energy industries have not been developed. Energy workers are eager to be part of solutions that address climate change and see the potential for future jobs in renewable energy. Labor unions need to be at the table for discussion of energy transitions to ensure that issues of equity, pay and benefits are addressed.

But beyond their policy relevance, the concerns of US energy workers are also theoretically useful to researchers. At the micro level, US energy workers confront unequal power relations within renewable and fossil fuel energy industries, underscoring the need to examine such power relations [59]. This analysis complements and complicates meso- and macro-level research that emphasizes power relations between niche

and incumbent energy industries [57,58]. These dynamics are crucial factors in determining the speed, effectiveness and justice of low-carbon energy transitions. Geels' influential Multi-Level Perspective conceptualizes the "landscape" of the sociotechnical energy regime [57,58] as shaped by a specific political and economic context. In the US, the context includes a globalized, financialized economy and a political environment deferential to market forces and neglectful of or hostile to labor rights. Renewable energy industries are currently developing in a twenty-first century context including global trade regimes, energy deregulation and competitive market pressures, which places them at risk to become non-union, low-wage and unsafe employment sectors. Understanding how these industries will displace workers or enable job creation [60,61] will require that researchers broaden their focus to examine the impact of technological change on employment in energy-related industries.

6. Conclusion

This study was based on in-depth interviews with 48 unionized energy workers who held a wide variety of occupations and worked in varied industries. But all our interviewees lived in the Mid-Atlantic region, and thus their views may not be generalizable to energy workers in other regions of the US. Policies on energy and labor are currently in flux in the US, and the changing political context means that views expressed in 2019 and 2020 may differ from views expressed later. Nevertheless, this study contributes to the need for research on energy workers in the US and other understudied regions of the world.

Future studies should include energy workers in a wide range of industries and occupations. Such studies must include those already working in solar, wind and other renewable energy industries so that fast-evolving labor practices in renewable energy can be understood and labor protection policies developed. This research is needed now, before low-carbon energy transition takes place. Comparative studies of low-carbon energy transitions in different countries examining the experience of unionized workers differentially empowered or disempowered by labor protection laws or international trade laws are needed in order to understand how the bargaining power of labor affects the impact of technological change on workers.

The Green New Deal proposal, Bernie Sanders' plan, and President Biden's American Jobs Plan all sought not just to decarbonize the energy system, but also to enact a just transition in the US while simultaneously reducing and redressing economic inequality [27,29,30,39]. Energy workers must be part of policy development because they have a working knowledge of energy technologies, know energy industries, and understand the opportunities and risks to workers in low-carbon energy transition. Unions have responded to sudden fossil fuel plant closures by organizing rapid response teams to provide transitional services to workers who have lost their jobs [36] and have built powerful state-level coalitions through which they are framing the issue of climate change in Green New Deal terms that link together decarbonization, job creation and reduction of social inequality. Working through the Climate Jobs National Resource Center, these coalitions are currently shaping low-carbon transition policy in Connecticut, Illinois, New York and Rhode Island and expanding their efforts to other states [74].

But effective decarbonization in the US at the scale needed to avert climate catastrophe requires a massive intervention from the state, including both new legislation and significant social and infrastructure spending [21]; both are resisted by energy corporations and their allies. Decarbonization will require a radical shift from the neoliberal, market-driven approach to taxation and regulation of industry that has been prevalent since 1980 [29]. Change will require political will and broad-based support, which cannot happen without the support of energy workers and their unions.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix

Labor, Energy, and Expertise

Interview Schedule

Union Members and Leaders who work directly with Energy Infrastructures.

Opening Comments

Thank you for taking the time to participate in this interview. We appreciate your willingness to do this. We are asking all participants the same questions; this will help us identify common themes and findings.

All of your answers are confidential. We will not use any identifying material. If there is a question you do not want to answer, you do not have to answer it. You can stop the interview at any time. Just let me know.

I'd like to record the interview. This will allow us to go back and look at your words in a precise way later in the analysis as new ideas or themes come up. Is recording the interview alright with you?

Introductory Questions

- Can you describe the work that you do?
- How were you trained for this job? College? On the job training? Other?
- Is this the way that union members usually acquire this expertise?
- In your opinion, what are the qualities of a good job in general?
- What do you think are the top issues regarding our energy system in the United States?

Fossil Fuel Energy Systems

- What do you think are strengths of our current fossil fuel energy system?
- (Probe: gas wells, pipelines, refineries and fossil-fueled power plants, liquid natural gas terminals, gasification terminals, coal mines)
- What do you think are weaknesses of our current fossil fuel energy system?
- Where do you get information about fossil fuel energy technologies?
- What is your impression of jobs in this sector?

Renewable Energy Systems

- What do you think are strengths of renewable energy technologies?
- (Probe: wind turbines, photovoltaic solar panels, thermal solar panels, geothermal power and hydropower, distributed generation)
- What do you think are weaknesses of renewable energy technologies?
- Where do you get information about renewable energy technologies?
- What is your impression of jobs in this sector?
- Do you ever express your views about the US's energy choices to politicians or news media? If so, how?

Union Views

- How does your union advocate for your interests?
- Are there areas where your union could advocate more for you?
- What is your union's stance on fossil fuel energy technologies?
- Do you agree or disagree with your union's stance on fossil fuel energy technologies?
- Does your local share the same stance as your national?
- What is your union's stance on renewable energy technologies?

- Do you agree or disagree with your union's stance on renewable energy technologies?
- Does your local share the same stance as your national?
- How does your union communicate its stance on energy issues to members?
- Do you think your union's stance has influenced your opinions about fossil fuel and renewable energy technologies? If so, how?

Energy Work, Standards and Policy

- What factors influence the design of energy technologies in your workplace?
- Do you think your expertise and knowledge has an impact on the design and use of the technologies that you work with?
- If yes, can you describe an example that shows this?
- Can you describe an example in which you used your expertise to impact workplace safety?
- What safety standards (union, state, or federal) impact your work the most? Why?
- Do you think that state safety standards reflect your experience and knowledge from working in your field?
- How do your expertise and knowledge shape your opinions about what energy policies the US should adopt?
- How do your expertise and knowledge shape your opinions about what environmental laws or standards the US should adopt?

Work and Environment

- What impacts do you think your work has on the environment?
- (Probe: Positive impacts? Negative impacts?)
- How have those impacts changed overtime?
- What kind of energy system would you like to see happen in the future?

Collective Economic Identity, Gender Identity

- How do you think your work shapes your identity?
- (Probe: family, social class, gender, race?)
- Is your work related to the history of the place where you grew up?
- What do you think of the idea that there are new, good jobs, but workers have to be willing to move to new areas to take them?

Political Identity and Energy Politics

- How would you characterize yourself in terms of your political identity? (Socialist, Very Liberal, Liberal, Liberal-Leaning, Moderate/Middle of the Road, Libertarian, Conservative-Leaning, Conservative, Very Conservative).
- Are you a registered voter? If so, what party did you register with? If not, what party would you register with?
- How do you think your political identity has influenced your opinions about fossil fuel and renewable energy technologies?

Concluding Questions

- Is there anything important about energy systems and labor that you think we've missed?
- Do you know of other union members who would like to participate in an interview with us?

Thank you for sharing your experiences and time with us.

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