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Impacts on manufacturing workers as part of a whole-system energy transition

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Providing access to good employment opportunities has become a key area of focus to ensure a just energy transition and to ensure that there is sufficient support for the technology transitions necessary for deep decarbonization. However, a societal transition to a decarbonized energy system will impact workers beyond those involved in energy resource extraction and energy production. Workers involved in manufacturing, especially those working in manufacturing industries that are energy- and emissions-intensive may face additional changes as those industries undergo technological changes. While discussions of the quality of jobs have focused on things like compensation, employment terms, and representation, other job dimensions, like the intrinsic characteristics of the work, health and safety, and work–life balance, stand to be directly impacted by technology change and are largely excluded from consideration. As these new technologies are developed and new energy sources are introduced to support manufacturing, we should also consider sociotechnical solutions that balance worker quality of life among other considerations like the utilization of new capital resources. Incorporating considerations across a wider definition of job quality dimensions will help to ensure that there is a sufficient workforce available to meet the demands of a decarbonization transition.

KEYWORDS

labor impact, decarbonization, job quality, manufacturing, industrial policy

Introduction

Meeting decarbonization targets will not only require the production of new zero-carbon sources of energy but also requires that we develop technologies that can use this energy. While other high-emitting sectors in the US such as transportation and electric power generation have made progress in reducing emissions in recent years, industrial emissions have remained relatively consistent (Greenhouse Gas Inventory Data Explorer, 2023) and are poised to become the second largest source of emissions in the US. Eenergy-related industrial emissions are driven by emissions from manufacturing as well as emissions from mining, construction, and agriculture. The diversity of input energy sources and process operations are significant contributors to this delay in reducing industrial energy-related emissions (Cresko et al., 2022), but technical strategies are centering on a few strategies for achieving decarbonization: increasing energy efficiency, electrifying manufacturing processes, using low-carbon fuels, feedstocks or energy sources, and using carbon capture and storage for processes that cannot be decarbonized by other means.

These new technologies will also require a sufficient workforce to implement them at scale. As steps are taken to fund research, development, and deployment (RD&D) projects to begin the technology transition of the industrial sector, there are calls to incorporate community-based feedback into the development of a workforce to serve these new industries (Cresko et al., 2022), and projects soliciting RD&D support are tasked with providing information on how they will create and sustain "high-quality and good paying jobs," and support "inclusive and supportive workforce development" (The White House, 2021). Much of this language echoes early just transition concepts identified in labor movements in the 1970s. While fair wages are a clear and important factor in the overall quality of a job, using that as the primary metric for determining job quality minimizes the broader impacts that jobs have on people's lives; worker roles are some of the most important social and economic roles held by most adults, and they dictate how most adults spend much of their time (Hauser and Carr, 1995; Rogers et al., 1999). Access to higher-status jobs also results in a lower risk of death than lower status jobs, even when controlling for factors like income and education (Rogers et al., 1999). While many of the factors that may increase or decrease the status or quality of a job are organizational or human resource management decisions, job quality can also be influenced by the technologies being developed to decarbonize the production of goods, and therefore require sociotechnical solutions.

The remainder of this article is organized as follows: There is additional context about the development of the just transition as a concept from early labor movements. Then, data about how the industrial energy transition compares to the energy production transition is provided. Next, a brief overview is given of social science perspectives on job quality and the impacts of job quality on workers' quality of life. Finally, a discussion follows regarding how to begin to develop sociotechnical metrics for ensuring that the industrial decarbonization transition centers opportunities for good employment within their design.

Jobs as a component of just transitions

The beginnings of the concept of a just transition are often attributed to Tony Mazzocchi of the Oil, Chemical, and Atomic Workers Union (OCAW). He posited that the industries that OCAW members worked in were the cause of health and environmental problems, and he organized strikes at several refineries over health and safety concerns (Morena et al., 2018). By the 1990s, after several decades of corporate-sponsored studies asserting that environmental regulation would result in job losses, the concept of a labor-focused just transition solidified around the idea that labor unions can advocate for both worker and community benefits, along with providing workers with resources necessary to retrain for new jobs so that environmental protection did not result in mass unemployment (Henry et al., 2020; Wang and Lo, 2021).

