JILLIAN E. MILES, CHRISTOPHE COMBEMALE, AND VALERIE J. KARPLUS

When the Energy Transition Comes to Town

Thousands of American towns are losing jobs in fossil fuels. More sophisticated analytical tools could help communities marshal their resources for a better future.

In July 2023, Homer City, Pennsylvania, saw its coal-fired power plant deactivated, only three months after the community got word of the impending closure. With the plant being the state's largest generating station, fossil fuel electric power generation was a major employer and one of Indiana County's largest revenue streams. The closure cut more than 120 jobs in a city of only 1,700 people. Not only were local officials concerned about residents' livelihoods, but they also worried about a possible domino effect as another coal plant just south of Homer City, the Conemaugh Generating Station in New Florence, announced that it would close by 2028.

Across the United States, closures of coal power plants have become increasingly common, largely in response to the favorable economics of natural gas and new environmental regulations. To give just one example, over the last decade the share of coal-fired power in the PJM Interconnection, a regional transmission organization that supplies power across 13 states from New Jersey to Illinois, has dropped from 40% to 15%. While this shift is helping to achieve national and regional climate and environmental targets, it also puts a heavy burden on communities like Homer City and New Florence, which stand to lose high-paying union jobs and tax revenue.

The local challenges of the energy transition have drawn attention at the national level. The 2022 Inflation Reduction Act reserves a portion of the funds to expand the Qualifying Advanced Energy Project Credit (48C) for places where the shrinking of the coal industry has had a substantial impact on local carbon-intensive economies, as identified by the Biden administration's Energy Communities initiative. Additionally, new federal infrastructure initiatives centered on environmental and economic justice require meaningful engagement with local communities as a condition of funding everything from hydrogen hubs to decarbonized manufacturing. To take advantage of these opportunities, regional decisionmakers need timely local data as well as models and frameworks designed to inform community discussions about the engineering and scientific realities of decarbonization options.

Already, the difficulty of navigating the energy transition without appropriate support is visible at citizen and stakeholder convenings in the southwest Pennsylvania region. In our activities as engineering and public policy researchers focused on hard-to-decarbonize industries such as coal, iron, and steel, we have seen community, union, and local government representatives pose questions for which there were no clear answers. For example, they wonder whether new, lower-emissions processes used in heavy manufacturing will require different skills or demand fewer workers than today's technology. They also want to know whether jobs will be created and whether local workers have the skills to fill those jobs. Will incumbent workers be supported, and will they be consulted about the implementation of technologies that affect their livelihoods? Most communities have few resources to devote to developing an individual—let alone shared—approach to these uncertainties.

As academics who are studying the energy transition in its earliest stages, we see that communities need better tools to inform decisions. But we also see that tools are only

as effective as communities' ability to understand and engage with them. At the same time, policymakers often don't fully grasp the labor implications of investments in decarbonization technologies and infrastructure, such as creating regional hubs for new industries like hydrogen. Although researchers are beginning to recognize labor implications when evaluating energy solutions, there is a great and evolving need for better tools.

Researchers, policymaking, and community organizations should start collaborating now to develop solutions that will serve regional populations' needs. These include deeper analysis of the labor implications of particular decarbonization investments—beyond general economic trends—and ways to support specific communities. Furthermore, to better reflect the complexity of specific regions and modern job contexts, these tools should be developed and benchmarked with input from communities to integrate workers' experiences into these transitions.

Challenges with current approaches

Today, local policymakers and planners eager to understand and address the labor impact of the low-carbon energy transition have few analytical approaches available, and those that exist have notable limitations. When decisionmakers in Homer City or New Florence want to know which investments or industries to prioritize for job growth, they face multiple challenges. First, they're likely to have more ability (and perhaps incentive) to focus on economic growth or tax revenues than labor force dynamics. And when they turn to modeling projections of the energy system transition, they're likely to find a focus on dollars rather than labor outcomes, which, to be fair, is a job the projections were often never designed to do. Moreover, because they often aggregate results across geographies, these projections may have little to say about outcomes for any specific community or worker. Although jobs numbers can be and often are extrapolated from these economic projections, they tend to average over sharp differences in unemployment, labor displacement, and underemployment—even within census tracts. The reality is that local communities, such as those in Indiana County, won't feel these jobs trends as smoothed curves, but as shocks to their economic equilibrium, with deeply personal consequences.

