



The justice and equity implications of the clean energy transition

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The transition to lower-carbon sources of energy will inevitably produce and, in many cases, perpetuate pre-existing sets of winners and losers. The winners are those that will benefit from cleaner sources of energy, reduced emissions from the removal of fossil fuels, and the employment and innovation opportunities that accompany this transition. The losers are those that will bear the burdens, or lack access to the opportunities. Here we review the current state of understanding—based on a rapidly growing body of academic and policy literature—about the potential adverse consequences of the energy transition for specific communities and socio-economic groups on the frontlines of the transition. We review evidence about just transition policies and programmes, primarily from cases in the Global North, and draw conclusions about what insights are still needed to understand the justice and equity dimensions of the transition, and to ensure that no one is left behind.

The urgency of the current energy transition from a fossil-fuel based global economy to one powered by cleaner, low- to no-carbon sources has been emphasized in recent reports from climate scientists¹. An important dimension of this transition is that, without specific efforts made to ensure an equitable transition, not everyone will benefit equally. The need to incorporate distributional considerations into energy and climate policy has long been embedded in international climate agreements through concepts such as common but differentiated responsibilities and intergenerational equity, and is also reflected in recent proposals, such as calls for a Green New Deal in the US. The Green New Deal specifically embeds equity and social justice within climate change mitigation goals, and emphasizes commitments to job training and economic development support for individuals and communities that might be adversely affected by a transition to new sources of energy.

While one can debate the technical feasibility and cost-effectiveness of such a proposal, the Green New Deal and similar proposals highlight the need for energy justice to the public. There are still innumerable gaps, however, in our collective understanding of how deep the inequalities associated with the energy transition are, exactly who is on the frontlines, what is currently in place to assist individuals and communities through the transition, whether everyone has the opportunity to serve as a stakeholder in decision-making processes and how to design effective programmes. In this way, there is both enormous potential to advance our collective understanding of the adverse consequences of the energy transition, and opportunities for scholars to provide basic scientific research to inform future policymaking.

In this piece, we review the inter-related literatures on energy justice and a just transition, and ask how some communities may be—and, in many cases, are already—affected by the energy transition. Our coverage of the topic extends beyond a consideration of those displaced from the decline of the fossil fuel industry, and is inclusive of others that are also on the frontlines of the clean energy transition. Our objective is to raise a series of topics that, upon expanded, continual, rigorous evaluation, can contribute key insights into why, how and where to design energy justice programmes, and integrate these programmes into broader energy and climate policy efforts.

Although many of the topics that we raise are present across the world, the majority of the literature that we draw on is related to the Global North.

We find that disparities are prevalent in the distribution of benefits and burdens from the energy transition, as well as in the opportunities for engagement and leadership. While those who work in legacy energy industries will be adversely affected, a demographic most commonly identified in the just transition literature, the energy transition will also potentially affect low-income communities and communities of colour by exacerbating energy insecurity, and fail to extend opportunities for engagement and technological access to disadvantaged groups. While jurisdictions are beginning to roll out policies to address these disparities, the literature on such policy efforts, and the extent to which they mitigate disparities, is still under-developed.

Energy transition, energy justice and a just transition

An energy transition refers to the shift from one dominant energy resource—or set of resources—to another. Historic examples include the replacement of whale oil with kerosene in the late 19th Century, and the transition from wood to coal during the Industrial Revolution. The modern energy transition is marked by a decline in fossil fuels, most significantly coal, to lower-carbon energy resources such as wind, solar and natural gas. Although energy transitions in which one resource is completely replaced by another are rare, if not unprecedented², it is more often the case that a transition is marked by one resource starting with a small share and growing to a large share of the energy mix. One definition is a shift from 5 to 80% of energy consumption for a specific energy resource or technology³.

The energy transition literature is robust and growing. While earlier studies focused on the pace of the energy transition^{3–6}, the literature has evolved to discuss variations in transition pathways⁷ and both the positive and negative impacts of the transition on households. As part of this evolution, studies have highlighted that transitions inevitably produce winners and losers, and a consideration of the inclusivity and distributional aspects of the transition is paramount.

