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Energy transition and social justice: Examining the impact of renewable energy supply chain

Tommi Lehtonen and Shah Rukh Shakeel

1. Introduction

The current global polycrisis, including climate change, biodiversity loss, and various types of social inequality, requires behavioural changes from individuals, communities, nations, and corporations. Moving from fossil fuels, including oil, coal, and natural gas, to renewable energy sources, such as solar power, wind, and hydro, is one of the most important steps to counteract biodiversity loss and climate change.

The 2023 United Nations Climate Conference in Dubai reached an agreement to shift away from fossil fuels—a particularly significant decision as it represented the first time a global climate conference resolution has included such a transition. This sends a strong signal to investors, who will now have a more difficult time justifying investments in the fossil economy. As expressed in the 2015 Paris Climate Agreement and confirmed in the Dubai resolution, the ultimate goal is to achieve zero global emissions by 2050 while limiting global warming to 1.5 degrees Celsius above pre-industrial levels by the end of the century.

While there are valid concerns about funding for low-carbon technology to meet global climate targets, many experts believe that the most difficult problem will be managing the energy transition in a way that does not exacerbate socioeconomic inequities (Sun et al. 2023). Millions of people have been pulled out of poverty by earlier industrial transformations, but these changes have also had the consequence of solidifying the position of power and wealth of the ruling class. There is a high risk that vulnerable populations may be left behind as countries transition to cleaner energy sources.

The transition from centralised energy systems to decentralised, renewable-based sustainable energy systems is a complex and multifaceted process influenced by various factors, including technology, resources, supportive policy regimes, and changes in consumption patterns (Balachandra et al. 2010; Droege et al. 2010; Papaefthymiou and Dragoon 2016; Shakeel et al. 2017; Hrnčić et al. 2021). While the development of renewable energy technologies (RET) is critical for a smooth transition, the mechanisms used across the RET supply chain have a significant impact on delivering justice.

To date, the scholarly discussion on energy transition has primarily focused on technological advancements and their integration into global energy systems. Renewable energy and efficient energy storage technologies are viewed as critical to decreasing reliance on traditional hydrocarbons as energy sources (Balachandra et al. 2010; Ould Amrouche et al. 2016; Papaefthymiou and Dragoon 2016; Shakeel 2019; IRENA 2023). The economic and legal frameworks needed to facilitate the just transition and its possible consequences on emissions, the environment, and energy access and affordability have also received attention (Sovacool and Dworkin 2015; Jenkins et al. 2016; García-García et al. 2020; Lacey-Barnacle 2020; Jenkins et al. 2021; Malerba 2022).

However, the role of the supply chain in technology development processes has received little attention. Exploring renewable energy development through a life cycle perspective reveals implications for social justice that extend beyond technology adoption. Strengthening justice within the renewable energy supply chain is crucial for ensuring that the transition benefits all stakeholders equitably rather than only those directly benefiting from technology application. This holistic approach ensures a consistent commitment to addressing the interests and concerns of all actors and communities through the energy supply chain.

Several examples illustrate how injustices in the renewable energy development process have led to inequities and broader social harm. For example, lithium mining operations in Salar de Uyuni, Bolivia, highlight significant energy justice issues. Lithium, a critical mineral for energy storage and the development of renewable energy technologies is essential to the global energy transition. However, its extraction has caused several environmental damages, including water depletion that affects local agriculture and drinking supplies. Moreover, ongoing conflicts between local communities and national authorities over revenue distribution, coupled with issues related to transparency and fairness, have exacerbated tensions (Sagárnaga 2015; Sanchez-Lopez 2021; Radwin 2024). Similarly, manufacturing renewable energy technologies, such as solar panels, in countries with lower labour costs perpetuate serious injustices, exposing workers to poor working conditions, low wages, and minimal labour rights (E+ELeader: For a Sustainable Future 2024).

Addressing these issues within the renewable energy sector can help mitigate social disparities, prevent unfair practices, and facilitate a fair transition by implementing inclusive measures, distributing resources fairly, and ensuring transparency and fairness throughout the supply chain. This will ensure that the shift to renewable energy is not only ecologically but also socially sustainable.

This book chapter explores how integrating social justice during the renewable energy supply chain can facilitate a just transition from conventional to sustainable energy systems based on renewables. The findings of this study provide valuable theoretical insights into social justice issues influencing the development of renewable energy technologies. On a practical level, the chapter offers actionable guidelines for companies and policymakers to align RET development with the principles of social justice.

To achieve this, we will identify and discuss significant social justice concerns raised by the energy transition, drawing on conceptual analyses and a comprehensive review of the literature. Recent reports and guidelines from major international agencies, such as the European Union (EU), the United Nations (UN), and the International Labour Organisation (ILO), along with real-life examples, provide particularly useful information about the social and economic challenges associated with the energy transition.

This book chapter is structured as follows: In the next section, we present a brief outline of the energy transition and discuss its historical context. Following that, through the concept of sufficiency, we explore the relationship between social justice and environmental sustainability—together, they form the theoretical lens through which we examine the existing literature on energy transition. In connection with this, we also present the ‘doughnut economics’ model and discuss a range of issues and challenges related to energy transition, such as energy poverty. Different ethical models are employed to provide a comprehensive analysis of these issues. We then delve into the concept of energy justice and its implications for the energy sector. Next, we examine energy justice challenges across the renewable energy supply chain, highlighting their significance for a just transition through various cases. Finally, based on these insights, we offer recommendations for policymakers on ensuring justice in energy transition by incorporating a supply chain perspective.

2. Basics of energy transition

As an important prelude to discussing energy justice, we will now briefly describe the key elements and starting points of the energy transition. Many readers are already familiar with the core aspects of the energy transition but will find it useful to revisit a few of them as an introduction to energy justice.

An energy transition is, by definition, a change in the energy sources required to meet global energy demand (Valkhof 2020). Using fossil fuels accelerates global warming and endangers biodiversity.

This drives the energy transition. The transition's goal is to protect the environment and climate from the harmful impacts of human activities.