Similarly, today's models do not reveal which workers will prosper and which will founder during a transition. Although initial analysis done by labor market scholars E. Mark Curtis and Ioana Marinescu suggests green job growth is occurring most in areas that have specialized in high-carbon extraction industries, it will be crucial to better understand what drives these patterns.

This gap means that even if policymakers and other stakeholders want to prioritize local employment, they may lack critical data on the skills or transition-readiness of their own workforces. They may not have usable insights that could enable them to identify and retrain workers who may be most at risk, or the information to find new industries that match well with local skills.

Additionally, retraining programs for displaced workers have often struggled to achieve success at scale. Anecdotal evidence over the last 20 years, from efforts such as coding initiatives in West Virginia or medical training in Texas, indicates that these initiatives can be costly and ineffective, both for communities and individuals. Academic evidence for wage recovery or gains in occupations affected by displacement paints a mixed picture. After the Great Recession, states are seeing trends in production occupations that specialize in assembly of goods or distribution of energy that could lead to general labor-market mismatch and worse outcomes for workers. This signals a need to better understand where to invest resources in occupational transition assistance.

The energy transition brings with it many unknowns, requiring types of analysis that either do not exist or have not yet been applied to decarbonization. For example, future labor markets may be very different from those of the past, as advances in automation, efforts to "reshore" jobs, initiatives to expand diversity, equity, and inclusion, and evolving worker preferences like flexible working hours reshape the labor landscape. In this rapidly evolving scenario, historical data and trends will not necessarily project future outcomes.

On the ground, there is already a great need for a new combination of data, tools, and empirical perspectives on the energy transition. Today, legislation requires detailed descriptions of anticipated workforce outcomes as part of applications for government investment. Furthermore, the White House Justice40 Initiative requires that 40% of the benefits of new infrastructure projects, including energy, accrue to disadvantaged communities. These include communities that are marginalized, underserved, and overburdened by pollution. Scholars involved in research and modeling should mobilize to provide more appropriate tools to consider trade-offs while involving communities in making decisions.

Building new tools for the job

We are encouraged to see that researchers have started to respond to this need. First are those paying more attention to representations of the labor market in policy-centered energy systems and decarbonization research, adding detail to or complementing modeling analysis with labor market studies. Scholars have started projecting labor impacts of the energy transition given different decarbonization technology preferences. Instead of exclusively modeling

least-cost approaches, researchers have grown interested in what it would instead cost to choose the next-best (albeit more expensive) solution that may have more favorable labor outcomes. From a policy analysis perspective, these trends are encouraging because they offer choices and trade-offs that can reflect multiple decision criteria. In addition, some academics are beginning to include workers and communities in the analytical process, building on traditions such as the mental models approach for gauging citizen's understanding of risk that was developed in the Engineering and Public Policy Department at Carnegie Mellon University. They are adapting modeling tools to include input from community members at the outset and during the decisionmaking process, rather than handing off scenario outputs to communities after modeling is complete.

However, new modeling techniques and analytical approaches are needed to reflect the broad range of community interests affected by decarbonization, and they should be built out of engagement with these communities. At their best, projections can provide help communities feel heard and offer them greater transparency in the solution selection process. With granular, verified information about skill availability and needs, they may even be able to answer questions being posed regarding where jobs will be lost and gained and who is likely to be able to fill those new jobs. Researchers should also work to explore whether policies such as prevailing wage requirements, or government-provided retraining or certification, could make workforce transitions better for workers.

Engagement, done well, provides an opportunity for a newfound level of public input lacking in the vast majority of decarbonization planning and implementation up to this point. Important work is being done by local coalitions and nongovernmental organizations, such as ReImagine Appalachia, on community benefits and visioning. When researchers fold these voices into the analysis process, results can better reflect on-the-ground needs. This bottom-up emphasis and local perspective can inform democratized decisionmaking, which could be a first at this scale for these communities.

We describe some of these promising trends in more detail below, along with their potential to support data-driven, inclusive choices among decarbonization options.