Energy justice is a modern branch of environmental justice, although distinct in many regards, particularly in its focus on energy



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systems and the full life-cycle of energy resources^{8,9}, from extraction to production to consumption to waste. Energy justice is centred around the notion that all individuals should have access to energy that is affordable, safe, sustainable and able to sustain a decent life-style, as well as the opportunity to participate in and lead energy decision-making processes with the authority to make change^{10,11}.

The energy justice literature features three core tenets^{12,13}. First, distributional justice refers to distribution of benefits and burdens across populations, and an objective to ensure that some populations do not receive an inordinate share of the burdens or are denied access to the benefits. Second, procedural justice focuses on who is included in energy decision-making processes and seeks to ensure that energy procedures are fair, equitable and inclusive of all who choose to participate¹⁴. Third, recognition justice requires an understanding of historic and ongoing inequalities, and prescribes efforts that seek to reconcile these inequalities¹⁵. Some add a fourth tenet, restorative justice, proponents of which advocate for using government or other intervention to either avoid distributional, recognition, or procedural injustices, or to correct for them¹⁶. Pulling from these objectives, a comprehensive energy justice framework can be said to include energy availability and access, affordability, due process, accountability and transparency, and both inter- and intra-generational equity^{17,18}.

The notion of a ‘just transition’—although owing its origins to the US labour movement in the late 1990s—sits at the intersection between the energy transition and energy justice bodies of literature, and establishes the importance of equity and justice in the planning, implementation, and assessment of every socio-energy system change that shapes the energy transition. In order to pursue a just transition, the literature argues, government and other stakeholders such as non-profits and private industry must work to redistribute welfare so as to avoid undue burden on any specific population and provide sufficient energy services to all, and also to provide an adequate safety net for all populations, especially those most marginalized or burdened^{19,20}.

Justice implications of the energy transition

A diverse range of scholars have published studies that highlight ways in which the energy transition is already affecting adversely individuals, households and communities across the world.

The effects are typically manifested as the infliction of excessive burden or a lack of access to energy transition opportunities. In this section, we connect this literature, and provide a comprehensive review of how the energy transition affects individuals, households and communities on the frontlines. Our focus is on the Global North, taking many examples from the US, although it is important to emphasize that similar issues, in different ways, exist in the Global South as well.

Disproportionate burden. The environmental justice literature has provided a detailed account of how the negative externalities of certain facilities, infrastructure or other locally unwanted land-uses disproportionately affect surrounding communities. In both developed and developing country settings, decades of research has shown that people of colour and those with lower incomes experience more of these burdens²¹. Consider, for example, communities that reside next to a coal ash pond, and the deleterious consequences for those communities in the event of a pond spill; or those that reside next to highways and inhale a much larger concentration of tail-pipe emissions. The energy justice literature features an analogue related to the energy transition: low-carbon energy technologies also produce negative externalities that will be borne disproportionately by those located next to the facilities^{22,23}. Examples include noise disruptions or ‘shadow flicker’ from wind turbines²⁴ or unpleasant smells, traffic and air pollution from landfill facilities²⁴. Studies have found that these negative externalities are disproportionately experienced by certain populations, such as in the case of wind by more rural and less educated populations, whereas a larger share of the benefits are borne by urban populations. None of this is to discount, however, the well-established environmental and health benefits of a shift away from the extraction and use of fossil fuels. The negative impacts of clean energy technology siting on local populations pale in comparison to communities, often predominantly people of colour and/or low-income, that experience the disproportionate effects of fossil fuel operations, such as mining, power plant and mobile source pollution.