The energy transition has many facets. First, it means a gradual move away from fossil fuel-based production and consumption. We are transitioning from oil, coal, and natural gas to green energy sources such as bioenergy, wind, solar, and hydropower. The energy transition also includes regulating energy, electricity storage, and demand response. Regulating energy refers to the part of production needed in electricity generation in addition to baseload power, which is utilised when demand for electricity exceeds baseload power generation capacity. Demand response refers to matching electricity demand to electricity availability, which means limiting electricity use and shifting it from hours of high consumption and prices to more favourable times. The energy transition also includes the shift from centralised to more decentralised generation and the electrification of transport and industry. Energy transition can also refer to efficiency gains and the use of industrial byproducts such as processing waste or surplus materials. This ties the circular economy and the energy transition together.

Many nations are already shifting to low-carbon energy sources, driven by economic or health concerns and bolstered by climate change legislation (United Nations 2021). However, governments, corporations, employees, and communities all tend to 'hasten slowly' and keep carbon-intensive industries alive for employment and economic reasons, as well as for a variety of social reasons.

The energy transition entails transforming energy production as well as accelerating the implementation of low- or zero-carbon technology in industry, transportation, agriculture, and households, to name a few sectors. Early engagement in a just energy transition in all sectors and by various stakeholders, such as investors, employees, and residents, can reduce negative repercussions while increasing positive outcomes. Therefore, the 2015 Paris Climate Agreement highlights just transition as a key principle. The Paris Agreement defines just transition as a vision and a dialogue-based process rather than a defined set of rules. Accordingly, it is a shared agenda among workers, industry, and governments that must be negotiated and implemented within their various geographical, political, cultural, and social settings. For the energy transition to be fair, it must adhere to a set of ethical and social norms, such as the International Labour Organisation's Just Transition Guidelines (ILO 2015).

Historically, the world has undergone several transitions, including automation and the collapse or relocation of entire industries, resulting in job losses and economic misery. People are concerned that future transitions will be equally difficult. The present energy transition represents the fourth major shift in energy sources (Valkhof 2020). First, coal replaced wood as a biofuel (1830–1950). The

second energy transition (1950–1980) developed and used refined oil products. The third transition (1980–2020) increased natural gas use. As examples of the fourth or current energy transition, wind and solar power have recently exceeded fossil natural gas in energy generation in Europe for the first time (European Commission 2023). Electric vehicle sales have also increased significantly (IEA 2023a).

Sustainability considerations, the most important of which is the need to combat climate change, drive the current energy transition. The past transitions were mostly driven by a desire for economic growth, which is closely linked with energy availability and consumption. In the current energy transition, affordability and access to renewable energy technologies are critical issues that ensure that the transition benefits all members of society.

3. Social justice

Social justice is the idea that everyone should be treated fairly, no matter their race, gender, sexual orientation, disability, or social class (Whaples et al. 2023). Today, some of the most important problems in social justice are economic inequality, racial injustice, gender injustice, disability injustice, and environmental injustice. Economic inequality and environmental injustice are the most pressing social justice issues surrounding the energy transition. However, a shortage of fairly priced green energy may reveal unique challenges related to race, gender, and disability that require consideration.

Many, if not all, countries have widening gaps between the rich and the poor (Blanchet and Martínez-Toledano 2023). People of low-income communities are frequently disproportionately impacted by environmental pollution and climate change (Morello-Frosch and Obasogie 2023). Women and girls have historically been denied similar rights and opportunities as men, and they face discrimination in employment, education, and politics, as well as potentially limited access to energy resources and new technology (Nations 2014; Shang Baoping 2022). Poverty, crime, and violence disproportionately affect people of colour, and they face discrimination in the workplace, housing market, and educational system (Pager and Shepherd 2008). All of these facets of social injustice must be considered in planning and implementing the energy transition.

A major ethical issue in social justice is whether wealth, such as energy resources, should be distributed as evenly as possible or whether it is sufficient that everyone's basic needs are addressed. Accordingly, there are two extremes to social justice: an equality concept and a sufficiency perspective. As a result, the concept of social justice can be refined and characterised in different ways. This conceptual issue needs to be clarified since it affects the entire subject of social justice.

3.1 Sufficiency

Recent discussions in sustainability studies have emphasised the idea of sufficiency, a concept that resonates with our research on energy justice as it addresses both social justice and environmental concerns (Princen 2003; Salleh 2009; Kanschik 2016; Bonnedahl and Heikkurinen 2019; Lehtonen and Heikkurinen 2022). More precisely, sufficiency relates to energy justice by tackling the problem of just and adequate renewable energy availability while also highlighting the potential risks associated with excessive and unnecessary energy use.

Aside from these preliminary remarks, the concept of sufficiency must be examined in further depth. On the one hand, 'sufficiency' can refer to the state and characteristic of being adequate or having enough—not too much or too little. (Hartmann 2024). On the other hand, when a task or resource is sufficient, it indicates it is exactly right and proper. Thus, sufficiency, whether defined as a situation or a quality, represents the “golden mean” between not having enough and having too much, or between exaggerating and downplaying (Manno 2017).

Sufficiency also entails balancing, either in quantity or quality, and establishing what is required—for example, how much energy is required under given conditions. When something is either too little or too much, an imbalance results—for instance, between supply and demand for renewable energy. In their 2016 study, U-tantada et al. say that we can think of sufficiency in terms of traits like moderation, equity, and reasonableness. The sufficiency idea thus involves an ethical element by nature (U-tantada et al. 2016).

In terms of sustainability, sufficiency typically refers to limits of production and consumption that, when surpassed, make the use of human-made resources (such as money, tools, equipment, and buildings) as well as natural resources (such as land, water, minerals, plants, and animals) unfair, harmful, or excessive (Princen 2003). Raworth's (2017) 'doughnut economics', a popular example of the limits model, asserts the existence of a lower limit, the social foundation, below which no one should fall, and an upper ecological limit that one should not cross. Accordingly, the essence of doughnut economics consists of two major boundaries: a social foundation of wellbeing that no one should fall below and an ecological ceiling of planetary pressure that we must not exceed. Between the two is a safe and equitable area for all.

