frontiers | Frontiers in Environmental Science

TYPE Original Research
PUBLISHED 07 November 2024
DOI 10.3389/fenvs.2024.1491946

OPEN ACCESS

EDITED BY
Amit Kumar,
Nanjing University of Information Science and Technology, China

REVIEWED BY
Farhad Ilahi Bakhsh,
National Institute of Technology, India
Saurabh Mishra,
Hohai University, China

*CORRESPONDENCE
Ziheng Shangguan,
ziheng.shangguan@unimelb.edu.au

RECEIVED 05 September 2024
ACCEPTED 25 October 2024
PUBLISHED 07 November 2024

CITATION
Shangguan C, Shangguan Z and Sun W (2024) Impact assessment framework of just energy transition: based on the justice principles. *Front. Environ. Sci.* 12:1491946. doi: 10.3389/fenvs.2024.1491946

Impact assessment framework of just energy transition: based on the justice principles

Chenyue Shangguan[1], Ziheng Shangguan[1,2,3,4]* and Wen Sun[5]

[1]Research Center for Reservoir Resettlement, China Three Gorges University, Yichang, China, [2]School of Public Administration, Guizhou University of Finance and Economics, Guiyang, China, [3]School of Geography, Earth and Atmospheric Sciences, The University of Melbourne, Parkville, VIC, Australia, [4]Asia Institute, The University of Melbourne, Parkville, VIC, Australia, [5]School of Criminal Law, East China University of Political Science and Law, Shanghai, China

The concept of a Just Energy Transition (JET) has gained prominence in sustainable development discussion, with impact assessment serving as a key foundation for advancing global energy justice. Currently, the primary assessment frameworks encompass distributional justice, procedural justice, and restorative justice. However, these dimensions exhibit a certain degree of overlap, and a standardized set of metrics for their evaluation remains conspicuously lacking. To address this research gap, this study employs a literature review and logical reasoning to construct a comprehensive framework consisting of four distinct assessment dimensions: cognitive justice, distributional justice, procedural justice, and redistributive justice. The framework delineation the boundaries and logical relationships among these dimensions. This study emphasizes the foundational role of cognitive justice, positioning it as the cornerstone upon which other dimensions of justice rely. Moreover, it puts forth a constructive argument that future generations, as direct beneficiaries, should bear additional responsibility to uphold intergenerational justice. This multi-dimensional framework deepens our understanding of the complexities of JET and encourage critical discourse on the subject.

KEYWORDS

just energy transition, impact assessment, cognitive justice, distributional justice, procedural justice, redistributive justice

1 Introduction

Over the past 2 decades, a prominent focus in energy transition research has revolved around two crucial aspects: energy transition technology and the energy transition economy (Jones et al., 2021; Popescu et al., 2022). This research strand has encompassed the development of state-of-the-art technologies and economic models aimed at facilitating the design and adoption of innovative energy solutions (Gallo et al., 2016; Østergaard et al., 2021; Carley and Konisky, 2020; Blazquez et al., 2020). The advantages associated with this emphasis are multifaceted, including the modernization of industrial structures, the proliferation of new energy technologies, climate change mitigation, environmental preservation, and the promotion of sustainable economic development (Wang and Lo, 2021; Montañés et al., 2023). These developments highlight the critical role of technological and economic advancements in driving the energy transition towards a more sustainable future, reflecting a growing commitment to addressing environmental challenges and fostering a resilient, low-carbon economy.

Addressing the energy inequalities that emerge from this transformative shift is crucial. In the early stages of the energy transition, a significant influx of human capital, technological resources, and investments is essential. This dynamic may render economically advanced nations and regions more adept at and predisposed towards enjoying the benefits of energy transition, thereby potentially exacerbating global or domestic economic disparities (Sinha et al., 2023). Energy transition inevitably mandates a restructuring of industrial frameworks, profoundly affecting employment prospects in various technical domains. The transition towards renewable energy sources may precipitate a reduction in employment opportunities within traditional energy sectors, such as coal and oil. This shift can also disrupt labor markets that lack the requisite skill sets, thereby underscoring the need for workforce adaptation and retraining initiatives (Cha et al., 2020). Ensuring that workers can transition smoothly to new roles in emerging energy sectors is essential for mitigating the socio-economic impacts of this industrial shift and for promoting sustainable employment growth in the long term.

It is essential to emphasize that disparities in energy access can lead to a cascade of secondary societal challenges. From a corporate development perspective, they may lead to non-democratic and unsustainable industrial processes, concentration of corporate power and profits, and the externalization of waste and pollution (Brock et al., 2021). Concerning equitable employment opportunities, it is essential to acknowledge the presence of gender and racial disparities, the prevailing trend of male dominance in high-tech, high-income occupations, and the significant "brain drain" effect exerted by high-tech zones on the surrounding regions (Carley and Konisky, 2020). The prominence of inequities arising from energy transition has been steadily increasing (Chen et al., 2024; Kashour, 2023; Lei et al., 2023). It is paramount to factor in considerations of energy justice and affordability throughout the energy transition process. This proactive approach is aimed at mitigating the developmental imbalances that stem from energy inequality and stands as a pivotal concern within the sphere of sustainable development.

In response to the inequities arising from the energy transition process, the concept of "just transition" emerged towards the end of the 20th century. This concept found its place in international dialogues, including the United Nations Sustainable Development Goals (SDGs) and climate change negotiations (Abraham, 2017; McCauley and Heffron, 2018). Within the context of globalization, the concept of a "just transition" has expanded its scope to encompass international dimensions, with a particular emphasis on the concerns of developing countries. Nations have sought to determine the allocation of responsibilities and obligations between developed and developing countries in the energy transition process through international cooperation. This collaborative approach seeks to ensure that the transition does not exacerbate global inequalities (Qi et al., 2023). In the 2015 Paris Agreement, the issue of a just energy transition (JET) was formally introduced, emphasizing the significance of global "climate justice" and "sustainable development." This recognition underscores the importance of equitable policy frameworks and support systems that prioritize both environmental sustainability and social equity on a global scale.

The assessment of the impacts of a JET serves as a valuable foundation for advancing global energy equity. This form of impact assessment typically entails a comprehensive evaluation of the repercussions that energy structural adjustments and transition policies have on diverse groups, industries, regions, and the environment (Majekolagbe, 2022). In alignment with the principles of environmental justice and climate justice, the assessment of energy justice commonly adopts analytical frameworks rooted in distributional justice and procedural justice (Sovacool and Dworkin, 2015). Distributional justice emphasizes maintaining a balanced distribution of resources and benefits among individuals or groups, aligning with their needs, rights, and contributions (Miller, 2017; McCauley and Heffron, 2018). While, procedural justice directs attention to the justice of decision-making and rule-making processes, beyond the ultimate outcomes. It scrutinizes whether the decision-making process is characterized by transparency, consistency, impartiality, and equity. This facet of justice plays a pivotal role in legal systems, organizational governance, and political decision-making (MacPartlin and Darcy, 2007; Lappe-Osthege and Andreas, 2017).

Some scholars assert that the paradigms of distributional justice and procedural justice may inadvertently overlook the imperative of punishing wrongdoers and providing restitution to harmed groups. This contention has given rise to the concept of restorative justice (Welton et al., 2015). Restorative justice centers on the restoration of harm inflicted upon individuals, rather than solely focusing on punitive measures against offenders (Hamilton and Hamilton, 2021; Speed, 2020). Other scholars argue that restorative justice fundamentally constitutes an integral facet of procedural justice. It can be delineated into two distinct dimensions: recognition justice and compensation justice (Lacey-Barnacle et al., 2020). Recognition justice emphasizes acknowledging and addressing the experiences and needs of affected individuals or groups, while compensation justice focuses on providing reparations and restoring the losses incurred. Together, these dimensions provide a comprehensive approach to ensuring that justice is not only about equitable distribution and fair processes but also about healing and rectifying past harms (McLaughlin, 2020).

Presently, there exists no unified framework in the analysis of energy justice, and a degree of overlap persists among various dimensions. This study endeavors to construct analytical dimensions for the assessment of energy justice, rooted in justice theories, and delineate the boundaries of each dimension comprehensively. Moreover, it offers meticulous elucidation of constituent elements and evaluation indicators, along with their respective definitions, with the intent of providing a comprehensive and effective analytical framework for the impact assessment of a JET. By establishing clear and distinct dimensions, this framework aims to address the complexities and intersections inherent in energy justice, facilitating a more structured and holistic approach to evaluating the socio-economic and environmental implications of energy transitions.

Literature review stated that there is no unified framework for the analysis of energy justice, and a degree of overlap exists among the various dimensions, with their logical relationships remaining unclear. Therefore, this study aims to develop a comprehensive analytical framework for energy justice, addressing the inherent complexities and intersections within this field. This framework

seeks to facilitate a more structured and holistic approach to evaluating the socio-economic and environmental impacts of energy transitions. The objectives of this study includes: i) Establishing analytical dimensions for assessing energy justice, with clear and comprehensive definitions for each dimension's boundaries, ii) Providing detailed explanations of the constituent elements and evaluation indicators within each dimension, along with their respective definitions, and iii) Clarifying the internal logical relationships between the different dimensions of energy justice.