Academic focus on just transitions began more recently. Many of the academic studies on the labor impacts of the energy transition tend to focus on the quantity of jobs that will shift away from fossil fuel energy production and toward renewable energy production (Wei et al., 2010; Garrett-Peltier, 2017; Ram et al., 2022). More recent studies also aim to determine the geospatial distribution of these labor impacts (Mayfield et al., 2021; Vanatta et al., 2022). Some studies have aimed to compare how the quality of these redistributed jobs may change as part of the energy transition (Popp et al., 2022), while others have examined how job quality, primarily in the form of wages, may impact the energy transition (Mayfield and Jenkins, 2021). Generally, these studies find the additional labor costs associated with wages and other benefits have minimal impacts on the cost of transitioning energy production. While some studies have focused on the manufacturing of the technologies used in low-carbon energy production, there has been little focus on how a decarbonization transition will impact other areas of manufacturing.

Comparing energy use transitions to energy production transitions

The scope of the manufacturing sector, both in energy-related emissions and employment, raises challenges when comparing the sector to energy production transitions. Figure 1A shows end-use energy-related CO_2 emissions in the US by segment of the manufacturing sector in 2021, along with total employment (Figure 1B) in each of those sectors. For comparison, energy-related CO_2 emissions and employment in the mining sector, which includes oil and gas extraction, coal mining, and other mining activities for metallic and non-metallic ores, is also shown. While employment within the mining sector is down from previous peak levels, the cumulative effects of a successful decarbonization transition of the industrial sector will ultimately impact more employees in the U.S. economy going forward.

While the number of employees impacted by industrial decarbonization may be larger, the impacts on jobs themselves will also be different. Unlike the energy transition, where many of the jobs lost were categorized as mining jobs while jobs gained were in sectors like construction or manufacturing, industrial decarbonization is unlikely to lead to cross-sector job switching. However, within the manufacturing sector, there are likely shifts away from some industries (e.g., refining) to other industries, especially to support the production of zero-carbon technologies. Even in industries that may not play a direct role in supplying the goods necessary to support the energy transition, the use of alternative sources of energy—for feedstocks or as process energy—may result in changes to manufacturing processes and associated jobs. It is important to note that these energy technology transitions are not the only challenge facing manufacturing. Automation is changing the skill sets necessary to perform job tasks, and overall, the sector saw a decrease in total employment during the COVID-19 pandemic. Trade reports indicate that manufacturers are already facing challenges to fill manufacturing positions, and workers cite concerns about both wages and work–life balance considerations as primary factors that may lead them to leave manufacturing (Wellener et al., 2021).

For manufacturing processes where the feedstock must change to decarbonize, while some feedstock replacements may be perfect drop-ins to existing processes, other manufacturing facilities may require additional retrofits or process changes to use zero-carbon