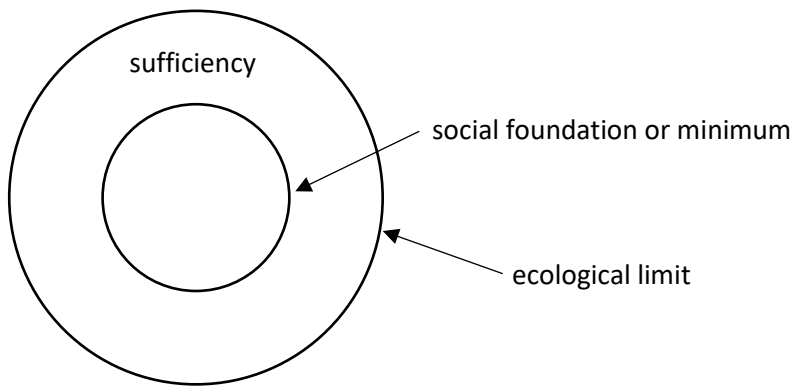


Figure 1: Doughnut economics can be represented by two concentric rings: a social foundation (or minimum sufficiency) to ensure that no one goes without the necessities of life, and an ecological ceiling to ensure that humanity does not collectively exceed the planetary boundaries.

The doughnut economics, then, teaches us that we must weigh everyone's desire for additional resources against everyone else's needs and available resources. Furthermore, a just allocation of resources must adhere to the ecological limit of sustainability.

When all these requirements are considered, significant dimensions of energy justice seem to include at least the following:

- 1) Energy availability or the sufficiency of energy supply
- 2) Affordability of energy
- 3) Availability of affordable green energy (non-fossil)

When these three dimensions of energy justice are examined through the lens of the doughnut economy, we may identify thresholds below which there is insufficient energy and above which the usage of energy exceeds the ecological safety threshold—that is, the planetary boundaries.

When sufficiency is considered as a moral principle, there is the issue of the equal division of energy across all three dimensions. Most, if not all, societies have the energy necessary to meet everyone's demands, but some people cannot afford it. In addition, some can afford green energy, while others must rely on fossil fuels and environmentally unfriendly technology such as fuel-intensive internal combustion engines. A related issue is that sufficiency varies depending on the subject and situation, meaning that one person's subjective or objective assessment of a sufficient energy supply may differ from another's under different circumstances.

3.2 Energy poverty

If we want to live in a just world, we must decide whether we should divide energy resources as evenly as possible or simply meet everyone's fundamental needs. When the bare minimum of energy sufficiency is not achieved, energy poverty ensues. Fuel poverty is a related concept to consider.

The phrase “fuel poverty” was first used in the UK more than 25 years ago to describe families whose energy bills take up more than 10% of their income (Hinson and Bolton 2023). Since then, many countries have started using the words “fuel poverty” and “energy poverty” to characterise homes that, for a variety of reasons, do not have access to the energy services required to heat, cool, and power various electrical equipment. High energy prices and limited access to energy services often lead to energy poverty. For instance, inadequate infrastructure can impact a home's ability to maintain sufficient warmth.

Energy poverty has a wide range of consequences for people's quality of life. People who live in chilly, damp homes are more likely to get respiratory ailments. A constant cold at home has a negative impact on both physical and emotional health. When children can't find a warm place to do their homework, it also makes it harder for them to learn. Many people feel ashamed and embarrassed when they don't have enough money for energy. In the worst circumstances, this issue may even be fatal. Mitchell (2023) says that more than 4,000 people died in England and Wales in 2022 because their homes were too cold.

People who do not have enough money for energy must make tough housing and energy use decisions. Studies have indicated that daily decisions pertain primarily to turning on the radiators or heating a hot meal, washing clothes or taking a shower, heating the entire house, or only one or two rooms. Living under such circumstances forces individuals to keep track of multiple things at once, which can make them feel stressed all the time. Studies from other countries have also found that those who are already in an unequal socioeconomic position are more likely to experience energy poverty (Mitchell 2023).

3.3 Other justice-based concerns related to energy transition

So far, we have offered just a brief outline of the vast topic of energy transition, disregarding specific political and technological intricacies. Before proceeding, we will attempt to present a non-technical summary of the technological means of the energy transition, with a particular emphasis on the political actions required to put the means into use.

Surprisingly or not, governments around the world are currently heavily subsidising the fossil fuel industry despite the fact that renewable energy sources are often more expensive. This creates

conditions in which fossil fuel businesses profit from their operations while the general public endures the environmental and social costs. To make sure that costs and benefits are shared fairly, governments should phase out fossil fuel subsidies while supporting the research and deployment of renewable energy sources. This will assist in levelling the playing field and making renewable energy sources more competitive with fossil fuels. Another key aspect is that the transition to renewable energy sources may result in increasing energy prices, which would disproportionately impact low-income households (National Conference of State Legislatures (NCSL) 2022).

Various ethical and economic considerations are driving the development and implementation of new, affordable technology to address major environmental problems around the world. The World Economic Forum identified and classified relevant technical solutions in a 2020 briefing paper. The solutions are divided into three groups, as follows:

1. Increasing energy efficiency: Recent studies show that just 33 percent of the fundamental energy used is turned into useful energy; the remaining 67 percent is lost due to inefficiencies in transportation, heavy industry, electricity generation, and buildings. Energy efficiency is thus among the best ways to reach an inclusive, sustainable, reasonably priced, safe energy system. Some areas in energy use have seen significant improvement (e.g., personal vehicles and aviation), whereas others (e.g., buildings) require more work.
2. Developing low-carbon energy alternatives: Well-known examples include switching from internal combustion engines to electric cars, as well as from fossil fuels to renewable energy sources such as wind and solar. However, scalable alternatives for kerosene in aviation, bunker fuels in ships, and naphtha in chemical manufacturing are still being developed.
3. Reducing unavoidable emissions: Finally, technological, economic, political, or sociological concerns may prevent the use of alternative low-carbon energy sources or the improvement of energy efficiency. In these situations, we should use carbon capture, either through carbon storage technology or natural alternatives such as reforestation.

However, no technical solution alone will solve all of the challenges related to energy transition; energy justice and the unequal distribution of economic resources must also be considered. As part of this broader justice-based solution, the benefits of the energy transition, such as reduced pollution and lower energy costs, should be distributed equitably. Otherwise, some communities are at risk of bearing a disproportionate share of the costs, such as the environmental impacts of renewable energy technologies.

Specifically, switching to renewable energy sources may require significant infrastructure investments, which could be difficult to finance in low-income areas (Lennon et al. 2019). Furthermore, renewable energy solutions like solar panels and energy-efficient appliances must be affordable and easily accessible. If these technologies are not accessible to all income groups, there is a risk of creating an energy divide where wealthier individuals benefit more from the transition.