Another consequence of the energy transition is a decline of carbon-intensive energy resources, as well as the industries that produce these resources. The coal mining industry and those that support coal-based electricity production, for example, will lose market share and employment opportunities. Former coal industry



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employees may be able to find replacement jobs, where they are offered, but often with a sacrifice: either with a lower salary²⁵ that introduce skills and wage gaps, or with a requirement to commute long distances to find employment opportunities since coal jobs and replacement renewable energy jobs²⁶ or other, non-energy jobs²⁷ may not align geographically. While there is ample evidence that clean energy industries provide more job opportunities than fossil fuel industries^{28,29}, a decline of coal and other fossil fuel jobs nonetheless significantly affects those that held the jobs, as well as the economies in which they reside³⁰. Meanwhile, pension funds through the coal industry are severely underfunded due to the economic decline of the industry³¹.

The economic and social consequences of such labour disruptions are broader than individual job losses^{32–34}. Studies in Appalachia²⁷ and Australia³⁵ for example have found that, as a result of coal mining or power plant operation closures, surrounding communities experience a significant loss of other retail and commercial employment, since laid-off coal industry employees reduce their demand for other local services and commodities. Power plants and mining operations are also often located in remote counties or in isolated locations of counties and are associated with a lower percentage of adults with college education and greater income volatility³⁶. The boom and bust nature of coal mining, paired with the mono-industrial composition of coal mining regions, may suppress small business formation and cause people to move away from such regions³⁷.

Coal industry closures also affect adversely the local tax revenue base, which can compromise not only the coal industry employees that lose their jobs but also the entire communities in which the industries once resided (see, for example, Haggerty et al.³⁶ for evidence of tax revenue erosion in the West and Jolley et al.²⁵ for findings from Adams County, Ohio). In Boone County, West Virginia, a centre of US coal extraction, about one third of the county revenue is dependent on coal activities. The coal revenue funds their county commission, trash pick-up, health department, county jail and public transportation as well as contributing funding statewide education. As coal mining production decreased from 2012 to 2015 in the region, Boone County's budget declined by 45% and, between 2012 and 2017, it closed three out of its ten schools, laid off at least 70 teachers, and made cuts to public services such as its solid waste

programme^{31,37}. Haggerty et al.³⁶ find that communities that are destined to suffer from such circumstances are often unprepared with alternative plans for retraining, economic development and revitalization. It is important to note, however, that the economic costs of fossil fuel job and revenue decreases may be offset by the benefits of cleaner air and water for these communities.

The social implications for communities that lose their main industrial base are also immense. Research in Appalachia²⁷ and Utah³⁸ in the US, and Lithgow in Australia³⁴ reveals that loss of coal and coal employment also compromises the culture and sense of both place and identity of these regions and their inhabitants. Since coal mining is a profession that is often passed down from generation to generation, and the coal industry can be such a present element of day-to-day community events (for example, children's sporting events and local parades), the decline of coal represents for some a loss of either personal or community identity, or both, as well as an individual's sense of place. In such regions, families have been forced to renegotiate their social structures when former, predominantly male coal miners take new jobs that require significant travel and female and other household members must take new jobs to help support the family²⁷.

While the majority of discussions about a 'just transition' tend to focus on employment losses in legacy industries—and more specifically coal miners—studies document another form of personal hardship related to the energy transition: enhanced energy insecurity. It is possible that the energy transition will result in a higher cost of energy, at least in the short- and medium-term, due to the need to cover new infrastructure and technology costs, for example, for smart meters, power lines and battery storage technologies. If the costs of energy rise, it will disproportionately harm those that already pay a large share of their income on energy and do not have extra income to absorb higher bills.

In the US, on average, urban low-income and African American households, respectively, spend 7.2% and 5.4% of their income on energy utilities³⁹. Rural US households, on average, spend 4.4%, while rural low-income, elderly, non-white, and renting populations pay much larger percentages. Rural low-income residents, for example, pay 9%⁴⁰. In contrast, urban higher income residents pay 2.3% and the average for all households is 3.3%³⁹. Other measures of energy insecurity reveal similarly concerning trends. As of

2015, 31% of Americans reported difficulty paying their household energy bills or maintaining adequate temperatures in their house; 20% reported that, due to high energy bills, it is necessary to forego buying other necessary household items such as food; and 14% reported that they have faced the threat of disconnection from their electric utility⁴¹. Approximately half of all US households that face energy insecurity—that is, the inability of a household to adequately meet energy consumption needs—are African American³⁹.