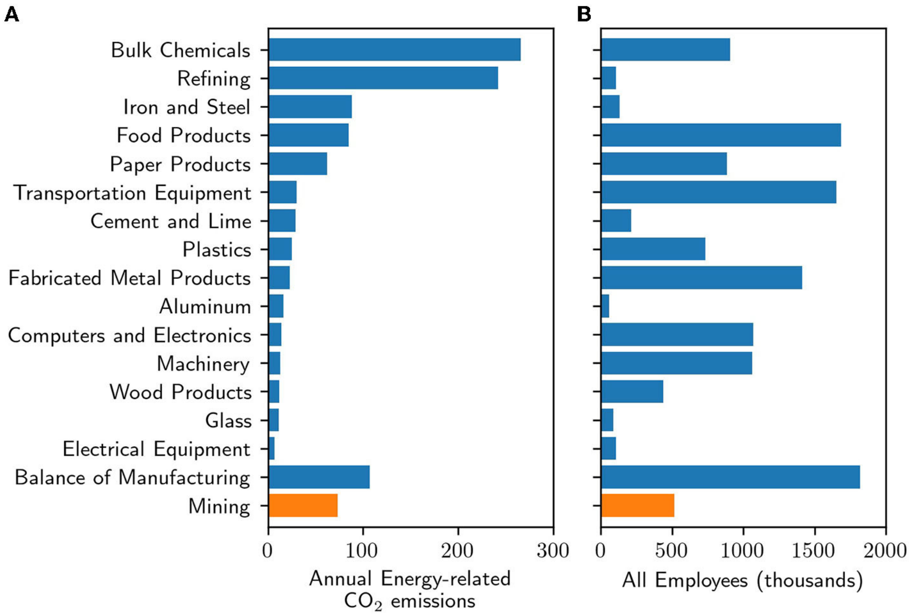

FIGURE 1
Energy-related CO_2 emissions **(A)** and employment **(B)** across the manufacturing sector in 2021. Data for the mining sector, which includes oil and gas extraction, is included (shown in orange) for comparison (U.S. EIA, 2022; U.S. BLS, 2023).

alternatives. These retrofits may include more automation, which has been shown to reduce the number of jobs, especially middle-skill manufacturing jobs, polarizing jobs as very low- or high-skilled (Autor et al., 2008; Acemoglu and Autor, 2011). However, if these process modifications include other technological changes, the introduction of new steps in the manufacturing process may counteract some of this polarization as combinations of low-skill and medium-skill processes are completed by workers (Combemale et al., 2021).

The transition to new energy sources may also impact manufacturing. Today, many manufacturing facilities, especially for energy-intensive industries such as chemicals, iron and steel, and cement, produce energy on-site from fossil resources. Often, these facilities have combined heat and power capabilities to provide both electricity and heat resources, and are therefore not dependent on the electricity grid for meeting their energy needs (Otis, 2015). While these facilities may experience energy outages as a result of a lack of access to energy resources, outage events for fossil fuel resources are infrequent, especially for industrial consumers with firm contracts (Freeman et al., 2020). Transitioning to using more electricity may result in additional scheduling challenges as a result of normal grid outages. Similarly, electricity prices are variable on an hourly time scale, while coal and natural gas contracts will last for months. This additional variability may also introduce new opportunities for facility managers to provide demand response resources to the grid (Nezamoddini and Wang, 2017), which may impact worker schedules as production output would be lower or completely curtailed when providing these services. The exact combinations of electricity generation resources and market pricing structures can introduce opportunities for more frequent adjustments to worker schedules around the availability of low-cost energy, which can exacerbate existing challenges with work–life balance.

Social science perspectives on good and bad jobs

Many studies of employment and job characteristics emphasize the impact that jobs can have on the health and well-being of workers, their families, and their communities. Bad jobs can increase rates of poverty, perpetuate gender inequality, and constrain social mobility (Carré et al., 2012; Adamson and Roper, 2019). The mechanisms that cause negative impacts from bad jobs can vary. While traditional employment models imply that workers are able to control the hours they work, in practice there are often mismatches in worker schedules, with many workers feeling overemployed because of long work weeks or undergoing temporary periods of over- and under-work reflecting other market conditions. This mismatch induces a feast-or-famine approach to employment, especially in industrial manufacturing sectors (Bluestone and Rose, 1997; Reynolds, 2004; Reynolds and Aletraris, 2006; Reynolds and McKinzie, 2019). Disparities between the hours workers would like to work and the hours they are scheduled to work can induce different types of stress: economic stresses if they are working fewer hours than they would like to work, and additional difficulties in balancing non-work family obligations if they are scheduled for more (or different) hours than they would ideally work (Reynolds, 2014). Beyond the number of work hours, not all combinations of work hours have the same benefits to workers; working non-standard schedules that include evenings, nights, or rotating schedules pose health risks and social costs (Presser, 2003).