Among other justice-based issues concerning energy transition, the shift from fossil fuels to renewable energy sources may result in job displacement in coal mining and oil extraction, among other industries, which might significantly impact workers' livelihoods (Simon 2020). Concerns about social justice arise when workers in these businesses, who are generally from underprivileged communities, are not appropriately supported with retraining and transition schemes.

A strong concept of social justice requires that all communities, especially marginalised groups (be they women, disabled people, or ethnic minorities), participate in energy transition decision-making processes. In these processes, a lack of inclusion can lead to policies that do not address the unique needs and concerns of different people. Environmental concerns linked with energy production and extraction disproportionately affect specific populations, most of whom are low-income (Blanchet and Martínez-Toledano, 2023). Transitioning to cleaner energy sources should not perpetuate or exacerbate existing economic and environmental injustices.

Indigenous communities may face unique challenges in the energy transition, as their land and cultural practices may be directly affected by renewable energy projects or other forms of energy development. Ensuring respect for cultural rights and engaging in meaningful consultation with these communities is essential.

The benefits of the energy transition should not be concentrated in certain regions while others are left behind. The Global South countries may face challenges in adopting clean energy technologies due to financial constraints, and efforts should be made to support them in their transition. A holistic and inclusive approach to policymaking is necessary to address these social justice concerns, with a focus on ensuring a fair distribution of the benefits and burdens of the energy transition among all citizens. Therefore, it is crucial to ensure that the public has a say in how the transition is planned and implemented. This includes making sure that the public is involved, that the community has a say in planned projects, and that the decision-making process is transparent.

Furthermore, the energy transition cannot occur in just one country or region. It is a global challenge requiring worldwide cooperation. This entails addressing climate change on a global basis and ensuring an equal transition for all countries. The energy transition should not come at the expense of

environmental justice. This includes ensuring that the site of renewable energy projects does not harm the environment or local residents. It also means addressing the legacy of pollution and environmental damage caused by the fossil fuel industry.

Governments, civil society organisations, and the private sector all contribute to a socially just and equitable transition to renewable energy (Hafner and Tagliapietra 2020). It should be underlined that not only do financial resources differ among countries, but so do cultural and political ideas on social justice, complicating efforts to address inequities in the global energy transition. The debate over the intricate connection between ecological sustainability and socially equitable distribution illustrates this.

3.4 Ethical frameworks related to energy transition

The energy transition generates numerous ethical concerns and a need for policy recommendations. As stated, the use of fossil fuels contributes to climate change, which poses a significant threat to biodiversity. This is what drives the energy transition. As a result, the energy transition is meant to protect the climate and nature from damage caused by people. Several aspects of this endeavour are worthy of consideration from an ethical point of view. Let us give a few examples.

A key principle of deontological ethics is the idea that some actions are morally obligatory, regardless of the consequences. In the case of the energy transition, this framework would argue that governments, companies, and individuals have a moral duty to reduce greenhouse gas (GHG) emissions because it is intrinsically wrong to harm the environment and future generations, irrespective of the economic costs or benefits of such actions.

From the perspective of utilitarian or consequentialist ethics, the benefits of the energy transition are what makes it important. According to Jeremy Bentham (1970), the criterion for the rightness of an action is the benefit it produces. Therefore, the utility of an action's effects, rather than the decency of its aims, should ultimately define its goodness. Bentham saw human happiness as the ultimate utility. He came to the conclusion that the 'greatest happiness for the greatest number' is what we ought to strive for (Bentham 1977 : 393, 440n).

Bentham's utility principle could also be used to frame the energy transition: produce as much environmentally friendly energy as possible for as many people as possible. While this may sound attractive, there are problems with the utility principle as applied to the energy transition. The largest amount of environmentally friendly energy for the largest number of people may be a counterproductive goal. The resulting increase in consumption may be beyond the ecological carrying capacity of

the planet while potentially meeting the lower limit of Raworth's (2017) doughnut economy: the social minimum of meeting basic human needs.

The third classical model is virtue ethics, which is equally relevant to the energy transition. Virtue ethics focuses on developing character traits necessary for a life with ethical integrity. Thus, virtue ethics highlights the moral agent's character as a critical component of ethics rather than duties or outcomes. Virtue ethics holds that in order for people to develop positive character traits like moderation and fairness, they need to be raised and educated. In today's world, when nature's carrying capacity is under threat and the distribution of wellbeing among various individuals is jeopardised, moderation and fairness are especially important. Let's consider the CEO of a large energy company such as Exxon Oil, Chevron, or PetroChina. If the CEO adopts a virtue ethics perspective when making decisions about the energy transition, they would not solely prioritise profits or adhere to legally mandated standards. Rather, they would actively foster a sense of responsibility for a variety of stakeholders, such as the environment, future generations, local communities, and employees.

4. Navigating social justice in renewable energy systems: The role of the supply chain in a just transition

Renewable energy technologies (RETs) are pivotal in driving the transition towards clean and sustainable energy systems. Recent advancements in technology, improved efficiencies, reduced costs, and the potential for small-scale distributed energy generation have brought RETs to the forefront of energy transition (IEA 2023b; IRENA 2023). However, despite offering environmental, economic, and social benefits, widespread adoption of RETs faces significant challenges (Shakeel et al. 2017).

The manufacturing and integration of RETs require critical raw materials and minerals, without which their development would not be possible. These include silicon for solar panels, rare-earth minerals for wind turbines, and lithium, cobalt, and nickel for batteries and other RETs (Giurco et al. 2019; Sovacool et al. 2020). Ensuring an uninterrupted extraction and supply of these essential resources is essential for a continued development and application of RETs. Many of these minerals are located in remote areas and geographically concentrated in specific regions of the world, often far from where manufacturing takes place, which is a critical aspect of mineral extraction (Sovacool et al. 2020). This necessitates a robust and functional supply chain to transport these minerals to manufacturing locations, making the supply chain an essential element for RETs availability and affordability.