2 Adams' equity theory: cognitive justice

When discussing principles of justice, Adams' Equity Theory often stands out as a seminal concept. Originating in 1963, this classic theory serves as a foundational framework for comprehending perceptions of equity and inequity within the workplace, along with its consequential effects on employee conduct. Adams' Equity Theory underscores the employee's assessment of justice by juxtaposing their personal inputs (such as effort, skills, loyalty, or the challenges they undertake) against the outcomes they receive (including salary, promotions, recognition, or other rewards) (Greenberg and Colquitt, 2021). Notably, Adams posited that the notion of justice hinges upon subjective perceptions, which are intrinsically linked to individuals' evolving cognitive capacities (Cropanzano et al., 2020). This theory highlights the importance of perceived fairness in shaping employee motivation, satisfaction, and behavior, providing a valuable lens through which to examine justice in various organizational contexts.

Drawing upon the principles of Adams' Equity Theory, the paper posits that cognitive justice merits inclusion as a vital evaluative dimension within the discourse on justice amid the energy transition. In the context of energy transformation, cognitive justice encompasses two key stakeholders: the proponents of energy transition (i.e., governmental bodies and corporate entities) and energy consumers (the general populace). Consequently, cognitive justice becomes pertinent in scrutinizing matters such as the cognitive levels of the proponents regarding energy justice, the capacity of energy community residents to discern the repercussions of their own interest concessions, and the intricate dynamics that manifest within their interactions.

By incorporating cognitive justice into the analytical framework, we aim to address the disparities in understanding and awareness between these stakeholders. This inclusion is crucial for evaluating how well the decision-makers comprehend the principles of energy justice and how effectively they communicate these principles to the affected communities. Furthermore, it examines whether the residents have the necessary knowledge and tools to understand and negotiate the trade-offs associated with energy policies and initiatives. Through this lens, cognitive justice provides a means to ensure that all parties are equally informed and capable of participating in the transition process, thereby fostering a more equitable and inclusive energy transformation.

2.1 Cultural sensitivities and essential societal requirements

The cognitive level of energy transition proponents is a pivotal determinant in achieving a JET (Healy and Barry, 2017). Research rooted in social psychology has delved into the influence of culture and social needs on JET, highlighting the critical role of understanding and addressing these factors. Specifically, it has been emphasized that energy corporations and relevant governmental entities must proactively cater to cultural sensitivities and fundamental requirements at individual, community, and societal levels. This comprehensive approach ensures the justice of the energy transition process by fostering greater acceptance and cooperation among all stakeholders (Sarrica et al., 2016).

Within the context of a study focused on energy transition in rural communities in Northern Italy, (Tiberio et al., 2020) conducted an in-depth examination of the interplay between knowledge, motivation, and cultural factors in shaping energy-related behaviors. Their research highlighted a crucial point: while community residents may possess some degree of understanding regarding energy issues and energy-saving options, this awareness does not necessarily translate into concrete energy choices when the adoption of new energy sources clashes with their entrenched cultural norms and individual needs. This case serves as a compelling illustration of the paramount role played by cultural sensitivity in the realm of energy transition (f et al., 2020).

Another illuminating case study scrutinized the energy transition strategies adopted within the Australian coal industry. This investigation underscored the necessity for these strategies to take into account the historical and cultural identities of local communities, as well as the substantial reliance of residents on the coal industry. These strategies encompassed the provision of basic social needs such as education and training opportunities in the energy transition, along with support for the development of nascent industries (Carley and Konisky, 2020).

In light of these research findings, it becomes evident that governmental bodies and corporate entities, in their role as drivers of energy transition, must not only give due consideration to cultural sensitivity but must also possess a comprehensive understanding of the objective and intrinsic basic needs of community residents as they advance the energy transition agenda. Building upon these empirical studies, the paper delineates the constituent elements for assessing cognitive justice, which include the attempt to reduce cultural sensitivity and the identification and fulfillment of essential societal requirements.

2.2 Participation and representativeness of energy community residents

The recognition and preservation of potential benefits by residents within energy communities play a pivotal role in establishing the fundamental criteria for a JET (Mundaca et al., 2018). An extensive investigation of 71 instances of energy transitions within European economic regions revealed that the initial step for community residents involves acknowledging their susceptibility to energy vulnerabilities and energy poverty, which is

crucial for effective participation in the decision-making processes of energy transition endeavors (Hanke et al., 2021). This active involvement is instrumental in advancing the principles of energy justice. It underscores the necessity for community residents to have a comprehensive understanding of the advantages and risks inherent in energy transition projects. Residents must be aware of their rights and know how to safeguard their interests through active participation, ensuring a more equitable and inclusive energy transition.

In an inquiry into the acceptance levels of local populations towards wind energy and bioenergy projects within the United Kingdom, researchers discerned a lower level of acceptance among local residents. This reduced acceptance was primarily due to a limited understanding of the benefits and technological safety aspects of the energy transition (Lennon et al., 2019). Conversely, in the context of 113 energy community projects in Germany's energy transition, there was widespread support from community residents. This support was facilitated by providing clear and cost-effective energy transformation blueprints and empowering local communities (Hanke and Guyet, 2023). These empirical cases underscore the pivotal role of comprehensive cognition in driving active public participation in energy transition initiatives, demonstrating that when communities are well-informed and actively engaged, the acceptance and success of energy projects significantly increase.

Furthermore, the participation of community residents must be characterized by representativeness, ensuring that it encapsulates the concerns and needs of all societal groups. In the context of the European energy landscape, a recurrent issue within the JET paradigm has been the underrepresentation of marginalized groups (Hanke and Lowitzsch, 2020). To address this concern, the European Union has instituted legislation that emphasizes the societal role of economic regions in mitigating energy poverty. It mandates the inclusive participation of all social strata within economic regions, with particular focus on those segments of society that are historically underrepresented among the economic region's members (European Union: European Commission, 2019). This legislative approach aims to create a more equitable energy transition process by ensuring that the voices of all community members, especially the marginalized, are heard and considered in decision-making processes.

Hence, it becomes evident that the level of awareness among energy community residents regarding their own energy vulnerability and energy poverty plays a pivotal role in determining the extent and scope of their involvement in the JET. Therefore, the paper includes participation of energy community residents and representation of energy community residents as decision-making members in the evaluation of cognitive justice.

2.3 Construction of communication and resolution mechanism

The effectiveness and sustainability of a JET are contingent upon the willingness of both businesses and energy community residents to engage in mutual communication and collaboration. This willingness, combined with their knowledge reservoirs and cognitive levels during the collaborative process, plays a crucial role in shaping the outcome (Siciliano et al., 2021). Effective communication fosters a shared understanding of goals and challenges, while collaboration ensures that diverse perspectives are integrated into decision-making processes. The cognitive levels of all stakeholders, including their ability to comprehend and apply knowledge related to energy transitions, significantly influence the success and durability of JET initiatives (Bal et al., 2023).

Within the ambit of the Social Innovation in Energy Transitions (SONNET) project's 500 social innovation practices, cities such as Mannheim and Warsaw are actively propelling the JET by extending support to citizen energy communities, fostering knowledge-sharing through dedicated knowledge centers and citizen groups, and embracing market-driven and multilevel governance models. These strategic approaches significantly enhance the effectiveness of communication and serve as catalysts for the promotion of sustainable energy transitions (Sovacool et al., 2023). Nevertheless, the continuity of such communication necessitates the establishment of regulatory mechanisms capable of sustaining long-term negotiations (Hoicka et al., 2021). Establishing these mechanisms is crucial to ensuring that dialogues remain productive and adaptive to evolving energy landscapes, thereby securing the ongoing engagement of all stakeholders in the transition process.

JET's sustainability, by contrast, needs to be anchored in a regulatory mechanism that can sustain long-term negotiations. The Global Subsidies Initiative emphasizes that JET is an ongoing process grounded in dialogue and a tripartite agenda, involving labor, industry, and government. This process mandates perpetual negotiation and implementation, considering the diverse geographical, political, cultural, and social contexts within which it unfolds (Hoicka et al., 2021; Global Subsidies Initiative, 2018). An illustrative example of this approach is seen in the establishment of National Regulatory Authorities (NRAs) during the European energy transition. These authorities constructed regulatory mechanisms for the energy transition due to their independence, which empowers them to advance the transition through the formulation of policy, negotiation, and rigorous technical assessments (Kaschny and Lavrijssen, 2023). This model underscores the importance of having dedicated regulatory bodies that are capable of navigating complex and evolving energy landscapes, ensuring that the transition process remains effective and equitable over the long term.

The inherent risks in communication and management processes are closely linked to stakeholders' awareness of their actual interests. Thus, evaluating the effectiveness of constructive communication processes, negotiation strategies, and regulatory mechanisms is crucial within the framework of cognitive justice. This evaluation should concentrate on the systematic assessment of communication effectiveness and the comprehensive evaluation of problem-solving capacity.

3 Procedural justice principle: procedural justice

The principle of procedural justice is a commonly applied concept in legal interpretations, emphasizing the fairness of the

decision-making process over the justice of the ultimate outcomes. This principle posits that even when outcomes are unfavorable, individuals may still perceive the process as fair if it exhibits transparency, consistency, and impartiality (Tyler and Allan Lind, 2001). Within the context of a JET, procedural justice assumes a pivotal role, primarily influencing the trajectory and results of this transition by ensuring transparency, justice, and inclusivity throughout the decision-making process (Wang and Lo, 2021). Among these aspects, transparency and equity serve as the fundamental pillars of a JET, while inclusivity determines the degree of alignment between the final outcomes and the envisioned objectives. The paper integrates procedural justice into the analytical framework for evaluating a JET and delineates the assessment elements of procedural justice based on these three aspects.