While there is significant evidence that bad jobs have negative outcomes, determining what constitutes a good job has been harder to define. Many of the definitions of good jobs also align with particular branches of social science. Economic research typically focuses on wages and other compensation, while sociologists may focus on the intrinsic quality of work and public health researchers focus on the impact of work schedules and work–life balance. Warhurst et al. identified six key dimensions of job quality across different disciplines that study job quality: pay and other rewards, intrinsic characteristics of work, terms of employment, health and safety, work–life balance, and representation and voice (Warhurst et al., 2017). For each of these dimensions, they emphasize the importance of both objective and subjective measures of job quality. Objective measures focus on the ability of a job to meet workers' needs, while subjective measures account for individual preferences for job features.

Discussion

Although all six dimensions of job quality have a role in a just transition to a decarbonized economy, three may be directly influenced by the technological changes necessary to decarbonize the industrial sector. The intrinsic characteristics of a job may change as the new technologies and energy sources require different combinations of skills from workers, and potentially introduce further automation or oversight that can impact worker autonomy and variety of their jobs. However, the introduction of new manufacturing processes may also require more middle-skilled tasks, counteracting some of the polarization into high- and low-skill jobs common when manufacturing becomes more automated (Combemale et al., 2021). Transitioning to decarbonized manufacturing processes could also impact the meaningfulness and fulfillment workers gain from their jobs if they believe they are making significant contributions to larger societal goals. Understanding which skills may persist or grow in demand in decarbonized manufacturing jobs and which skills are no longer useful will help to determine how workers are trained for these positions. Additional study of how workers in a decarbonized economy feel about the meaningfulness of their work can also help to clarify what job attributes increase their overall satisfaction.

Work–life balance may also be affected by a decarbonization transition. The use of variable renewable energy may introduce more uncertainty into worker schedules, and adjusting manufacturing schedules to utilize least-cost energy sources where prices vary hourly may require different worker schedules. Energy-intensive processes are likely to be the most exposed to these changes, and we should aim to measure the working hours, reliability, and percentage of non-social working hours on worker schedules to ensure that these jobs are attractive enough to maintain the workforce necessary to support these industries. Technology transitions to decarbonize industrial processes may also impact the health and safety of workers; alternative processes may reduce the operating temperatures and pressures, instead utilizing catalysts or electrical potentials to create the thermodynamic conditions necessary for the chemical reactions that drive production processes. While reducing the high temperature and pressurized environments workers are exposed to may reduce the potential for some accidents, additional risk analysis of new processes should consider the potential for multiple risk pathways.

Other job quality dimensions, such as rewards and pay, terms of employment, and representation and voice are very frequently found in discussions of the dimensions of good jobs in the decarbonization transition. While these dimensions can be used to compensate for potential adverse effects from the technological transition to decarbonized manufacturing, they cannot overcome the job quality dimensions that are built-in by manufacturing technologies. As has been the case in other industries, if these job characteristics are too incompatible with workers' lives, then even increasing pay and improving employment terms are inadequate to ensure there is a sufficient workforce (Viscelli, 2016; Zabin et al., 2020). While much of the research focus for industrial decarbonization has focused on technical solutions, sociotechnical solutions may be better poised to address the additional challenge of ensuring a trained and willing workforce to participate in decarbonized industrial production. Metrics to determine the quality of jobs created in developing these jobs should consider how the jobs created affect multiple dimensions of job quality, in addition to ensuring adequate pay and worker rights, and metrics to assess the quality of technologies developed should consider more holistic metrics beyond utilization of capital and other non-labor resources. Failing to consider each of these job characteristics could mean that there are an insufficient number of workers available to sustain a decarbonized industrial sector at the pace necessary to meet climate targets.

Data availability statement

Publicly available datasets were analyzed in this study. This data can be found here: https://www.eia.gov/outlooks/aeo/data/browser/#/?id=22-AEO2023&cases=ref2023&sourcekey=0; https://www.bls.gov/web/empsit/ceseeb1a.htm.

Author contributions

RC contributed to the conceptualization and writing of the manuscript.

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Conflict of interest

RC declared that they were an editorial board member of Frontiers, at the time of submission. This had no impact on the peer review process and the final decision.

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