The RET supply chain encompasses several stages: raw material extraction, manufacturing, installation and deployment, operation and maintenance, and end-of-life handling. Mining operations perform the extraction, obtaining necessary resources that undergo refinement and processing for

technology development. Manufacturing is the process of producing components and assembling technologies. Installation and maintenance focus on the application of RETs and ensuring their ongoing functionality. The end-of-life handling process entails managing the disposal or recycling of components and systems that have reached their useful life. Each stage involves different actors and stakeholders, including policymakers, regulators, companies, local communities, and nongovernmental organisations, and presents unique challenges that influence aspects of justice.

Transitioning from a conventional to a renewables-based energy system necessitates addressing justice issues at each step to guarantee that the transition is just and equitable for all actors and stakeholders across the entire value chain. They must integrate justice considerations from the outset and not only address them at the final stage of applying renewable energy technologies. Neglecting justice implications during the extraction process means that efforts to address challenges and implement remedies will be inherently flawed, allowing early-stage injustices to persist throughout the life span of RETs.

Researchers have devised numerous frameworks and methodologies to investigate the extent to which justice aspects are considered in energy settings. Sovacool and Dworkin (2015) introduced a principle-based approach to energy justice, including availability, affordability, due process, transparency and accountability, sustainability, intergenerational equity, and responsibility. Subsequently, Sovacool et al. (2017) added resistance and intersectionality as additional justice principles. Availability ensures individuals and communities have reliable access to energy, while affordability emphasises fair pricing, especially for lower-income and vulnerable populations. Due process demands fair and equitable procedures, and transparency and accountability guarantee open systems that hold actors accountable for their actions. Sustainability encompasses environmental factors, while intergenerational equity safeguards the needs of future generations. Responsibility acknowledges the impact on individuals and communities, requiring actors to take responsibility for their actions. Resistance recognises individuals' and communities' rights to oppose projects with negative consequences, while intersectionality considers the overlap and intersections of various justice aspects. These principles collectively aim to foster an equitable and sustainable energy transition by acknowledging different impacts and considerations relevant to the decisions and actions (Tolonen et al. 2023).

Similarly, another influential framework in the study of energy justice is the tenet-based approach to justice, including distributive justice, procedural justice, and recognition justice (Jenkins et al. 2021). Scholars have widely adopted this framework, often referred to as the triumvirate of energy justice, to delve deeper into energy justice issues (McCauley et al. 2013). Distributive justice guarantees a fair distribution of benefits and costs from energy projects among the actors and stakeholders

(McCauley et al. 2019). Procedural justice emphasises inclusive and fair decision-making processes, particularly considering vulnerable and marginalised communities. It also underscores the importance of transparency in sharing information and the adoption of fair practices and procedures (Jenkins et al. 2016; Milchram et al. 2020). Recognition justice asserts that we should consider the needs and concerns of all actors and stakeholders and not ignore or under-represent any part of society (Schlosberg 2004). It also emphasises the importance of addressing historical and existing injustices. Siciliano et al. (2018) and McCauley and Heffron (2018) build on the framework and advocate for an additional dimension focused on restoration activities to rectify harm caused by energy activities. Restorative justice acknowledges the need to implement measures that prevent harm to society, the environment, or the ecosystem due to energy projects. This underscores the importance of a proactive approach to establishing restorative measures that mitigate environmental damage and address challenges resulting from the activities.

The following explores how justice issues manifest in the exploration phase of the renewable energy supply chain (Table 1).

4.1 Distributive justice

Distributive justice is critical in the mineral extraction process for RET development. Ensuring a fair distribution of benefits and costs arising from extraction activities establishes the foundation for fairness and equity throughout the process. Many of these essential minerals are found in remote areas far from urban centres, where people live in small, rural settlements. Large national or multinational corporations, prioritising profit-making and lacking local dynamics, often carry out complex extraction processes, requiring sophisticated technology and equipment.

As these companies aim to expand extraction and generate revenues, a significant portion of the profits often translates into financial gains for the companies, with very little returned to local communities and society. This disparity often leads to contention, as communities view these vital, depletable resources as potential means to improve their wellbeing and prosperity. While companies reap substantial profits, the extraction process frequently degrades the environment and disrupts local ecosystems, making daily life difficult for communities.

For instance, lithium extraction in the Atacama Desert in Chile has raised several distributive justice concerns (Liu and Agusdinata 2020; Jerez et al. 2021). The global increase in demand for electric batteries has driven the need for lithium extraction, making it a major economic activity in the region (Jerez et al. 2021). However, the lack of fair distribution of benefits to local communities, coupled with adverse environmental impacts such as depletion of local water resources and harm to agriculture

and traditional livelihoods, has sparked conflict and legal disputes (Babidge 2019; Jerez et al. 2021). Similarly, cobalt mining in the Democratic Republic of Congo (DRC) illustrates distributive justice issues. Local communities criticise the extraction process, noting that community members, miners, and the local ecosystem suffer health issues and environmental degradation without receiving adequate economic returns. Artisanal miners, including children, endure hazardous conditions without receiving their fair share, while the majority of the profits accrue to the companies conducting operations (Katz-Lavigne 2019; Sovacool 2019).

These examples of justice are not just limited to the global south countries or developing economies alone, rather, members and actors from the developed countries also suffer from similar injustices. The Voisey's bay Nickle mine in Canada highlights distributive justice concerns resulting from the mineral extraction. The mine, located on indigenous lands, had significant impacts on the local communities. The concerns of environmental degradation related to water and wildlife, negative impacts on traditional ways of living, and harmful long-term impacts on the surroundings have caused conflict among the locals and the parties involved in extraction processes (Gibson 2006). Similar concerns were raised at Talvivaara Nickle and Cobalt mine in Finland. The mine is home to nickel and cobalt used in various RETs and equipment. The leak of toxic metals into local waterways led to severe pollution in surrounding lakes and rivers. The contamination resulted in loss of fish stock, contaminated water supplies, and significant health issues. Residents registered reservations that they were inadequately compensated for the damage, have greatly suffered from the negative outcomes, while external parties and investors benefited from the economic yields resulting from the mining activities (Tiainen et al. 2014; Sairinen et al. 2017).