3.1 Publication and transparency of energy policies

Openness and transparency are fundamental prerequisites within judicial proceedings. Procedural justice necessitates that the decision-making process be transparent and subject to review, allowing all stakeholders to comprehend and oversee the development and implementation of policies (Nunn, 2020). This transparency serves to foster public trust in new policies and mitigate resistance. In the context of the energy transition process, it is crucial that energy enterprises ensure the clarity and comprehensibility of information while upholding its timeliness and accessibility (Carley and Konisky, 2020). This entails the regular release of detailed information regarding energy strategies, including policy objectives, implementation strategies, progress updates, anticipated impacts, and pertinent scientific and economic analyses. Moreover, it involves disclosing the data and analytical methodologies employed in policy formulation, enabling external experts and the general public to verify and comprehend the data and rationale underlying the decisions. Articulating the policy formulation process, including the consideration of varying perspectives and evidence, is paramount. This comprehensive approach ensures that all stakeholders are adequately informed and can actively engage in the transition process, thereby enhancing the legitimacy and effectiveness of the energy transition.

Simultaneously, government energy departments and non-governmental energy organizations should engage in ongoing process monitoring of these strategies. This encompasses the establishment of robust public audit and regulatory mechanisms, whose pivotal role has been evident in the energy transition processes of nations such as Canada, Egypt, Indonesia, India, Poland, and Ukraine (Global Subsidies Initiative, 2018). Effective monitoring ensures that energy transition policies are implemented as intended and that deviations or issues are promptly identified and addressed. These mechanisms not only enhance accountability but also build public confidence in the transition process by demonstrating a commitment to transparency and continuous improvement. The principles of openness and transparency are relevant across various judicial contexts, making them critical for assessing a JET and essential to the evaluation framework. In the assessment of procedural justice, particular emphasis is initially placed on two key elements: the dissemination of energy policies and their transparency.

3.2 Consistency and equity in energy policy formulation

Another essential prerequisite for upholding procedural justice within a program is the imperative of maintaining uniformity and equitability in the decision-making process. This imperative underscores the necessity for all decisions to be firmly grounded in legal statutes and to meticulously adhere to standardized criteria. The pursuit of consistency in decision-making mandates that the governing body establish explicit, enduring energy policy objectives and comprehensive frameworks to ensure the harmonization of all strategies and measures with these overarching objectives. This approach serves the dual purpose of mitigating the inherent uncertainties arising from policy vacillations and fostering the congruent alignment of diverse measures towards the attainment of common objectives.

Empirical analysis of failed instances of energy transition within the contexts of Mexico and Chile reveals that factors such as the erosion of decisional motivation, incongruent standards, erroneous trajectories, and ill-conceived choices often contribute to the detriment of energy transition initiatives (Natorski and Solorio, 2023). Notably, the inconsistency in decision standards escalates the complexity of decisional processes, consequently inflating the associated costs and provoking resistance from the populace. Therefore, maintaining consistency and equitability in decision-making is critical for the success of energy transition programs, ensuring that all actions and policies are aligned and implemented effectively (Sovacool et al., 2020).

Within the domain of procedural justice, the field of equity accentuates the indispensability of ensuring that energy transition initiatives are not only compliant with domestic legal provisions and regulations but also uphold the principles enshrined within international energy accords. Furthermore, it is imperative to recognize that energy-related legal statutes represent the baseline standard of procedural justice, while achieving a truly JET relies heavily upon the moral and ethical obligations assumed by both energy enterprises and governmental entities. This moral and ethical responsibility extends to the comprehensive consideration of the environmental impact of emerging energy sources during the course of an energy transition. This includes addressing the potential utilization of hazardous chemicals in solar panel production and the ecological ramifications of wind power generation on avian and other wildlife populations. This analysis identifies the second evaluative elements of procedural justice as the harmonization of policy standards and the legal and ethical foundations of these policies.

3.3 Feedback mechanisms and policy adaptability

The fundamental aim of a Just Energy Transition (JET) is to promote and implement renewable energy sources. To achieve this, it is essential to meet the procedural requirements of transparency

and equity while fostering greater acceptance of renewable energy through inclusive means. Inclusivity necessitates the establishment of robust feedback mechanisms that ensure the efficient collection and utilization of feedback on policies and decisions. This includes a thorough evaluation of the presence of effective corrective measures to rectify erroneous or unjust decisions (Ruano-Chamorro et al., 2022). Moreover, examining the role of policy feedback in the governance of renewable energy reveals that the sector becomes increasingly institutionalized when feedback results in positive reinforcement. This process cultivates enhanced domestic and international connections and cooperation, thereby supporting the overall goals of the energy transition (Meckling, 2019).

Another facet of inclusivity manifests in the assurance of policy adaptability and flexibility. In this nascent phase of the energy transition, renewable energy disrupts established technologies, organizations, and infrastructure, compelling decision-makers to recalibrate their strategies. This recalibration is necessary to address declining commercial models and technologies, intensified economic and political struggles among pivotal stakeholders such as utility companies and industry associations, as well as substantial challenges confronting the overall functionality and performance of the energy sector (Markard, 2018). Ensuring that policies are adaptable and flexible allows for a more resilient energy transition, capable of responding to evolving challenges and uncertainties.

Transition to sustainable energy sources requires a more inclusive approach to ensure a just transformation. This underscores the necessity for energy custodians, particularly governmental bodies, to develop effective feedback mechanisms during the implementation of energy transition processes. Such mechanisms are crucial for ensuring that energy strategies remain responsive and adaptable to changing conditions. By incorporating strong feedback systems, policymakers can continually evaluate and improve energy strategies, aligning them with the evolving needs of stakeholders and broader sustainability goals. To achieve this, it is essential to evaluate the effectiveness of feedback mechanisms and the flexibility and adaptability embedded in energy policies.

4 Distributive justice principle: distributive justice

The principle of distributive justice is dedicated to investigating and establishing equitable and just patterns of societal resource allocation, encompassing various aspects such as income, wealth, and opportunities (Bergsmo et al., 2010). In the context of a JET, distributive justice takes center stage, with its primary focus on ensuring the equitable distribution of resources and benefits (McCauley and Heffron, 2018; Wang and Lo, 2021; Bal et al., 2023). However, it is essential to note that some scholars advocate for its extension to encompass broader aspects, such as the energy transition's impact on residents' livelihoods and employment, including changes in energy expenditure structures and shifts in employment patterns (Axon and Morrissey, 2020; Pellegrini-Masini et al., 2020). These aspects are often viewed as externalities of energy distribution and highlight the multifaceted nature of distributive justice within the energy transition process.

Building upon the existing academic discourse, the paper introduces distributive justice as an additional analytical dimension for evaluating a JET. It places particular emphasis on examining energy distribution and its associated economic effects while also considering its externalities. The overarching objective is to comprehensively elucidate the constituent elements of distributive justice.

4.1 Distribution of energy resources and their economic benefits

The foremost challenge of distributive justice revolves around the allocation of resources and their associated benefits (García-Muros et al., 2022). Within the context of an energy transition, it is paramount to ensure equitable access to new energy opportunities for residents across different nations and regions, thus avoiding the concentration of new energy resources within specific geographical areas or socio-economic groups (Romero-Lankao et al., 2023). In response to this challenge, the International Energy Agency (IEA) has issued a set of 20 policies aimed at promoting international energy justice. These policies recommend enhanced collaboration among IEA member states and partner nations to ensure universal access to new energy sources. They encompass shared investments in energy infrastructure, such as grids and charging stations, as well as technology-sharing initiatives (IEA, 2018). The U.S. Department of Energy has developed policies focused on energy equity and environmental justice to improve the health, safety, and energy resilience of communities disproportionately affected by fossil fuels. These policies ensure access to clean energy for all Americans (ROOM, 2021).

Some scholars argue that it is essential to balance the objective economic impacts of the energy transition across different societal groups and regions. This includes ensuring a fair transition concerning employment structures resulting from the energy transition (Oswald et al., 2020). An investigation into job creation during the decarbonization process of the U.S. electricity industry reveals that the reduction of carbon emissions generates employment opportunities. However, these opportunities are not uniformly distributed among various states, industrial sectors, and skill requirements (Muttitt and Gass, 2023). The unequal distribution of benefits within communities raises concerns, particularly in renewable energy projects. This phenomenon is frequently observed in hydropower projects in some developing countries, where local residents make significant sacrifices for project construction, including large-scale relocations, shifts in employment patterns, loss of land tenure security, and the need for rebuilding social networks. Regrettably, they do not share in the benefits of hydropower (McCauley and Heffron, 2018; Cernea, 2008).

These pertinent policies and research studies provide a compelling rationale for reassessing the aspects that need allocation within the framework of a JET. This reassessment extends beyond the equitable distribution of new energy resources and includes the allocation of economic benefits generated throughout the energy transition. Consequently, the paper incorporates the following elements into the dimension of distributive justice, namely, the fair allocation of new energy

resources and the equitable distribution of economic benefits derived from the energy transition process.