Engaging communities

Energy system models, economic analyses, and other models being used in decisionmaking must be flexible enough to recognize that communities are not homogenous entities; they possess unique characteristics that shape their residents' willingness to transition, their preferences for specific types of work, acceptable conditions, and pay, and their commitment to preserving their cultural heritage and historical identities. While some counties or regions may want to prioritize job creation and economic prosperity, others may reject a technology-neutral approach based on distinct experiences or opinions, such as objections to living near industrial sites. Gaining public support for climate change policies may require continued public engagement, humanizing the data, and leadership from trusted community members. Moreover, modelers must consider the influence of additional key metrics such as air pollution, water resource availability, ecological impacts, and tribal land considerations, and allow community members to weigh in on how to prioritize those factors.

> The reality is that local communities, such as those in Indiana County, won't feel these jobs trends as smoothed curves, but as shocks to their economic equilibrium, with deeply personal consequences.

Sustained community engagement can inform the process of creating models so that the models better respect the complexities of local livelihoods and decisions. To truly assist in regional planning, researchers must engage community members from the outset, demonstrating a commitment to ensuring community input, buy-in, and trust in models' findings and assumptions. Connecting research findings to regional decisionmaking is especially important for enabling communities to compete effectively for both public and private investment. Beyond that, communities are likely to realize greater benefits when they can work together effectively to put enabling technologies and infrastructure—such as expanded transmission lines and wind farms—in place, managing risks and associated public opposition.

The most obvious benefit of this community engagement is the generation of results tailored to community needs. However, including local voices will also likely lead to a better understanding of the results, less pushback on their merit, and a greater sense of control over outcomes from the community itself.

Advancing modeling approaches

Currently, much of the research that projects employment, unemployment, and skills-matching does not reflect the complexity of real-life job transitions. When a worker loses a job and seeks another, the outcome is affected by many factors. For example, depending on the availability of local jobs, some displaced workers may take temporary jobs with lower pay, requiring new skills, before finding a job that offers comparable wages. And those initial jobs may create a path-dependency for future employment. Moreover, opportunities for workers can seem sparse if they limit their search to jobs similar to their occupation, but it can be difficult for workers to assess which "dissimilar" jobs they can reasonably expect to get and what skills they need. And of course, it is even harder to figure out how to get those skills or how to weigh the cost of gaining skills against possible future wage and employment gains. New empirical approaches, grounded in longitudinal data, are needed to understand the pathways that individuals and communities may follow (and what drives workers to one path or another) as they transition away from employment in high-carbon industries.

In particular, not enough is known about how the skills of individual workers, especially those in communities focused on fossil fuel production, can be applied to jobs in a deeply decarbonizing economy. While a 2022 International Monetary Fund study showed that green jobs in the United States are close in proximity to communities where polluting and fossil fuel jobs are high, there is evidence to suggest these jobs are not being filled by workers from the incumbent industries, which brings a significant amount of uncertainty to how impactful investment in green jobs could be in these areas. Research on this phenomenon has yet to explain why this might be the case or what that trend suggests about the transferability of skills related to the energy industry. Broader analysis of skills-matching could identify the best transitional occupations for at-risk climate-dependent jobs or occupations that expose workers to climate extremes.

One possible source of insight into changing labor markets is the extensive economics literature on the implications of skill-biased technical change (SBTC) and skill segmentation and polarization, which can change the relative productivity, compensation, and employment of workers with different levels or types of skill. However, the SBTC literature generally relies on education or wages as a proxy for skill, potentially masking important differences in demand effects on different types of skills. Engineering-informed approaches may help here. Although recent work has focused on the skill content and demand implications of one key decarbonization technology, battery electric vehicles, there remains a need for information on skill bias in other decarbonization technologies and pathways (including in the battery electric vehicle context) and how technical choices being shaped by policy incentives may affect skill demand.

Another subject for deeper analysis is the reason for workers' departures from jobs. Today, there are implicit assumptions that misalignments of individual workers' skills and employers' needs are barriers to job transitions or retention. But other forces influence choices and opportunities. The availability of other work in the region, for instance, plays a strong role, along with access to resources that support workforce transition. Indeed, workers may experience successive disruptions from repeated economic shocks, possibly from different sources of vulnerability driven by the energy transition. A displaced coal worker may find a new opportunity in manufacturing batteries for renewable energy infrastructure, only to be displaced again by disruptions in critical material supply chains. Analytical approaches that do not characterize transition pathways for workers and, especially, don't pay attention to disruption risks across the supply chain may fail to realistically characterize the outcome space for displaced workers. And they may not provide the level of detail needed to inform policymakers on *which* skills to support or *which* workers may need the most assistance.