These disparities highlight the need for measures to ensure that the local community benefit from mineral extraction related activities through economic gains and improved living conditions. All key stakeholders should be involved in developing strategies and plans to improve the local ecosystem, broaden knowledge bases, and offer community members better job opportunities beyond labour-intensive tasks. When approached with a focus on equity, projects can contribute to the local community and wellbeing. The Reglan mine, Quebec, highlights positive initiatives undertaken to ensure the distribution of benefits to the local communities. An agreement was signed between the extraction company and a local community owned economic development company, Makivvik corporation, along with five Inuit partner corporations. The agreement emphasised environmental stewardship, local empowerment, and priority to local business corporations for procurement. The agreement also ensured profit-sharing arrangements and a commitment to provide 4.5 percent of operating profits once the mine has recouped initial capital investment. The accumulated funds were then distributed

to local communities (Reglan Mine 2021; ICMM 2022; SIFEE 2023). Measures of such nature improve the sense of equity and fairness in the distribution of benefits.

4.2 Procedural justice

The principles of inclusivity and fairness should guide decision-making processes concerning the extraction of mineral resources, as emphasised by procedural justice. A participatory and inclusive approach ensures that diverse perspectives are considered, thereby increasing the likelihood that the distribution of benefits and costs adheres to the principles of fairness. Decision-making bodies often include individuals and groups with greater knowledge, resourcefulness, and interest in the issues at hand (Gillard et al. 2017; Milchram et al. 2018). However, these decision-making bodies often overlook the concerns of vulnerable and marginalised communities due to their lack of representation. Bias in the process often results in outcomes that disproportionately affect vulnerable and marginalised groups.

For instance, mining in Inner Mongolia, China, illustrates significant procedural injustices. The decision-making processes that govern the mining projects have excluded local communities, including herders, from meaningful participation. Government officials and large corporations dominated these processes, undermining local population concerns regarding land use, protection, and community impacts. Such procedural injustices have led to the displacement of herders and the disruption of their traditional livelihood, fostering community resentment and distrust throughout the entire process. (Denyer 2015; Woodworth 2017).

This pattern of exclusion is also noticeable in other cases, such as the Philippines, where nickel mining highlights cases where local communities were sidelined in consultations and decision-making processes concerning mining activities. Mining interests often manipulated environmental impact assessments and community consultations, leading to environmental hazards like water pollution, deforestation, and detrimental impacts on the local ecosystem, which significantly affect communities' livelihoods. The neglect of procedural justice issues undermines genuine participatory engagement of local communities and their ability to have their voices and concerns heard, thereby diminishing fairness and transparency (Holden et al. 2011; Nem Singh and Camba 2016). Rare earth elements mining in Greenland also showcased several procedural justice issues. Limited public participation despite the project's significant environmental impacts, lack of transparency, worries concerning social impact assessment processes, and political interferences to proceed with the project despite serious environmental concerns highlight the case where process and procedures were influenced to gain favourable decisions (Bjørst 2016; Reuters 2021; Henriques and Böhm 2022).

Similarly, lithium extraction at Argentina's Salar de Olaroz project highlights concerns regarding procedural issues. Local communities repeatedly voiced concerns about deteriorating environmental conditions and negative impacts on agriculture and cultural practices. Despite their concerns, the decision-making processes did not fully integrate community input, raising concerns that the decisions favoured mining operations over the protection of local resources (Dorn 2021; Escosteguy et al. 2022; Díaz Paz et al. 2023). This raises issues of fairness and transparency in the process, leading to disputes.

On the contrary, companies' efforts to strengthen procedural aspects can smoothen development and ensure that the community benefits from extraction activities. For instance, efforts to enhance community engagement and increase local actors' participation at the Salobo copper mine in Brazil helped relieve the conflict. Vale, the mining company, initiated a close collaboration with indigenous groups to the mine's impacts on the local national forest, which is home to various Indigenous tribes and is an important element of the local ecosystem can be mitigated. A multistakeholder committee was also established to oversee the environmental and social impacts of the project. Additionally, measures were designed to increase transparency in decision-making processes, enabling affected communities to register their concerns and provide input on mining operations. These activities played a part in engaging local communities and ensuring that their cultural and environmental concerns were considered (Vale 2021; Vale 2022). However, a lot more is required to strengthen engagement and address community concerns (Saes et al. 2021).

4.3 Recognition justice

Recognising vulnerable and marginalised communities, as well as the impact of mining activities on their wellbeing, is a critical aspect of recognition justice. This is essential because, intentionally or unintentionally, ignoring certain groups of individuals, communities, and members of society means that their voices, concerns, and valuable contributions remain unheard. This sets the stage for future injustices and challenges to transparency and fairness.

For example, in the case of bauxite extraction in Guinea, a major producer of minerals used in several RETs, significant recognition justice issues arise. Local communities, reliant on agriculture and fishing, see their livelihood threatened by the environmental impact of the mining activities. Water contamination and degradation of the farmland severely impact their wellbeing (Camara et al. 2021). The lack of recognition of these local people and communities has contributed to the decision-making processes and activities that have led to serious consequences for the wellbeing of vulnerable and marginalised communities (Dibattista et al. 2023). This has fuelled conflicts and resentment towards

mining activities (Bolay 2014; Knierzinger 2018). A collaborative approach involving all key actors and stakeholders, establishing pathways for sustainable living and protection of the environment, is essential to address these challenges.

Similarly, Mozambique's graphite mining operations present several issues related to recognition and justice. Mining activities in Cabo Delgado province, one of the largest producers of graphite used in RETs, have displaced communities as their local lands and resources were taken over by companies for mining operations without proper consent and compensation mechanisms (Kirshner and Power 2015; Wiegink 2020). This has resulted in the loss of assets and sources of income for affected groups. The lack of attention to local issues has fostered discomfort and diminished trust in the actors and stakeholders, negatively impacting community confidence. Therefore, key stakeholders must acknowledge the concerns of vulnerable and marginalised communities and implement alternative strategies to sustain their livelihoods (Hilson et al. 2021). The mining operations should provide adequate compensation for their lands and vital resources.

For example, the Oyu Tolgoi mine in Magnolia illustrates measures undertaken by the development companies to address local communities' concerns about inadequate consultation and representation of the interests of local herders and the general public. The companies' operations faced resistance as the community felt they were not adequately recognised as stakeholders, and their concerns were unheard. This fuelled mistrust between the company, the government and the local communities regarding the operations. To address these challenges, efforts were made to ensure the inclusion of nomadic herders' concerns in the decision-making, recognising the importance of indigenous and traditional knowledge and cultural identity, as well as involving herders in consultation and negotiation about local resource management. This offered marginalised communities a platform to express their concerns and propose solutions (Tinto 2024). However, many called for more extensive measures and an in depth understanding of the local dynamics to improve the justice considerations (Oyu Tolgoi Watch 2012). The recognition of key actors and stakeholders in the decision-making processes and the impacts in terms of consequences can act as a foundation based on which a project's fairness can be determined.