Many studies based in Organization for Economic Cooperation and Development (OECD) countries, such as New Zealand⁴², present similar statistics. Some OECD countries such as Greece have much higher rates of energy insecurity⁴³; and many developing countries not only have high proportions of their population that have difficulty paying for basic energy services, but also have a portion of their population that simply lacks access to any modern energy sources whatsoever. These statistics reveal that energy costs produce a significant financial burden for some households, and require many to confront difficult trade-offs such as 'heat or eat' financial decisions and an increasing likelihood of electric utility disconnection. All of these consequences have the potential to compromise mental and physical health, and lead to further personal hardships^{42,44,45}.

Studies find that low-income households and households of colour are more likely to live in energy inefficient dwelling units, have inefficient appliances, or poorer structural building conditions, all of which requires more energy to heat or cool to adequate living conditions^{39,46,47}. These conditions both exacerbate energy insecurity and, where the costs of energy rise as a result of the energy transition, these populations may be further disproportionately burdened, and potentially face more severe circumstances such as utility financial burden and the threat of utility disconnection^{47–50}. In addition, as climate change continues to alter weather patterns, and affect residential thermal conditions, vulnerability toward energy insecurity may continue to grow^{51,52}. For example, hotter summers and more excessive heat days will likely increase the amount of time that people use fans or run their air conditioners, which can in turn increase their energy bills^{53,54}. This example highlights the possibility that climate change has the potential to exacerbate energy justice concerns over time.

Lack of access to energy transition opportunities. The justice implications of the energy transition are not exclusively attributed to an uneven distribution of burdens. Potential benefits of the transition—including but not limited to new employment opportunities, involvement in decision-making processes, and access to advanced, low-carbon and efficient technologies—are also unevenly spread across populations, as well as across socioeconomic groups.

As discussed above, as the energy transition facilitates a shift toward more efficient and lower-carbon energy resources, employment opportunities in related fields will increase, including jobs in manufacturing, construction and installation, operations and maintenance, sales and distribution, fuel extraction and supply, and transmission. Although it is difficult to generate accurate potential 'green economy' employment predictions, studies from across the world provide evidence that net employment will increase due to renewable energy and energy efficiency development^{55,56}, and policies that are in place to facilitate a lower-carbon economy⁴⁹. Recent reports demonstrate that employment in low-carbon energy industries is rising. As of 2017, renewable energy industries employed about 10.3 million people across the world, up from 7.14 million in 2012⁵⁷. Approximately 33% of these jobs are concentrated in the solar photovoltaic industry and 19% in the liquid biofuels industry⁵⁷. In the US, one study estimates that, as of 2016, the energy efficiency, wind and solar industries represented approximately 1.3 million jobs, whereas the coal industry had approximately 160,000 jobs²². The US Bureau of Labor Statistics predicts that solar photovoltaic installers and wind turbine service technicians will be the

two fastest growing occupations in the US over the next decade, and will far outpace any other occupation⁵⁸.

Despite this notable growth in employment opportunities in the clean energy economy, energy jobs are infrequently held by women and people of colour, as is also traditionally the case with fossil fuel industries. Within the 2018 US solar industry workforce, for example, 26.3% were women and 7.6% were black or African American, both percentages that are well below the national average for all occupations⁵⁹ (although similar to fossil fuel industries; for example, 15% of the oil and gas industry workforce is female)⁶⁰. Similarly, women and black or African Americans, respectively, represent 24% and 8% of the US energy efficiency workforce⁶¹. Reports from Europe⁶², and surveys conducted across the world by the International Renewable Energy Agency, also confirm that women tend to hold somewhere between than 30% and 35% of jobs in renewable energy industries. These female-held jobs tend to be lower paid, and more administrative, non-technical and public relations oriented, than jobs in the same industries held by male counterparts^{57,63}.