Further research is also needed on how workers find pathways to new employment. Today's discussion focuses primarily on whether a worker's skills fit the needs of an employer, but additional occupational characteristics may determine workers' willingness to accept employment opportunities (either to continue participating in the labor market or to meet demand created by decarbonization investments): these may include ability and willingness to relocate for work, salary requirements, the opportunity to use skills from prior positions (and identity connections to their former occupations), and relative autonomy of the position.

> Engagement, done well, provides an opportunity for a newfound level of public input lacking in the vast majority of decarbonization planning and implementation up to this point.

These additional dimensions from the theory of labor transitions can provide a clearer picture of the balance of power between workers and employers and can demonstrate the resiliency of regional labor markets and their ability to absorb displaced workers. And, of course, the outcomes of these models, in the form of theoretically compatible jobs and worker skills, will need to be validated by asking workers and employers to evaluate the match (with further work to be done understanding *what* makes a good match from each perspective).

In addition, modelers should explore more ways to evaluate which transition policies are likely to be effective. This means going beyond modeling decarbonization policies to combining them with labor-related interventions. Federal, state, or even local programs to incentivize local hiring, retraining, and salary subsidies can help the transition at both the individual and regional levels. An example of this type of thinking can be found in the regional case studies recently conducted by the Roosevelt Project, which used modeling scenarios alongside stakeholder input to examine options for simultaneously addressing the transition to decarbonization and the needs of workers and communities. Specifically, when modeling scenarios as part of the Roosevelt Project suggested that national New Deal-style industrial policies would not fully offset the economic and job losses of climate policy in southwest Pennsylvania, interviews with local stakeholders revealed the potential for state and local initiatives to help support the region in a clean energy transition.

Too many conversations about the energy transition are framed in terms of "winners" and "losers," as though that dichotomy is inevitable.

Creating receptive conditions for new analytical tools

The new analytical approaches that we have described here have the potential to shed light on not only which workers may face the greatest risks, but also on interventions that may improve worker outcomes and offer communities more than just bad news. Emerging research tools should quantify the scale of unemployment from energy transition trends, identify feasible occupational transition pathways, evaluate and compare technology solutions from an employment perspective, and incorporate community engagement. By doing so, they could show how policies such as specific training interventions or wage requirements in future public investment agreements could alleviate the effects of job displacement. The combination of these approaches helps local policymakers understand trade-offs when considering how to legislate and regulate, while providing communities with necessary tools to advocate for their interests and needs.

Today, too many conversations about the energy transition are framed in terms of "winners" and "losers," as though that dichotomy is inevitable. With appropriate approaches, policymakers can come to understand ways that recognizing labor outcomes offers an opportunity space for the creation of jobs that enhance inclusive prosperity while realizing climate goals, and they can adopt policies that facilitate positive work transitions. Conversely, the success of large public investments in the energy transition will be threatened if skill supply is inadequate to meet demand. Public support for the transition will be adversely affected if employment disruptions are not paired with viable transition pathways that consider *regional* skill demand and supply profiles to make realistic trade-offs.

To realize the potential of the methodological approaches we have laid out, there must be broader incentives for employing them. The Justice40 initiative is a great start to ensure the needs of workers and communities are represented at every stage of new policy development. However, a broader shared, increasingly evidence-based understanding of the ways engagement can translate into meaningful long-term benefits for workers, communities, and employers could permanently transform best practices.

The citizens of Homer City, New Florence, and the other communities of Indiana County hope that it is not too late to bring jobs and revenue to fill the gaps left by the coal plant closures. Today, it remains unclear whether new opportunities—along with state and federal sources of support—will deliver, but it is obvious that an improved understanding of the potential impact of decarbonization investments on workers could help unlock a much more equitable, engaged, and just energy transition.

Jillian E. Miles *is a doctoral student in the Department of Engineering and Public Policy at Carnegie Mellon University.* ***Christophe Combemale*** *is an assistant research professor in the Department of Engineering and Public Policy at Carnegie Mellon University, with a research appointment at the Block Center for Technology and Society at CMU's Heinz College.* ***Valerie J. Karplus*** *is a professor in the Department of Engineering and Public Policy and the associate director of the Wilton E. Scott Institute for Energy Innovation at Carnegie Mellon University.*