4.2 The mechanism for sharing the costs of energy use and energy transition

Energy transition inherently brings about shifts in production methods and lifestyles, entailing a redistribution of energy expenses and changes in industrial structures (Carley and Konisky, 2020). The imperative of justice in the context of energy costs within a JET is underscored by the necessity for the equitable allocation of costs and burdens incurred throughout the transition, ensuring that no specific social group bears an inequitable share of these burdens (Cantarero, 2020). However, ensuring the long-term economic resilience of marginalized groups in the face of the adoption of new energy sources remains a formidable challenge in practical energy transitions. Research examining the clean energy transition in several Chinese provinces revealed that the utilization of clean energy imposes financial burdens on rural inhabitants and low-income urban households. In the absence of sustained policy support and subsidies, residents tend to curtail their utilization of new energy sources, exacerbating the issue of energy poverty (Wang et al., 2023).

Regarding employment, the repercussions of energy transition on traditional energy sectors are profound. Research conducted by the Global Energy Monitor indicates that the global coal industry may need to reduce its workforce by nearly one million jobs by 2050. This reduction is primarily attributed to the anticipated closure of hundreds of labor-intensive mines over the coming decades, coupled with the global shift toward substituting coal with cleaner, low-carbon energy sources (Reuters, 2023). Scholars have emphasized the importance of considering the sunk costs incurred by workers in the energy sector during the transition. The initial benefits of employment in the new energy sector may be comparatively lower than those in the traditional industry, necessitating investments in new technologies and equipment upgrades. Consequently, when governmental subsidies fall short in the initial stages, employees from traditional energy sectors may find it challenging to transition into roles within the emerging new energy sector (Martinot et al., 2002).

Research based on data drawn from over 130 million online job resumes revealed that less than 1% of workers who exited the traditional energy sector managed to transition into “green” jobs between 2005 and 2021. The majority of these workers was compelled to seek alternative employment or faced unemployment (Curtis et al., 2023). This data underscores the critical need for comprehensive support systems and retraining programs to facilitate a smoother transition for workers affected by the energy shift.

Hence, taking into account the external benefits that result from energy distribution, such as changes in production and lifestyle, the paper integrates the following elements into the dimension of distributive justice, specifically the allocation of costs related to adopting new energy sources and the allocation of costs linked to the energy transition process.

5 Redistributive justice principle: redistributive justice

In connection with the principle of distributive justice, redistributive justice diverges in its specific focus, centering on the reassignment of preexisting resources. Its primary concern lies in mitigating societal inequalities through the implementation of policies such as taxation and social welfare (Barry, 2004). This concept holds a pivotal position in political philosophy and social policy, intricately linked to dialogues surrounding social equity and economic disparity (Bower, 2022). By reallocating resources, redistributive justice aims to address the root causes of inequality, ensuring a more balanced and fair distribution of wealth and opportunities within society. It emphasizes the role of governmental intervention in correcting imbalances that arise from market dynamics, thus fostering a more just and equitable social order.

Within the context of a JET, the discourse on redistributive justice is conspicuously scarce. This scarcity can be attributed to the fact that redistribution necessitates a more expansive consideration, encompassing both a longitudinal temporal aspect and a lateral spatial aspect. The longitudinal aspect entails the equitable distribution of energy resources and associated benefits across generations, while the spatial aspect involves grappling with the equitable allocation of energy resources among different regions, be they nations or states. Both intergenerational energy equity and regional energy equity constitute forms of reallocation within the existing energy distribution framework. Consequently, the paper undertakes an exploration of these two critical aspects, namely, intergenerational justice and regional equity, within the purview of redistributive justice.

5.1 Inter-generational justice redistributive

From a temporal perspective, the concept of redistribution encompasses intergenerational equity. Intergenerational equity pertains to the aspiration for justice and equality across distinct generations, finding application in various domains, including environmental preservation, economic policies, social welfare, and resource allocation. At its core, it underscores the imperative of ensuring that the decisions and actions of the present generation do not detrimentally impact the interests and rights of future generations (Page, 2007; Pellegrini-Masini et al., 2020). Within the context of an energy transition, a pertinent focus revolves around the current consumption of renewable energy and the capacity of renewable energy infrastructure, such as photovoltaic systems, wind turbines, and hydropower facilities, to sustain the development of succeeding generations. This necessitates a more in-depth examination of renewable energy development rates and the feasibility of long-term sustainability.

Furthermore, the extended temporal horizon of an energy transition can facilitate economic and social advancement, encompassing facets like education, healthcare, and employment. Nonetheless, this trajectory entails a protracted process during which different generations contribute to and make sacrifices to varying extents. Within the realm of environmental justice discourse, it is a prevailing notion among scholars that the

preceding generation bears a moral obligation to compensate for the environmental degradation resulting from their actions, acting as custodians of future generations' interests. However, in the context of energy justice, this conventional perspective undergoes a reversal. This is because the preceding generation is confronted with the responsibility of shouldering supplementary costs related to energy utilization and the transition process, as elaborated in Section 4.2 of the paper. Consequently, the question of whether descendants, who stand to reap the benefits of societal, economic, and environmental advancements, should also assume additional burdens to uphold intergenerational justice remains a topic ripe for scholarly discourse and examination.

Maintaining an equitable balance between the contributions and outcomes of different generations is essential within the framework of intergenerational equity. Building on the exploration, the paper identifies key elements of the redistributive justice, namely, the rates of resource development and consumption, as well as intergenerational economic and social responsibility.

5.2 Inter-regional justice redistributive

From a spatial perspective, the concept of redistribution delves into the realm of spatial justice, wherein the principles of social justice are expected to manifest within geographical spaces or spatial environments (Soja, 2009). This concept posits that spatial design and planning, encompassing urban planning, regional development, and land-use policies, should equitably account for the needs and rights of diverse societal groups. It aims to ensure that everyone has equal access to and utilization of spatial resources (Soja, 2013). In the discourse surrounding energy spatial justice, particular attention is directed towards examining the influence of geopolitical and economic factors on the JET among nations. Geopolitical sensitivities often hinder countries from relinquishing control over their energy policies to global institutions, resulting in weaknesses and underdevelopment in global and regional energy governance structures (Meckling, 2019).

Especially in the contemporary fragmented global political landscape, Western countries are rapidly disengaging from China, thereby obstructing progress in various facets of energy technology and regulatory standards. This disengagement not only impacts bilateral relations but also has broader implications for global energy cooperation and technological advancement. However, it is crucial to acknowledge that the environmental effects stemming from the new energy transitions of neighboring countries can also contribute to enhancing the overall regional environment. Consequently, the challenge of dismantling technological barriers and ensuring the dissemination of new energy technologies in today's intricate political environment warrants further consideration. This necessitates collaborative efforts and innovative policy frameworks to facilitate the equitable distribution of energy benefits and technologies across geopolitical boundaries.

The economic impact on spatial justice primarily emanates from disparate interests among societal groups. At the international level, the interests of global elites often diverge from the energy needs and environmental vulnerabilities of the world's poorest populations, resulting in a lack of motivation to advocate for global energy justice. Domestically, energy injustices are shaped by a myriad of actors, institutions, and interest groups whose actions hold sway over domestic energy supply, consumption, and the obstacles and conditions pertaining to energy access (Bouzarovski and Simcock, 2017). Consequently, an increasing number of energy scholars and international organizations are calling for the sharing of benefits and economic cooperation within the context of new energy transitions. From the aforesaid, it is clear that geopolitical and economic factors play a crucial role in shaping energy spatial justice. This consideration brings attention to the following spatial elements when evaluating redistributive justice, namely, the allocation of energy technologies and economic development cooperation.

6 Assessment system for JET

In accordance with principles of equity, this study constructs a framework encompassing four dimensions for assessing the impact of a JET: cognitive justice, distributive justice, procedural justice, and redistributive justice. Drawing on existing research and real-world case studies, specific elements are delineated for each dimension, as depicted in Figure 1. This composite framework serves as the overarching structure for evaluating the ramifications of a JET. Within the paper, our objective is to furnish a comprehensive set of assessment criteria and accompanying explanations for each element. This endeavor seeks to provide academic institutions and energy stakeholders with meticulous evaluation guidelines, enhancing the granularity and rigor of the evaluation process.

6.1 The evaluation dimension of cognitive justice

Drawing on the principles of Adams' Equity Theory, this study meticulously develops a set of comprehensive indicators to measure cognitive justice, as presented in Table 1. Cognitive justice underscores the profound significance of cognitive awareness levels among key actors in the energy transition process, such as government, businesses, and energy consumers, i.e., the general public. It accentuates the need for governments and businesses to possess a comprehensive understanding of the cultural and social needs of marginalized groups. Similarly, it emphasizes the proactive involvement of the public in comprehending the adverse facets of energy transition and actively participating in initiatives aimed at rectifying them. Furthermore, it calls for the establishment of effective communication mechanisms rooted in mutual understanding.