As discussed above, one tenet of energy justice is procedural justice, which refers to the fairness of energy processes as well as equitable opportunities for participation in energy decision-making processes. Several studies have revealed that decision-making procedures involving the energy transition are not currently inclusive of communities that host the new infrastructure, such as in cases of wind turbine siting in Canada⁶⁴ and the US²³, and indigenous populations and their involvement in wind energy development in Mexico^{65,66}. These cases persist despite significant evidence that public participation can lend important local knowledge, inform policy or other solutions⁶⁷, and lead local citizens to perceive the result of decisions more positively. One study on US wind turbine siting, for instance, found that when citizens that live near the turbines believe that the planning process was fair, they are more likely to perceive positive benefits of the turbines, and vice versa²³.

Nor are decision-making processes always inclusive of citizens and consumers writ large, or involve them in the leadership of and planning for such processes. This is especially the case for low-income people and people of colour. For an example, consider citizen involvement in US utility commission and Federal Energy Regulatory Commission decisions²². Even in those 43 US states that have a consumer advocate that can participate in public utility commission cases, the role of this representative is typically to advocate for low rates, not an equitable distribution of welfare²².

Researchers have also identified many cases in which access to low-carbon and efficient technologies that accompany the energy transition is not universal and, in most cases, is exclusively seized by higher income households. Scholars have drawn such conclusions about low-emissions and electric vehicles^{68,69}, residential solar photovoltaic panels^{70,71}, community solar⁷², smart meters⁷³, efficient appliances⁷⁴ and LED lightbulbs⁷⁵. This lack of technological availability or access across all demographics is typically attributed to the high upfront costs of these technologies, incentives for purchase of the technologies that reduce eligibility of those that do not have strong credit or do not pay taxes, for example, and a misalignment between required installation and use of the technology with living conditions (for example, rental properties).

This collective body of literature that documents both the disproportionate burden and the lack of access to opportunities has significantly expanded our understanding of the justice implications of a clean energy transition; but much is still unknown about the magnitude and geographic distribution of these problems. In the US context, several surveys such as the American Housing Survey and the Residential Energy Consumption Survey, measure some of these concepts and provide estimates of the magnitude of energy poverty. However, there exists no comprehensive, annual or

geographically explicit data collection efforts that enable scholars, practitioners and policymakers to understand exactly who suffers from these inequalities, to what degree and where they are located⁷⁶. Also, how do these burdens or lack of opportunities affect other aspects of one's life, as well as communities at large? In addition to these questions about vulnerability, important questions arise about potential solutions. In the next section, we review the literature on what policies, programmes and other efforts can help address some of the disparities reviewed above, and to help facilitate an inclusive and just transition.

Building adaptive capacity

Scholars have made a case for policy and business interventions to ensure a just transition. There are, at a minimum, five different types of efforts that could address some of the disparities discussed above: workforce and economic diversification programmes; energy assistance and weatherization; expansion of energy technology access; collective action initiatives; and new business development⁷⁷. We discuss each in turn, following two important notes. First, the literature on just transitions tends to feature policies that directly address adverse outcomes of the energy transition, such as coal workforce transition programmes. However, a broader set of policies, including some that are outside traditional notions of a just transition, are also important to consider given that the energy transition may exacerbate pre-existing disparities, such as energy insecurity. Second, pursuit of a just transition does not prescribe a specific set of policies and processes; rather, it encourages a shared vision and inclusive planning and decision-making that involve all affected actors in a way that is tailored to local circumstances⁷⁸.