4.4 Restorative justice

Because mining operations have significant environmental and social impacts, restorative justice is critical in mineral extraction. Extracting minerals often requires extensive use of water resources and can lead to adverse environmental consequences for the land, surrounding communities, and biodiversity. Several restorative justice issues have emerged in the case of nickel mining activities in

Norilsk, Russia. Decades of nickel mining have resulted in extensive environmental pollution and contamination of air and water sources (CBEES 2023). The heavy operations have also caused noise pollution and loss of property, significantly affecting the livelihood, health, and wellbeing of local indigenous communities. Addressing restorative justice issues is central to ensuring that companies and stakeholders commit to improving environmental conditions and restoring affected areas to their original state, both during and after mining (Yakovlev et al. 2008; Bellona 2023; Norisk Nickel 2023). This includes efforts such as water purification, reforestation, and biodiversity restoration. Furthermore, it is crucial for companies to consider and respect the local culture and values of indigenous communities. The Nenets and Sámi, indigenous communities of Norilsk, have strong ancestral ties to their lands. Their orientation and relationship with the land often differ significantly from individuals coming from urban settings. Therefore, all stakeholders must carefully consider these differences and ensure that restorative actions address these cultural factors to conduct restoration in a manner that meets the needs of local communities.

Similarly, tin mining in the Bangka-Belitung region of Indonesia has raised serious restorative justice challenges. Significant environmental damage, including coastal erosion, deforestation, loss of natural resources, and damage to coral reefs, has been a major concern. Furthermore, the loss of income from local finishing activities and agriculture has been a significant factor. To mitigate these effects, local NGOs, governmental agencies, and local stakeholders have collaborated on restoration efforts (Ibrahim et al. 2018; Rosyida et al. 2018; Darwance et al. 2023). These initiatives focus on repairing coastal damage, promoting sustainable fishing practices, and training local communities in sustainable fishing and agriculture. Such efforts not only help address past damages but also build resilience and foster a sustainable future for affected communities.

The Talvivaara mine restoration in Finland further showcases how restorative measures can minimise the effects of extraction activities. The environmental challenges in the form of water pollution and metal emissions, soil contamination, and disruption of the local ecosystem raised restorative justice issues. The mine restoration activities focused on wastewater management and treatment through the construction of own central water treatment plant and the creation of an area for passive water purification. Actions were also taken to ensure biodiversity conservation through the development of biodiversity offset areas, the introduction of native plant species, and the creation of artificial habitats for displaced wildlife (Förvaltningsdomstolen; TEM 2017; STUK 2024). These measures focused on restoring wildlife, natural ecosystem, water quality, and mitigating the environmental damage caused by the extractive operations.

In addition to corrective measures, adopting a proactive approach can significantly strengthen restorative justice. Rather than waiting for extractive activities to conclude before initiating the restoration process, it is essential to plan and implement restorative actions from the outset. This includes taking measures to prevent environmental and livelihood damage during the operations, establishing clear corrective actions, identifying responsible authorities in the event of accidents, and providing clear guidance on correction plans and remedies for the affected communities.

Table 1: Justice issues in renewable energy extraction processes

Justice Consideration	Manifestation in Renewable energy extraction processes
<i>Distributive justice</i> Equitable and fair distribution of benefits and costs among all actors and stakeholders	- Inequitable distribution of benefits between companies and stakeholders - Fairness, openness, and transparency about benefits, with financial incentives passed to local communities and stakeholders - Negative environmental externalities, such as contamination of water, land degradation and pollution - Loss of local biodiversity affecting livelihoods and economic activities of the residents - Inadequate compensation for damages and harms suffered - Limited employment and business opportunities for locals - Lack of development or underfinancing of local infrastructure support - Minimal or no contribution towards the local society from companies - Inadequate investment in community services, e.g. education and healthcare
<i>Procedural Justice</i> Access to and participation in decision making processes that guide activities with an emphasis on fairness and transparency	- Lack of transparency in permitting processes for extraction activities - Insufficient community engagement and consultation efforts - Bias in the engagement process, limiting participation to first movers who are typically more knowledgeable and resourceful, leading to flawed procedural outcomes - Exclusion of marginalised groups from decision making processes - Flawed application of regulations and policies - Manipulation of processes, laws, and practices to gain favourable outcomes - Inadequate practices for community feedback and a desire to overhaul processes based on recommendations - Limited public consultations or discussion before actual project implementation - Failure to involve local leaders and community representatives in planning processes
<i>Recognition Justice</i> Acknowledgement, participation and appreciation of stakeholders and actors, especially vulnerable, marginalised communities	- Lack of recognition for vulnerable, and marginalised communities - Ignorance of local customs and traditions - Overlooking the cultural significance of local lands and indigenous communities - Lack of recognition for locals' rights and failure to honour responsibilities towards them - Stereotyping or misrepresentation of local communities in project narratives - Neglect of traditional knowledge and their spiritual connection to local customs, traditions and land - Limited support for local cultural initiatives - Disregard for historical injustices faced by locals
<i>Restorative Justice</i> Repairing harm and reinstating the state to minimise damage caused by the establishment and operationalisation of the energy projects	- Unclear or weak grievance mechanisms for local residents - Limited reparations for communities impacted by operations - Commitment to environmental restoration and repairing harm caused by activities - Community led monitoring and evaluation of environmental impacts - Educational programs to build trust and understanding between stakeholders - Capacity building to prevent accidents, with clear compensation mechanisms and legal actions for responsible parties - Neglect of rehabilitation and improvement for local surroundings. - Failure to acknowledge past issues and undertake preventive actions to avoid future accidents - Active engagement of affected communities in designing restorative actions - Regular assessment of social impacts to inform ongoing project management