While some scholars have categorized factors like "Participation and representativeness of energy community residents" and "Construction of communication and resolution mechanism" within procedural justice (Bal et al., 2023), the paper situates them under the cognitive justice dimension. This decision arises from the recognition that procedural justice primarily focuses on the normative aspects of procedures, which may not always yield ideal outcomes in practice. This limitation is inherently linked to the definition of procedural justice itself (Tyler and Allan Lind, 2001). In contrast, energy transition necessitates outcomes that are more

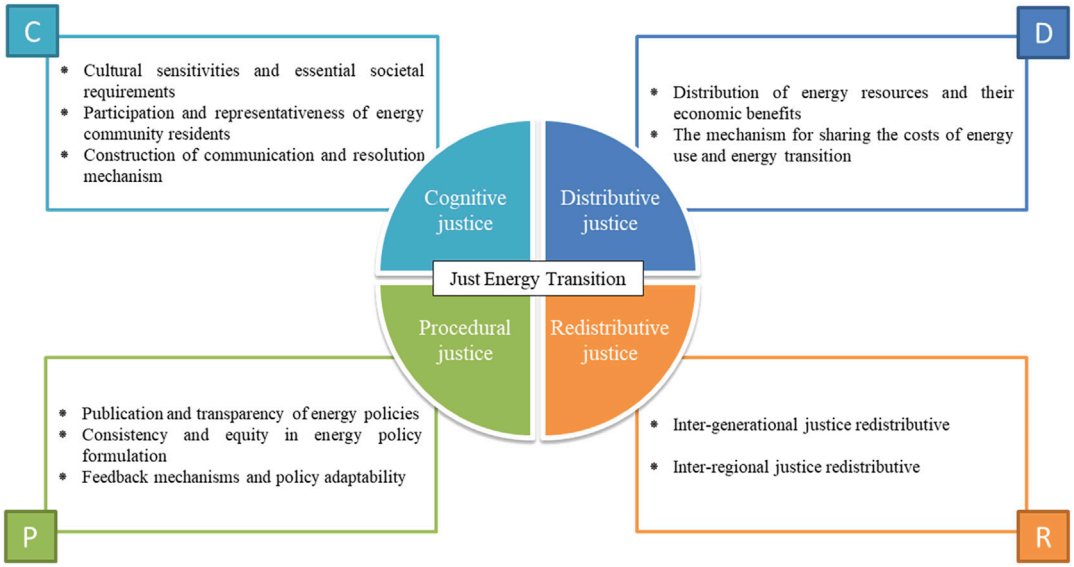

FIGURE 1
Impact assessment framework for JET.

TABLE 1 Assessment content of cognitive justice in JET.

	Factors	Elements	Indicators
Cognitive justice	Cultural sensitivities and essential societal requirements	The attempt to reduce cultural sensitivity	Consideration of diverse cultural backgrounds in the design of energy policies and projects. (Sarrica et al., 2016) The recognition and respect accorded to local knowledge and traditional practices. (Tiberio et al., 2020)
		The identification and fulfillment of essential societal requirements	The provision of compensation to communities affected by energy-related initiatives. (Zhang et al., 2022) Initiatives related to employment training and economic assistance for impacted communities. (Carley and Konisky, 2020)
	Participation and representativeness of energy community residents	Participation of energy community residents	The frequency and extent of participation by different societal groups in energy decision-making. (Hanke et al., 2021) The breadth of participation, which pertains to the diversity of groups involved, and the depth of participation, which concerns the quality and influence of their involvement. (Hanke and Guyet, 2023)
		Representation of energy community residents as decision-making members	The proportion of representation of marginalized groups within decision-making bodies or committees. (Hanke and Lowitzsch, 2020) The methods employed for selecting representative members and the effectiveness of their representation. (European Union: European Commission, 2019)
	Construction of communication and resolution mechanism	The systematic evaluation of communication effectiveness	Timeliness and transparency in the exchange of information. (Bal et al., 2023) Adaptation of language and communication approaches to accommodate various cultural and educational backgrounds. (Tiberio et al., 2020)
		The comprehensive assessment of problem-solving capacity	The presence of channels for expressing dissent and raising objections. (Global Subsidies Initiative, 2018) The ongoing monitoring and adjustment of the policy implementation process. (Kaschny and Lavrijssen, 2023)

substantive in nature, extending beyond mere procedural compliance. Consequently, incorporating these elements within the cognitive justice dimension serves to underscore the proactive role and positive agency of all stakeholders in fostering a JET.

The paper incorporates "Cultural sensitivities and essential societal requirements" into the cognitive justice dimension, recognizing them as pivotal assessment elements within cognitive justice. In prior energy transition endeavors, especially in the context

TABLE 2 Assessment content of procedural justice in JET.

Evaluative dimension	Factors	Elements	Indicators
Procedural Justice	Publication and Transparency of Energy Policies	Dissemination of Energy Policies	The frequency, timeliness, and accessibility of information dissemination. (Nunn, 2020) Clarity and comprehensibility of information. (Carley and Konisky, 2020)
		Transparency of Energy Policies	Transparency in the formulation and implementation of policies and procedures. (Mundaca et al., 2018) Implementation of public auditing and oversight mechanisms. (Global Subsidies Initiative, 2018)
	Consistency and equity in energy policy formulation	Harmonization of policy standards	Adherence to consistent standards and guidelines in decision-making. (Natorski and Solorio, 2023) Ensuring justice and impartiality in the decision-making process. (Sovacool and Dworkin)
		Legal and ethical underpinnings of policies	Compliance with domestic and international legal norms in decision-making. (Biswas et al., 2022) Ethical considerations throughout the decision-making process. (Outka, 2022)
	Feedback mechanisms and policy adaptability	The assessment of the effectiveness of feedback mechanisms	Mechanisms and processes for collecting and handling feedback. (Ruano-Chamorro et al., 2022) The extent to which feedback is taken into account during decision-making.(Meckling, 2019)
		The flexibility and adaptability inherent in energy policies	Responsiveness of the decision-making process to new information and changing circumstances. (Healy and Barry, 2017) Frequency and timeliness of decision adjustments.(Markard, 2018)

of large dam construction, decision-makers often overlooked the need for rebuilding the livelihood capital of affected populations, consequently trapping them in prolonged poverty and adversity (Zhang et al., 2022). Substantial improvements in this regard have been achieved with the support of institutions such as the World Bank. In subsequent large-scale hydroelectric projects, social impact assessments have become a requisite to prevent encroachment upon the culture of affected communities, ensure compensation for their livelihoods, and facilitate the reconstruction of their means of production (World Bank, 1996).

Therefore, viewed from the perspective of energy transition advocates, including governments and businesses, it is imperative to fully recognize and incorporate "Cultural sensitivities and essential societal requirements" into the impact assessment of a JET. This acknowledgment reflects their paramount importance in ensuring a comprehensive and just energy transition.

6.2 The evaluation dimension of procedural justice

Lacey-Barnacle et al. (2020) argue that restorative justice is part of procedural justice. However, we believe that restorative justice should instead be incorporated into the dimension of cognitive justice, particularly in relation to the element of "identifying and addressing fundamental social needs." As previously mentioned, restorative justice requires energy stakeholders to fundamentally recognize the severity of the disruption that new energy developments can cause to the livelihoods of indigenous communities. Its effectiveness is more dependent on the awareness and cognition of decision-makers and managers, rather than purely on procedural aspects. Therefore, we have not included elements of restorative justice under the dimension of procedural justice.

It is worth noting that certain elements in Table 2, such as "The flexibility and adaptability inherent in energy policies," may bear some resemblance to "The comprehensive assessment of problem-solving capacity" outlined in Table 1. Both sets of indicators emphasize the importance of information exchange and the ability to make adjustments in decision-making. However, the distinction lies in the emphasis placed on the willingness of stakeholders to engage in proactive communication and problem-solving within the cognitive justice framework, while procedural review focuses more on the mechanics of the decision-making process itself.

6.3 The evaluation dimension of distributive justice

Table 3 displays the indicators used for evaluating distributive justice within the context of energy transition. These indicators offer

TABLE 3 Assessment content of distributive justice in JET.

Evaluative dimension	Factors	Elements	Indicators
Distributive Justice	Distribution of energy resources and their economic benefits	The equitable allocation of new energy resources	Accessibility of Renewable Energy Technologies across Demographic Groups (Romero-Lankao et al., 2023) Equity in the Geographical Distribution of Energy Infrastructure (IEA, 2018)
		The equitable distribution of economic benefits stemming from the energy transition process	Socioeconomic Group Disparities in Employment Opportunities within the New Energy Industry (McCauley and Heffron, 2018) Community-Level Distribution of Economic Gains from Renewable Energy Projects (Berka, 2018)
	The mechanism for sharing the costs of energy use and energy transition	Mechanisms for sharing the cost of energy use	Government Subsidization for Low-Income Households Utilizing New Energy Sources (Wang et al., 2023) Mechanisms of Price Fluctuation for Low-Income Households Utilizing New Energy Sources (Bird and Hernández, 2012)
		Mechanisms for sharing the cost of energy transition	Effects of Energy Transition on Professionals in Diverse Energy Sectors (Reuters, 2023) Government Policies and Support Allocation across Diverse Energy Sectors (Geng and Cui, 2020)

TABLE 4 Assessment content of redistributive justice in JET.