Workforce and economic diversification programmes support workforce training, job development and regional economic transition for those communities that have historically relied on the fossil fuel industry as the main source of employment. The US Congressionally-funded Partnerships for Opportunity and Workforce and Economic Revitalization (POWER) Initiative administered through the Appalachian Regional Commission, Europe's Just Transition Mechanism, the US Just Transition Fund and the Alberta, Canada's Coal Workforce Transition Fund and Coal Community Transition Fund are examples of programmes that seek to provide assistance to coal workers and communities. Economic diversification programmes may create special economic zones that provide incentives for new businesses, such as those supported by the Australian Council of Trade Unions⁷⁹.

Assistance programmes improve the affordability of energy services, typically through bill subsidies and support for those facing legal challenges with utility companies. Energy efficiency and weatherization programmes help improve the efficiency of a dwelling unit. Efficiency programmes provide home audits and efficient light-bulbs, for example, while weatherization programmes improve the overall efficiency of a home through window sealing and insulation, as two examples. In the US, the federal government provides energy assistance through the Low Income Home Energy Assistance Program (LIHEAP) and weatherization support through the Weatherization Assistance Program (WAP). Utility regulatory commissions in most states also mandate utilities to use ratepayer dollars to fund low-income energy efficiency programmes and bill assistance programmes; these programmes tend to operate parallel to, if not in coordination with, WAP programmes. Ratepayer supported programmes such as these account for about half of all low-income energy assistance, as of 2016³⁹. In addition to abiding by any relevant state-mandated utility shut-off protection programmes⁸⁰, utilities may also help customers through the provision of level-billing, by waiving or eliminating late fees, and through debt-forgiveness or flexible deferred payment programmes⁵⁰.

Technology access programmes aim to build energy efficient and renewable energy infrastructure and extend these resources to

marginalized communities. Jurisdictions—as well as utilities—across the country are rolling out such programmes. Examples include the state of Washington's Solar Plus programme, which applies US Department of Energy grant funds to deploy community-owned solar for the state's low-income communities; the use of earmarking incentives for specific demographics, such as Sacramento, California's mandate that 35% of all Volkswagen settlement funds for electric vehicles go toward a Community Car Share programme that serves low-income residents; Colorado's community solar programme, which reserves 5% of all projects for low-income residents; and San Diego Gas & Electric's Power Your Drive programme, which is deploying thousands of charging stations in traditionally underserved neighbourhoods and locations. Several authors have noted the importance of providing purchase incentives that are not exclusively tied to income or property taxes, since low-income households tend to pay lower taxes, if they qualify for taxes at all^{68,81}. Others offer community solar as one possible solution, which allows solar installers to share the cost of the system and avoid the need to provide a roof on a home that they may not own⁷².

Collective action initiatives seek to provide community education and awareness about energy issues and the local impacts that they may produce, as well as engage members of the community in decision-making processes. An example is Community Energy Scotland⁸², which provides support for community energy project development. Another example is the Inclusive Financing for Energy Savings programme, run by a US non-profit, which provides financing and hosts stakeholder sessions to build community and utility demand for energy efficiency upgrades or renewable energy investments.

Business interventions may include energy innovation or new business model opportunities, especially those that provide energy efficiency services; appeal to the case that sustainability within business can be profitable; and typically focus on extending access to technologies, jobs and energy services, but rarely on addressing energy insecurity^{82–84}. To our knowledge, no studies provide an assessment of, or guidance for, integrated policy and business approaches.

While the literature has started to identify the policies and programmes that help facilitate a just transition, few studies evaluate the effects and effectiveness of programmes that are already in place⁸³, or extend lessons learned. In the US context, only a few studies evaluate the efficacy of WAP^{84–86} or LIHEAP^{50,87,88}. These studies generally confirm that the assistance programmes achieve their desired outcomes, but typically not as efficiently as they could and often at the neglect of those that are most in need. In 2008, the most recent year of analysis, the WAP served 97,965 dwelling units and saved the average unit 29.3 MMBTUs, for an average cost per unit of US\$4,700 compared to environmental and health benefits of US\$22,000 and total savings across all units of US\$420 million^{85,86}. Additional benefits reported by WAP participants—and reaffirmed by studies on weatherization in other countries^{89,90}—include better health, less draftiness, less thermal stress and fewer days of work missed⁸⁶. In 2014, LIHEAP distributed approximately US\$3.4 billion across 6.3 million households for heating assistance and winter crisis relief⁹¹.