5. Policy recommendations for the energy transition

The examination of current publications has helped us to classify the social issues related to the energy transition into five main groups: rising energy prices, energy poverty, job displacement and unemployment due to the energy transition, unequal benefit distribution, and gender and ethnic injustices caused by the transition. This distinction reflects a risk- and problem-orientated approach to energy justice. However, when discussing justice in the energy transition, it is also essential to consider the various aspects of justice stated earlier, including distributive justice, procedural justice, recognition justice, and restorative justice. In response to various risks and problems, as well as different dimensions of justice, we can now propose the development and implementation of the following policy recommendations, which address critical challenges in the energy transition from various social justice standpoints. We frame the following recommendations as deontological orders and duties, but we can also justify them in terms of consequential ethics based on the anticipated environmental and societal benefits of their implementation. In each recommendation, we also specify, in square brackets, the dimension of justice that the recommendation in question particularly represents. For each recommendation, we provide a real-life example of a successful policy:

1. Governments across the board should phase out subsidies for fossil fuels while simultaneously promoting the development and use of renewable energy sources throughout the supply chain. [procedural justice]
Example: Canada, a major fossil fuel producer, has committed to phasing out inefficient fossil fuel subsidies by 2025 as part of its commitments under the G7 and G20 frameworks. In 2022, the Government of Canada started scaling back subsidies for oil and gas companies, especially those that support exploration and extraction activities (Government of Canada 2023).
2. All income groups must have access to clean energy technologies like solar panels and energy-efficient appliances. In this, the supply chain is critical and needs to be carefully considered. [distributive justice]
Example: In the United States, the Low-Income Home Energy Assistance (LIHEAP) Weatherization Assistance Program provides funding to help low-income households improve their home energy efficiency, reduce energy bills, and increase comfort. This includes installing energy-efficient appliances, insulating homes, and upgrading heating and cooling systems (Office of Community Services 2024).
3. Workers in industries like coal mining and oil extraction must be adequately supported with retraining and transition programmes. [restorative justice]

Example: Spain has committed to shutting down all coal mines and coal-fired power plants by 2030. To mitigate the impacts on workers and communities dependent on coal, the Government of Spain has developed a comprehensive Just Transition Strategy (World Resources Institute 2021).

4. Social justice requires that all communities have a say in the decision-making processes related to the energy transition. Ensuring respect for cultural rights and engaging in meaningful consultation with indigenous communities is essential. [procedural justice and recognition justice]

Example: In Canada, several provinces, including Ontario and British Columbia, have programmes that provide financial support and technical assistance to indigenous communities to develop and own renewable energy projects. For example, Ontario's Aboriginal Renewable Energy Fund helped indigenous communities participate in the development of solar and wind projects (Mongabay 2024).

5. The benefits of the energy transition, such as reduced pollution and lower energy costs, should be distributed equitably. Transitioning to cleaner energy sources should not perpetuate or exacerbate existing environmental injustices. [distributive justice]

Example: In South Africa, the Integrated National Electrification Program (INEP) initiative aims to provide universal access to electricity, with a focus on renewable energy. The Government of South Africa has been deploying solar home systems in rural areas that are not connected to the national grid, ensuring that low-income households have access to reliable and clean energy (Energypedia 2018).

6. It is important to assist the Global South countries with their energy transition. [distributive justice and recognition justice]

Example: The Green Climate Fund (GCF) is the world's largest dedicated climate finance fund, created under the United Nations Framework Convention on Climate Change (UNFCCC) to support developing countries in mitigating and adapting to climate change, including energy transitions (United Nations Climate Change 2024).

7. Governments, civil society, and businesses should all be involved in ensuring a socially just and equitable transition to renewable energy. [procedural justice and recognition justice]

Example: The Africa Clean Energy Corridor, led by the International Renewable Energy Agency (IRENA), involves partnerships between governments, civil society, and private businesses to scale up renewable energy development in East and Southern Africa. The initiative

focuses on ensuring affordable and reliable energy access while promoting job creation and social inclusion (IRENA 2022).

These recommendations extensively consider various aspects of justice. As a result, justice in the energy transition includes the realisation of the right to speak, the adoption of inclusive procedures, the rectification of historical injustices, and the fair distribution of costs and gains. These extensive policies require collaboration between different stakeholders. Furthermore, tailoring the recommendations should take various national and international settings into account. In summary, we must understand the recommendations inclusively and contextualise them.

6. Conclusion

We must transition to a low-carbon economy in order to mitigate the climate crisis, but we must also remember that this transition is not just about technology and economics; it is also about social change. We have seen that addressing a number of key issues is necessary to make the energy transition socially just. These considerations have been offered to assist academic researchers and practitioners, including policy planners and community developers, in integrating communality activities and the energy transition.

In terms of social justice, the biggest challenge in the energy transition is fairly distributing benefits and expenses to various groups of people across the renewable energy supply chain. The negative environmental impacts of energy production and consumption are often borne by marginalised communities, such as indigenous peoples and people of colour. Therefore, it is crucial to ensure that the public, understood broadly, has a say in how the transition is planned and implemented. This means ensuring that there is public participation in decision-making processes, that communities are consulted about proposed energy transition projects, and that there is transparency in the decision-making process.

As countries transition to cleaner energy sources, there is a risk that vulnerable populations may be left behind. The transition to renewable energy sources may result in higher energy prices, disproportionately affecting low-income households. Affordability and access to clean energy technologies are crucial to ensure that all members of society can benefit from the transition.

The transition to renewable energy sources typically requires major infrastructure investments across the supply chain, which may be difficult to finance in low-income areas. Furthermore, the transition to renewables may result in job losses in the fossil fuel industry, having a severe impact on workers'

livelihoods. This necessitates providing targeted support to help these groups access clean energy and ensure that they are not disproportionately affected by the transition.

The energy transition should not come at the expense of environmental justice. This means ensuring that the locations of renewable energy projects have no negative impact on the environment or local residents. It also means addressing the legacy of pollution and environmental damage caused by the fossil fuel industry.

Dealing with these challenges calls for a comprehensive approach considering the interests and concerns of all stakeholders, including low-income households, fossil fuel industry workers, and marginalised communities. Ensuring a socially just and equitable transition to renewable energy is a shared responsibility of governments, non-governmental organisations, and the corporate sector.

The energy transition cannot be a purely national or regional endeavour. It is a global challenge that requires international cooperation. This means tackling climate change on a global basis and ensuring that the transition is fair to all countries. The energy transition could benefit everyone by addressing these critical issues.

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