Evaluative dimension	Factors	Elements	Indicators
Redistributive justice	Inter-generational justice redistributive	Rates of resource development and consumption	Assessing the Impact of Current Energy Consumption on Resource Availability for Future Generations (Pellegrini-Masini et al., 2020) The Rate and Sustainability of Renewable Energy Development (Wang and Zhan, 2019)
		Inter-generational economic and social responsibility	Examining the Long-Term Benefits of Energy Transition on Education, Health, and Employment (Carley and Konisky, 2020) Inter-generational Allocation of Social Welfare and Social Responsibility
	Inter-regional justice redistributive	Allocation of energy technologies	The Transfer and Dissemination of New Energy Technology and Knowledge Across Different Regions (Meckling, 2019) The Application and Diffusion of New Energy Technologies in Diverse Regional Contexts (Neij et al., 2017)
		Economic development cooperation	Economic Cooperation in the Transformation of New Energy Systems (Blondeel et al., 2021) Benefit Sharing in Geopolitically Driven Economic Development Effects (Bouzarovski & Simcock,2017)

a comprehensive assessment of the justice pertaining to the distribution of energy resources, considering the associated externalities. These externalities encompass a spectrum of impacts, ranging from economic consequences to changes in production processes and everyday lifestyles. It is generally consistent with existing research paradigms.

6.4 The evaluation dimension of redistributive justice

The assessment of redistributive justice in this article takes into account two crucial factors: intergenerational justice and interregional justice, as delineated in Table 4. These factors scrutinize whether, within the existing energy distribution framework, nations and their future generations can achieve a JET through the process of redistribution (Manderscheid, 2011).

Within the realm of intergenerational justice, the paper places significant emphasis on the sustainability of new energy allocation and utilization across successive generations, alongside the redistribution of the ensuing economic and socio-developmental benefits. An intriguing concept introduced within the discussion of "Intergenerational economic and social responsibility" posits that the next generations benefiting from societal, economic, and environmental progress should shoulder an added responsibility to uphold intergenerational justice. This concept, which has received scant attention in prior literature, suggests a reciprocal duty for future generations to maintain the balance of justice across time. While this notion appears plausible, its practical evaluation necessitates a more robust theoretical framework.

The assessment of interregional justice may appear reminiscent of distributive justice regarding the "distribution of energy resources and their economic benefits." However, the distinctive feature of interregional justice assessment lies in its emphasis on dismantling

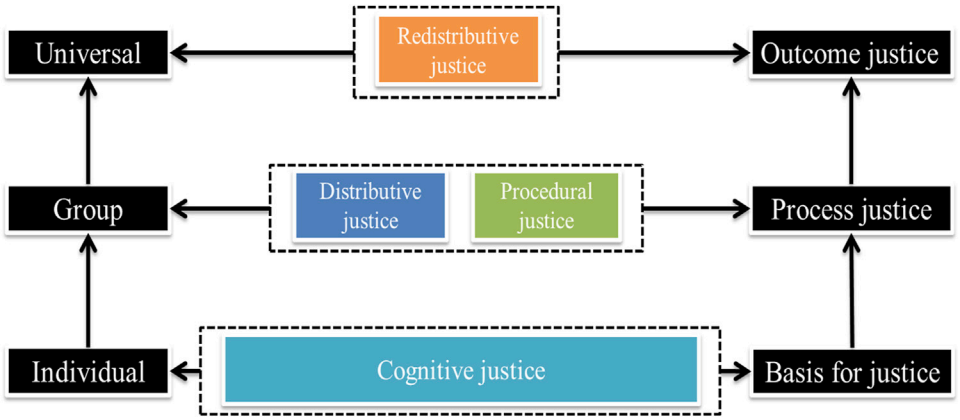

FIGURE 2
Logical relationships between dimensions.

technological barriers at the international level and actively promoting new energy technologies. It underscores the paramount importance of long-term global cooperation grounded in geopolitical and economic relations. Conversely, distributive justice focuses more acutely on the short-term allocation of energy resources and their economic dividends among disparate groups and communities within relatively confined geographical regions.

7 The logical relationship between the assessment dimensions of JET

Incorporating Adams' equity theory as a foundational concept, this paper introduces cognitive justice into the assessment framework for Just Energy Transition (JET), addressing a critical gap in prior research. While existing analyses of distributive and procedural justice provide a solid foundation, this study also brings in a fresh dimension: redistributive justice. Together, these four dimensions—cognitive, distributive, procedural, and redistributive justice—form a comprehensive and coherent framework for evaluating the fairness and overall impact of a JET, as illustrated in Figure 2.

Cognitive Justice is positioned as the foundational element of JET, emphasizing the role of stakeholder awareness and understanding in achieving fairness. Unlike other dimensions, cognitive justice requires stakeholders to actively engage with the diverse interests involved in energy transitions, facilitating inclusive dialogue and negotiation processes. Adams' equity theory posits that perceptions of justice are shaped through social comparisons, interactions, and negotiations, relying heavily on the cognitive capabilities of those involved (Cropanzano et al., 2020; Jasso, 2020). Thus, cognitive justice operates at the individual level, serving as a prerequisite for realizing a just and equitable energy transition.

Distributive and Procedural Justice are integral components of process justice and ensure fairness in both the allocation of resources and the processes governing such allocations. Distributive justice focuses on the equitable sharing of energy benefits, ensuring that both new and existing energy resources are fairly distributed across different social groups and regions. Procedural justice, on the other hand, ensures that decision-making processes are transparent, consistent, and inclusive, fostering trust and legitimacy among stakeholders (Schlosberg, 2019; Tyler and Allan Lind, 2002). These two dimensions work together to maintain fairness throughout the transition process and reduce the risk of reinforcing existing inequalities.

Redistributive Justice extends the analysis by incorporating intergenerational and interregional dimensions of justice. This perspective focuses on ensuring long-term fairness in energy distribution, taking into account the equitable distribution of resources across different generations and regions. Redistributive justice addresses the need to correct historical imbalances in access to energy resources and technologies, particularly in regions that have been disproportionately affected by climate change or energy scarcity (Sovacool et al., 2020; Heffron and McCauley, 2020). By ensuring fairness over time and space, redistributive justice represents the ultimate goal of a JET, where all stakeholders—both present and future—have equitable access to energy.

This conceptual framework highlights the interconnectedness of the four justice dimensions Cognitive justice serves as the foundation, shaping the perception and understanding necessary for implementing distributive and procedural justice. Redistributive justice, in turn, ensures that these efforts are sustained over generations and across regions, creating a truly just and inclusive energy transition.

8 Conclusion

This paper presents a comprehensive impact assessment framework for Just Energy Transition (JET) grounded in the principles of justice. The framework encompasses four critical dimensions: cognitive justice, distributive justice, procedural justice, and redistributive justice. Instead of replacing existing JET assessment models, this framework is designed to complement them, enhancing clarity in the evaluation of justice

dimensions. By providing detailed interpretations of key elements and indicators within each dimension, the framework helps to differentiate between superficially similar concepts, offering a more nuanced understanding of energy justice. Additionally, the inclusion of a logical framework clarifies the target groups and stages of the transition process relevant to each justice dimension, representing a novel contribution to the field.

A key innovation of the framework is the introduction of cognitive justice as a foundational dimension. Grounded in Adams' equity theory, cognitive justice is seen as the basis for addressing other dimensions—distributive, procedural, and redistributive justice. This perspective emphasizes the critical role of stakeholder awareness and understanding in the energy transition process, particularly for governmental bodies, corporations, and the general public. Encouraging active participation from all stakeholders in decision-making processes is essential for fostering a more transparent and inclusive framework for negotiation and communication.

Another significant contribution of the paper is its exploration of intergenerational justice within the impact assessment framework. The study raises the important question of whether future generations, as beneficiaries of improved environmental conditions and economic growth, should bear part of the burden for ensuring intergenerational justice. This issue, while briefly touched upon, deserves deeper investigation in future research, particularly in determining the ethical and practical implications of burden-sharing between current and future generations.

The framework also emphasizes "inter-regional redistributive justice," promoting cooperation between regions and nations to achieve global energy justice. While the paper acknowledges that this goal may seem aspirational—akin to the mathematical concept of an asymptote that can be approached but never fully reached—it argues that setting ambitious standards can elevate the baseline for human society. Achieving even incremental progress toward inter-regional justice can have meaningful impacts on reducing global energy inequality.

Based on the analysis in this paper, further research can consider the following questions:

- Refining Cognitive Justice Metrics: Further research is needed to develop standardized metrics for assessing cognitive justice, particularly how stakeholder understanding can be measured and improved across different energy transition contexts. This will require cross-disciplinary collaboration between political scientists, energy policy experts, and cognitive scientists to establish practical and implementable indicators.
- Exploring Intergenerational Justice in Depth: The concept of intergenerational justice deserves more attention, particularly in terms of how future generations could be involved in energy transition policies. Researchers could explore frameworks for including long-term sustainability considerations in present-day policy decisions, balancing the benefits and burdens across generations.
- Operationalizing Inter-Regional Justice: Scholars should investigate ways to operationalize inter-regional redistributive justice, exploring how cooperative frameworks between nations can be fostered to support less-developed regions in the energy transition. Case studies of successful international energy partnerships could provide valuable insights into how equitable resource distribution might be achieved on a global scale.

Integrating Justice Frameworks in Policy Development: Future studies should explore how the justice dimensions outlined in this framework can be more effectively integrated into real-world energy policy development. This may include testing the framework in specific JET projects, evaluating its practical utility, and providing guidelines for policymakers.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Author contributions

CS: Writing–review and editing, Data curation, Formal Analysis, Investigation, Resources, Writing–original draft. ZS: Writing–review and editing, Conceptualization, Supervision. WS: Supervision, Validation, Writing–review and editing.