These diverse benefits, however, are accompanied by many challenges to the implementation and impact of the programmes. First, both the WAP and the LIHEAP are significantly underprovided^{50,85}. Approximately 35 million households were eligible for the WAP in 2008, but only 0.3% of those benefited from it⁸⁵; of the approximately 38.5 million households eligible for LIHEAP in 2013, only 16% received assistance⁹¹. Second, WAP participation rates are low due to the onerous application process, the split incentive between landlords and renters⁸⁴, distrust of government among homeowners⁸⁴, a lack of perceived importance of energy efficiency over other issues⁸⁴, the need to meet certain housing safety conditions before WAP application, and, in the case of those that reside in US Department of Housing and Urban Development (HUD) housing, the need for



Credit: Jeff Hu

residents to secure preapproval⁸¹ through HUD. Third, the eligibility requirements of the LIHEAP, and specifically the asset tests imposed by some states, regressively restrict access⁸⁷. Fourth, those that implement the WAP have struggled to ensure health and safety conditions in homes, maintain consistent work quality⁸⁸ across those that weatherize the homes, and avoid fraudulent activities⁹¹.

Few studies evaluate the efficacy and implementation of other types of assistance programmes, and especially those outside of the US context. The literature is also silent on the distribution of such efforts, and whether the regions that are most in need have targeted programmes. Although energy injustices tend to be specific to place, and one should expect immense variation across space in the nature of disparities and potential mitigation programmes for frontline communities, empirical reflection on best practices could provide at least some general guidance for the practitioner and scholarly communities. The literature is, however, conspicuously void of large or comparative studies on energy assistance programmes.

It is also important to highlight that other social assistance programmes, though not explicitly designed to address issues of energy, are connected to energy justice through their efforts to improve general social welfare. For instance, according to Hernández and Bird, energy insecurity is significantly higher than most policymakers might assume, and a coordinated energy and housing assistance effort is necessary to target such energy insecurity⁵⁰. There is also emerging literature on the intersection between health, housing and energy efficiency⁹². Intersections between energy assistance and other assistance such as through, in the US case, the Supplemental Assistance Nutrition Program or the Temporary Assistance for Needy Families programme, and how receipt of such services may affect energy behaviour and security, is virtually unexplored in the current literature, especially through systematic empirical analysis of individual and household wellbeing.

The literature is similarly nascent on the effects, effectiveness and lessons learned from technology access programmes. Is it better, for example, to target underrepresented groups through one type of policy instrument over another (for example, earmarks for financial incentives versus incentives designed exclusively for low-income residents)? Do carve-out programmes for solar access in low-income communities successfully reach their target populations? Studies that highlight exemplar programs of renewable

energy and energy efficiency provision programmes⁹³, and key strategies for successful programme implementation (<https://www.lowincomesolar.org/>)⁹⁴ stress the importance of leveraging multiple funding streams, building partnerships including those with the local community, designing predictable policies, seeking low-hanging and highly cost-effective interventions, and prioritizing quality control and training.

The literature on workforce training and economic diversification programmes argues the importance of both short-term and long-term interventions, as well as a diversified assistance programme that includes retraining and relocation support, income to support individuals through retraining, guaranteed pensions and community-level transition programmes^{31,79}. For example, the state government of Victoria, Australia, provides both short-term and long-term assistance: short-term financial relief and psychological counselling for those that lose their jobs and long-term retraining and education assistance. It also seeks to attract new business development through business incentives⁷⁹.

Additional lessons emerge from the literature on workforce training and economic diversification. First, while programmes can be run by any level of government, studies have found that programmes are perceived as more successful when they are led by local stakeholders and are bottom-up, rather than state or national initiatives^{48,79}. Second, and closely related, studies highlight the importance of open dialogue with the affected population in building solutions and facilitating inclusion in decision-making processes. Such engagement, in turn, will facilitate trust among stakeholders⁷⁹. Third, efforts that involve collaboration and coordination among different levels of government as well as different stakeholders will be more successful^{48,79,95}. Finally, studies highlight the importance of early detection of vulnerability so as to ensure adequate time and preparation for just transition programmes⁹⁵.

Moving forward. Scholars from disciplines spanning the social sciences are increasingly focused on important distributional questions related to the ongoing energy transition. In this Review, we have taken stock of this emerging research on energy justice and the just transition, which collectively are advancing our understanding of the nature of disproportionate burdens, gaps in access to new technologies, and efforts to enhance adaptive capacity to help

burdened frontline communities cope with large economic, social and cultural changes.

One important theme that emerges is that the adverse effects of an energy transition toward cleaner sources of energy has implications far beyond the fate of coal miners. This is not to suggest that attention to coal miners and coal mining communities is unimportant, only that other segments of society are also on the ‘frontlines’ of the transition, and that much of the public and political discourse tends to have too narrow an emphasis. Often overlooked, for example, are non-extractive communities that rely on coal, such as communities that host coal-fired power plants. Although there are immensely important health and environmental benefits—both local and societal—of shutting down these power plants, they have historically provided high-wage jobs and substantial local tax revenue, and their retirement will likely create economic hardship. Communities whose economies are closely linked to oil may experience similar economic impacts in the future, including not just communities reliant on oil extraction, but also those whose economies and labour forces are based in oil-related industries, such as manufacturing and assembly plants for combustion engine automobiles. Also on the frontlines are communities vulnerable to potential increases in electricity and other energy prices—and with insufficient energy housing conditions that will only worsen with the effects of climate change—which will likely exacerbate existing energy insecurity. These examples illustrate that just transition and energy justice issues affect diverse populations.

The research described in this Review reveals important existing findings, but additional scholarship is necessary to better identify the nature and extent of burdens and benefits from the energy transition, and how they vary across different segments of society. In general, it is vital that analyses of climate change mitigation and adaptation policies, as well as other initiatives intended to hasten a global energy transition, comprehensively evaluate distributional impacts. Typically, such analyses focus on questions of efficiency and cost effectiveness, with distributional issues, if addressed at all, done only in a secondary manner.

Among the key research questions that require further attention is how to make renewable energy and energy efficiency technologies more widely-accessible, especially to those with limited income? Of specific need is the identification and evaluation of promising models, including public and non-profit programmes and public-private partnerships, that specifically aim to expand access to these technologies. In addition, there exist few formal, careful evaluations of energy assistance efforts to mitigate energy insecurity. Important inquiries that remain include what ways and to what degree can energy assistance, legal support and weatherization programmes help alleviate energy poverty; how the design of such programmes can be improved to reach a greater number of households in need; and how energy programmes can best be coupled with housing and health programmes to target common causes of material hardship and personal health. Similarly, there has not been careful analysis of the efficacy of workforce development and training programmes aimed at workers displaced by the energy transition, as well as efforts to diversify the economies of communities dependent on the extraction of what will be legacy energy sources. For example, we know little about which specific economic diversification approaches work well in regions that formerly relied heavily on coal mining or power plant operations as a source of employment. More extensive and cross-disciplinary research can help address these issues, as well as inform decisions about how to prioritize efforts and how to manage trade-offs.

Changes of the scale that come with an energy transition inevitably create winners and losers. As countries and the international community continue to devise strategies to transform their energy economies as part of efforts to address climate change, it is imperative that such efforts incorporate justice considerations. The scholarly

community has an important role to play in assuring that efforts are evidence-based and grounded in the experience of individuals, households and communities that will be most affected. This is a big challenge that will require multi- and inter-disciplinary research employing varied research designs conducted at different scales. The magnitude of the challenge is large, but so too are the opportunities for moving scholarly inquiry and policy forward.

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Competing interests

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Additional information

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