Funding

The author(s) declare that financial support was received for the research, authorship, and/or publication of this article. Open Fund Project of Key Research Base of Humanities and Social Sciences in Hubei Province Universities, Research Center for Reservoir Resettlement (2022KFJJ04) and Shanghai Pujiang Program (2019PJC039).

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

References

Abraham, J. (2017). Just transitions for the miners: labor environmentalism in the Ruhr and Appalachian coalfields. *New Political Sci.* 39 (2), 218–240. doi:10.1080/07393148.2017.1301313

Axon, S., and Morrissey, J. (2020). Just energy transitions? Social inequities, vulnerabilities and unintended consequences. *Build. Cities* 1 (1), 393–411. doi:10.5334/bc.14

Bal, M., Stok, M., Bombaerts, G., Huijts, N., Schneider, P., Spahn, A., et al. (2023). A fairway to fairness: toward a richer conceptualization of fairness perceptions for just energy transitions. *Energy Res. and Soc. Sci.* 103, 103213. doi:10.1016/j.erss.2023.103213

Barry, D. (2004). Increasing renewable energy accessibility in Ireland, in *Proceedings of the 19th World Energy Congress*, 1–10.

Bergsmo, M., Rodriguez-Garavito, C., Kalmanovitz, P., and Saffon, M. P. (2010). *Distributive justice in transitions* (Torkel Opsahl Academic EPublisher), 6.

Berka, A. L., and Creamer, E. (2018). Taking stock of the local impacts of community owned renewable energy: a review and research agenda. *Renewable and Sustainable Energy Reviews* 82, 3400–3419.

Bird, S., and Hernández, D. (2012). Policy options for the split incentive: increasing energy efficiency for low-income renters. *Energy policy* 48, 506–514. doi:10.1016/j.enpol.2012.05.053

Biswas, S., Echevarria, A., Irshad, N., Rivera-Matos, Y., Richter, J., Chhetri, N., et al. (2022). Ending the energy-poverty nexus: an ethical imperative for just transitions. *Sci. Eng. ethics* 28 (4), 36. doi:10.1007/s11948-022-00383-4

Blazquez, J., Fuentes, R., and Manzano, B. (2020). On some economic principles of the energy transition. *Energy Policy* 147, 111807. doi:10.1016/j.enpol.2020.111807

Blondeel, M., Bradshaw, M. J., Bridge, G., and Kuzemko, C. (2021). The geopolitics of energy system transformation: a review. *Geogr. Compass* 15 (7), e12580. doi:10.1111/gec3.12580

Bouzarovski, S., and Simcock, N. (2017). Spatializing energy justice. *Energy Policy* 107, 640–648. doi:10.1016/j.enpol.2017.03.064

Bower, E. Z., Hiebert, M., Pumphrey, D. L., Poling, G. B., and Walton, M. A. (2012). *Sustainable Energy Futures in Southeast Asia*. Center for Strategic and International Studies (CSIS).

Brock, A., Sovacool, B. K., and Hook, A. (2021). Volatile photovoltaics: green industrialization, sacrifice zones, and the political ecology of solar energy in Germany. *Ann. Am. Assoc. Geogr.* 111 (6), 1–23. doi:10.1080/24694452.2020.1856638

Cantarero, M. M. V. (2020). Of renewable energy, energy democracy, and sustainable development: a roadmap to accelerate the energy transition in developing countries. *Energy Res. and Soc. Sci.* 70, 101716. doi:10.1016/j.erss.2020.101716

Carley, S., and Konisky, D. M. (2020). The justice and equity implications of the clean energy transition. *Nat. Energy* 5 (8), 569–577. doi:10.1038/s41560-020-0641-6

Cernea, M. M. (2008). Compensation and benefit sharing: why resettlement policies and practices must be reformed. *Water Sci. Eng.* 1 (1), 89–120. doi:10.1016/s1674-2370(15)30021-1

Cha, J. M., Wander, M., and Pastor, M. (2020). Environmental justice, just transition, and a low-carbon future for California. *Envtl. L. Rep.* 50, 10216.

Chen, H., Jang, S. G., Zhang, Y., and Liu, Y. (2024). Clean energy for all? Mapping inequity potential in the clean energy transition in the United States. *Energy Res. and Soc. Sci.* 108, 103400. doi:10.1016/j.erss.2023.103400

Cropanzano, R., Bowen, D. E., and Gilliland, S. W. (2020). The management of organizational justice. *Acad. Manag. Perspect.* 34 (3), 34–48. doi:10.5465/amp.2007.27895338

Curtis, E. M., O'Kane, L., and Park, R. J. (2023). Workers and the green-energy transition: evidence from 300 million job transitions (No. w31539). *Environmental and Energy Policy and the Economy* 5 (1), 127–161.

European Union: European Commission (2019). *The European green deal—communication from the commissionto the European parliament, the European council, the council, the European economic and SocialCommittee and the committee of the regions*. COM. Available at: https://ec.europa.eu/info/sites/info/files/european-green-deal-communication_en.pdf (accessed on March 12, 2020).

Gallo, A. B., Simões-Moreira, J. R., Costa, H. K. M., Santos, M. M., and Dos Santos, E. M. (2016). Energy storage in the energy transition context: a technology review. *Renew. Sustain. energy Rev.* 65, 800–822. doi:10.1016/j.rser.2016.07.028

García-Muros, X., Morris, J., and Paltsev, S. (2022). Toward a just energy transition: a distributional analysis of low-carbon policies in the USA. *Energy Econ.* 105, 105769. doi:10.1016/j.eneco.2021.105769

Geng, C., and Cui, Z. (2020). Analysis of spatial heterogeneity and driving factors of capital allocation efficiency in energy conservation and environmental protection industry under environmental regulation. *Energy Policy* 137, 111081. doi:10.1016/j.enpol.2019.111081

Global Subsidies Initiative (2018). *Real people, real change strategies for just energy transitions*. International Institute for Sustainable Development. Available at: https://www.iisd.org/sites/default/files/publications/real-people-change-strategies-just-energy-transitions.pdf.

Greenberg, J., and Colquitt, J. A. (2021). *Handbook of organizational justice*. New York: Psychology Press.

Hamilton, M., and Hamilton, M. (2021). "The benefits and limitations of restorative justice conferencing," in *Environmental crime and restorative justice: justice as meaningful involvement*, 157–180.

Hanke, F., and Guyet, R. (2023). The struggle of energy communities to enhance energy justice: insights from 113 German cases. *Energy, Sustain. Soc.* 13 (1), 16. doi:10.1186/s13705-023-00388-2

Hanke, F., Guyet, R., and Feenstra, M. (2021). Do renewable energy communities deliver energy justice? Exploring insights from 71 European cases. *Energy Res. and Soc. Sci.* 80, 102244. doi:10.1016/j.erss.2021.102244

Hanke, F., and Lowitzsch, J. (2020). Empowering vulnerable consumers to join renewable energy communities—towards an inclusive design of the clean energy package. *Energies* 13 (7), 1615. doi:10.3390/en13071615

Healy, N., and Barry, J. (2017). Politicizing energy justice and energy system transitions: fossil fuel divestment and a "just transition". *Energy policy* 108, 451–459. doi:10.1016/j.enpol.2017.06.014

Heffron, R. J., and McCauley, D. (2020). The concept of energy justice across the disciplines. *Energy Policy* 105, 658–667. doi:10.1016/j.enpol.2017.03.018

Hoicka, C. E., Lowitzsch, J., Brisbois, M. C., Kumar, A., and Camargo, L. R. (2021). Implementing a just renewable energy transition: policy advice for transposing the new European rules for renewable energy communities. *Energy Policy* 156, 112435. doi:10.1016/j.enpol.2021.112435

IEA (2018). *20 renewable energy policy recommendations*. Paris: IEA. Available at: https://www.iea.org/reports/20-renewable-energy-policy-recommendations.

Jasso, G. (2020). Justice and equity: cognitive perspectives. *Soc. Sci. Res.* 91, 102487. doi:10.1016/j.ssresearch.2020.102487

Jones, A., Brown, P., Green, D., and Shahbaz, M. (2021). Technological innovations in energy transition: a review of current advancements. *Energy Policy* 149, 112007. doi:10.1016/j.enpol.2020.112007

Kaschny, L., and Lavrijssen, S. (2023). The independence of national regulatory authorities and the European Union energy transition. *Int. and Comp. Law Q.* 72 (3), 715–736. doi:10.1017/s0020589323000271

Kashour, M. (2023). A step towards a just transition in the EU: conclusions of a regression-based energy inequality decomposition. *Energy Policy* 183, 113816. doi:10.1016/j.enpol.2023.113816

Lacey-Barnacle, M., Robison, R., and Foulds, C. (2020). Energy justice in the developing world: a review of theoretical frameworks, key research themes and policy implications. *Energy Sustain. Dev.* 55, 122–138. doi:10.1016/j.esd.2020.01.010

Lappe-Osthege, T., and Andreas, J. J. (2017). Energy justice and the legacy of conflict: assessing the Kosovo C thermal power plant project. *Energy Policy* 107, 600–606. doi:10.1016/j.enpol.2017.03.006

Lei, L., Liu, J., and Zhou, X. (2023). Addressing carbon inequity: examining factors driving the path to just transition. *Environ. Impact Assess. Rev.* 103, 107280. doi:10.1016/j.eiar.2023.107280

Lennon, B., Dunphy, N. P., and Sanvicente, E. (2019). Community acceptability and the energy transition: a citizens' perspective. *Energy, Sustain. Soc.* 9 (1), 35–18. doi:10.1186/s13705-019-0218-z

MacPartlin, B., and Darcy, C. (2007). "Theories of procedural justice and criteria for fairness judgements," in *IIRA HRM study group working papers in human resource management*.

Majekolagbe, A. G. (2022). Towards a just transition impact assessment framework (doctoral dissertation).

Manderscheid, K. (2011). Planning sustainability: intergenerational and intragenerational justice in spatial planning strategies. *Antipode* 44(1), 197–216. doi:10.1111/j.1467-8330.2011.00854.x

Markard, J. (2018). The next phase of the energy transition and its implications for research and policy. *Nat. Energy* 3 (8), 628–633. doi:10.1038/s41560-018-0171-7

Martinot, E., Chaurey, A., Lew, D., Moreira, J. R., and Wamukonya, N. (2002). Renewable energy markets in developing countries. *Annu. Rev. energy Environ.* 27 (1), 309–348. doi:10.1146/annurev.energy.27.122001.083444

McCauley, D., and Heffron, R. (2018). Just transition: integrating climate, energy and environmental justice. *Energy policy* 119, 1–7. doi:10.1016/j.enpol.2018.04.014

McLaughlin, J. (2020). The role of recognition in addressing historical injustice. *J. Soc. Justice Stud.* 45 (2), 123–140.

Meckling, J. (2019). Governing renewables: policy feedback in a global energy transition. *Environ. Plan. C Polit. Space* 37 (2), 317–338. doi:10.1177/2399654418777765

Miller, D. (2017). "Distributive justice: what the people think," in *Distributive justice* (London: Routledge), 135–173.

Montañés, C. C., O'Shaughnessy, E., Bednar, D., Nock, D., Carley, S., Kammen, D. M., et al. (2023). Enabling and centering equity and justice in clean energy transition research. *Joule* 7 (3), 437–441. doi:10.1016/j.joule.2023.02.005

Mundaca, L., Busch, H., and Schwer, S. (2018). Successful'low-carbon energy transitions at the community level? An energy justice perspective. *Appl. Energy* 218, 292–303. doi:10.1016/j.apenergy.2018.02.146

Muttitt, G., and Gass, P. (2023). How energy transition affects jobs. *Nat. Clim. Change* 13, 1162–1163. doi:10.1038/s41558-023-01830-1

Natorski, M., and Solorio, I. (2023). Policy failures and energy transitions: the regulatory bricolage for the promotion of renewable energy in Mexico and Chile. *npj Clim. Action* 2 (1), 8. doi:10.1038/s44168-023-00039-4

Neij, L., Heiskanen, E., and Strupeit, L. (2017). The deployment of new energy technologies and the need for local learning. *Energy Policy* 101, 274–283. doi:10.1016/j.enpol.2016.11.029

Nunn, G. A. (2020). Law, fact, and procedural justice. *Emory lj.* 70, 1273.

Østergaard, P. A., Duic, N., Noorollahi, Y., and Kalogirou, S. A. (2021). Recent advances in renewable energy technology for the energy transition. *Renew. Energy* 179, 877–884. doi:10.1016/j.renene.2021.07.111

Oswald, Y., Owen, A., and Steinberger, J. K. (2020). Large inequality in international and intranational energy footprints between income groups and across consumption categories. *Nat. Energy* 5 (3), 231–239. doi:10.1038/s41560-020-0579-8

Outka, U. (2022). "Ethical drivers for the renewable energy transition," in *Research handbook on energy, law and ethics* (Cheltenham: Edward Elgar Publishing), 266–279.

Page, E. A. (2007). Intergenerational justice of what: welfare, resources or capabilities? *Environ. Polit.* 16 (3), 453–469. doi:10.1080/09644010701251698

Pellegrini-Masini, G., Pirni, A., Maran, S., and Klöckner, C. A. (2020). Delivering a timely and just energy transition: which policy research priorities? *Environ. Policy Gov.* 30 (6), 293–305. doi:10.1002/eet.1892

Popescu, C., Panait, M., Palazzo, M., and Siano, A. (2022). "Energy transition in European union—challenges and opportunities. In *Energy Transition. Industrial Ecology*. Editors S. A. R. Khan, M. Panait, L. Puime Guillen, and L. Raimi (Singapore: Springer). doi:10.1007/978-981-19-3540-4_11

Qi, X., Sun, L., Hu, Z., Li, E., and Ning, Z. (2023). An applied framework to assess sustainability awareness and corporate misconduct considering just transition. *Environ. Impact Assess. Rev.* 103, 107261. doi:10.1016/j.eiar.2023.107261

Reuters (2023). Coal industry faces 1 million job losses from global energy transition - research. Available at: https://www.reuters.com/markets/coal-industry-faces-1-million-job-losses-global-energy-transition-research-2023-10-10/.

Romero-Lankao, P., Rosner, N., Brandtner, C., Rea, C., Mejia-Montero, A., Pilo, F., et al. (2023). A framework to centre justice in energy transition innovations. *Nat. Energy* 8 (11), 1192–1198. doi:10.1038/s41560-023-01351-3

Room, B. (2021). Executive order on advancing racial equity and support for underserved communities through the federal government.

Ruano-Chamorro, C., Gurney, G. G., and Cinner, J. E. (2022). Advancing procedural justice in conservation. *Conserv. Lett.* 15 (3), e12861. doi:10.1111/conl.12861

Sarrica, M., Brondi, S., Cottone, P., and Mazzara, B. M. (2016). One, no one, one hundred thousand energy transitions in Europe: The quest for a cultural approach. *Energy Research & Social Science* 13, 1–14.

Schlosberg, D. (2019). Reconceiving environmental justice: global movements and political theories. *Environ. Polit.* 28 (2), 253–273. doi:10.1080/09644016.2019.1573841

Siciliano, G., Wallbott, L., Urban, F., Dang, A. N., and Lederer, M. (2021). Low-carbon energy, sustainable development, and justice: towards a just energy transition for the society and the environment. *Sustain. Dev.* 29 (6), 1049–1061. doi:10.1002/sd.2193

Sinha, A., Bekiros, S., Hussain, N., Nguyen, D. K., and Khan, S. A. (2023). How social imbalance and governance quality shape policy directives for energy transition in the OECD countries? *Energy Econ.* 120, 106642. doi:10.1016/j.eneco.2023.106642

Soja, E. (2009). The city and spatial justice. *Justice spatiale/Spatial justice* 1 (1), 1–5.

Soja, E. W. (2013). *Seeking spatial justice*, 16. London: U of Minnesota Press.

Sovacool, B. K., Brugger, H., Brunzema, I., Dańkowska, A., Wemyss, D., Vernay, A. L., et al. (2023). Social innovation supports inclusive and accelerated energy transitions with appropriate governance. *Commun. Earth and Environ.* 4 (1), 289. doi:10.1038/s43247-023-00952-w

Sovacool, B. K., Burke, M., Baker, L., Kotikalapudi, C. K., and Wlokas, H. (2020). Decarbonization and its discontents: a critical energy justice perspective on four low-carbon transitions. *Clim. Change* 155 (4), 581–619.

Sovacool, B. K., and Dworkin, M. H. (2015). Energy justice: conceptual insights and practical applications. *Appl. energy* 142, 435–444. doi:10.1016/j.apenergy.2015.01.002

Speed, J. (2020). "Restorative justice: emergence, institutionalization, and critiques. Peace," in *Justice and strong institutions*, 1–13.

Tiberio, L., De Gregorio, E., Biresselioglu, M. E., Demir, M. H., Panno, A., and Carrus, G. (2020). Psychological processes and institutional actors in the sustainable energy transition: a case-study analysis of a local community in Italy. *Frontiers in Psychology* 11, 980.

Tyler, T. R., and Allan Lind, E. (2002). Procedural justice and the courts. In *Handbook of Justice Research in Law*, 65–92. doi:10.1007/0-306-47379-8_3

Tyler, T. R., and Allan Lind, E. (2001) "Procedural justice," in *Handbook of justice research in law*, 65–92.

Wang, Q., Fan, J., Kwan, M. P., Zhou, K., Shen, G., Li, N., et al. (2023). Examining energy inequality under the rapid residential energy transition in China through household surveys. *Nat. Energy* 8 (3), 251–263. doi:10.1038/s41560-023-01193-z

Wang, Q., and Zhan, L. (2019). Assessing the sustainability of renewable energy: an empirical analysis of selected 18 European countries. *Sci. Total Environ.* 692, 529–545. doi:10.1016/j.scitotenv.2019.07.170

Wang, X., and Lo, K. (2021). Just transition: a conceptual review. *Energy Res. and Soc. Sci.* 82, 102291. doi:10.1016/j.erss.2021.102291

Welton, S., Biasutti, M., and Gerrard, M. B. (2015). Legal and scientific integrity in advancing a land degradation neutral world. *Colum. J. Envtl. L.* 40, 39.

World Bank (1996). "Resettlement and development," in *The Bankwide review of projects involving involuntary resettlement 1986-1993*. Environment department papers. Paper no. 032.

Zhang, R., Owen, J. R., Kemp, D., and Shi, G. (2022). An applied framework for assessing the relative deprivation of dam-affected communities. *Sustain. Dev.* 30 (1), 176–190. doi:10.1002/sd.2237