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Review

Renewable, ethical? Assessing the energy justice potential of renewable electricity

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Abstract: Energy justice is increasingly being used as a framework to conceptualize the impacts of energy decision making in more holistic ways and to consider the social implications in terms of existing ethical values. Similarly, renewable energy technologies are increasingly being promoted for their environmental and social benefits. However, little work has been done to systematically examine the extent to which, in what ways and in what contexts, renewable energy technologies can contribute to achieving energy justice. This paper assesses the potential of renewable electricity technologies to address energy justice in various global contexts via a systematic review of existing studies analyzed in terms of the principles and dimensions of energy justice. Based on publications including peer reviewed academic literature, books, and in some cases reports by government or international organizations, we assess renewable electricity technologies in both grid integrated and off-grid use contexts. We conduct our investigation through the rubric of the affirmative and prohibitive principles of energy justice and in terms of its temporal, geographic, socio-political, economic, and technological dimensions. Renewable electricity technology development has and continue to have different impacts in different social contexts, and by considering the different impacts explicitly across global contexts, including differences between rural and urban contexts, this paper contributes to identifying and understanding how, in what ways, and in what particular conditions and circumstances renewable electricity technologies may correspond with or work to promote energy justice.

Keywords: energy justice; renewable energy; intergenerational justice; energy poverty socioeconomic justice

1. Introduction

Whereas the global economy runs on oil, it is electricity that powers it. Electricity pervades the residential, commercial, and industrial sectors providing lighting, heating, and cooling services whilst ensuring that assembly lines are moving and metros deliver their passengers on time. As a source of energy, electricity can be easily used, accessed, and demand-adjusted [1]. Historically, hydrocarbon and nuclear resources, especially coal, were used in electricity production propelling the developed countries towards prosperity [2]. However, this prosperity came at the high environmental, social, and political costs associated with extraction, transportation, and combustion of fossil fuels [1]. Additionally, the intensive use has limited easy to access and economically competitive non-renewable fossil fuel reserves [2,3]. It is thus essential to look for alternatives to continue electricity production to meet future energy demands.

Whilst hydro has served as an affordable and reliable renewable source since the dawn of electrification, other renewable energy resources, solar and wind, in particular, have emerged as economically viable options to meet current and future energy needs with significantly lower environmental, social, and political impacts. Globally, investments in renewable resource-based electricity (RE) have been made at an unprecedented rate [4]. This has led to a momentous worldwide increase in the number of RE facilities and the overall capacity including 1064 gigawatts (GW) of hydropower, 433 GW of wind power, and 231 GW of solar power in 2015 [5]. The scale of RE operation required to significantly reduce societal dependence on fossil-fuel energy can be imagined as colossal [6,7,8].

The transition of electricity production from fossil fuel to non-fossil fuel energy sources is fundamentally changing how energy is produced around the world. The proliferation of new RE technologies not only alters supply chains and energy infrastructure – RE projects change social and political structures in the nations, regions, and communities in which they are implemented. Such new developments also open a floodgate of positive and negative externalities affecting people with the ills or benefits of RE projects. Thus, the impacts of RE externalities have been subject of research specifically to examine these effects. In some cases, new RE projects affect the connections people have with the place where they live [9–12], leading to societal acceptance [13,14], rejection [15], or other mixed responses towards RE projects [16]. These reactions can be based on actual or perceived injustices of the negative externalities resultant from RE development that can impact social life [17]. The burdens resulting from RE development may also be unequally distributed within societal groups, affecting different groups differently [18,19]. Apart from the impact of the socio-physical realities of new RE developments, other issues may also arise related to the capability of RE in mitigating energy poverty from access and affordability constraints [20,21,22].

In order to envisage the emergent RE sector as an integral part of a sustainable future, it is critical to avoid and if not possible, minimize negative externalities that give rise to injustices associated with energy development while transitioning to a low-carbon future. Therefore, at the current juncture when traditional ways of producing energy are increasingly being replaced by new RE, there is a need to take stock of the interlinkages among RE and energy justice. Recent scholarship tends to highlight the energy justice potential of renewable sources (for example, [17,19,23,24,25]). Also, there is a line of scholarship targeting qualitative assessment and effective measurement tools for energy-related injustices (mainly fossil fuel and nuclear) [1,26,27]. However, there is perhaps no existing work where an energy-justice related framework is used to assess the justice and injustice potential of RE projects.

A sustainable energy future calls for energy systems to be guided by principles of justice. This requires the inclusion of justice goals in RE planning and development and necessitates understanding how RE projects can adhere to principles of energy justice. Given this development, the goal of this paper is to assess existing research to find out to what extent the literature on RE development worldwide addresses energy justice considerations. We use the energy justice assessment framework proposed by Sovacool et al. [1]. In this work, the scholars use the framework to mainly discuss energy justice related to fossil fuels and nuclear energy. We use this framework to assess the energy justice of RE development, identifying dimensions of energy justice in RE development discussed in current literature, noting the tradeoffs and challenges ensuring energy justice and pointing out the future research needs.

This paper focuses specifically on electricity generation technologies based on the three leading forms of RE worldwide, according to recent data, i.e. wind, solar, and hydro [5]. We selected these three forms of renewable resources given their global scope of operation. Further, wind, water, and solar technologies can be scaled up or down to address electricity demands without substantial changes in technologies or to operationalizing its use. Additionally, wind, solar hydro, and hydro resources can potentially provide energy to the transportation sector with required technological and infrastructural development. We conduct our review via systematic appraisal of existing original research analyzed in terms of the dimensions and principles of energy justice. In the following sections, we first introduce the conceptual framework regarding energy justice used in our analysis. Then, taking note of RE development in both highly centralized electrically and electrically dispersed contexts, we review the literature and analyze it in terms of geographic, temporal, technological, economic, and sociopolitical dimensions and based on the affirmative and prohibitive principles of energy justice.

2. The Analytical Framework

Justice is a highly contested concept with diverse meanings. One definition of energy justice is “a global energy system that fairly disseminates both the benefits and costs of energy services, and one that has representative and impartial decision-making” ([27], p. 436). In the fair dissemination of benefits and costs, future generations should also be represented so that they do not bear the burdens resulting from current energy consumption [28]. However, when considering low-carbon energy transition, researchers have recognized energy poverty, fuel poverty, energy insecurity, energy deprivation, and other problems of associated with lack of access and affordability of energy [29,30]. Therefore, energy justice should also be defined to consider that all people need energy to meet necessities and thus should be able to access and afford energy. McCauley et al. [31] summarizes these aspects in their work proposing energy justice should be based on three central tenets: distributive justice (where ills and benefits are justly distributed), procedural justice (where procedures equitably allow the participation of all stakeholders), and recognition justice (inclusion of the needs of the energy poor, the people opposing power plants in their communities etc. in decision making).

Energy justice is an emerging field of study, and there are many ways in which energy justice is being theorized (notably [31,32,33]). However, what lacks in most of this work is how we can use the tenets and put them in practice to evaluate research emerging on RE developments. In their work, Sovacool et al. [1] developed a framework to highlight how current and future development of energy systems (relying on traditional sources) have a tendency to interfere with populations ability to meet basic needs and obtain basic goods. Critiquing fossil fuel and nuclear resource-based energy projects in this work, Sovacool et al. [1] establish that: (i) energy justice can be explained using two principles, affirmative and prohibitive; and (ii) energy injustices can be categorized as occurring in often overlapping geographic, temporal, technological, economic, and sociopolitical dimensions.

The philosophical underpinning of understanding energy justice foundational to Sovacool et al. [1] aligns with the philosophical conceptions of justice as reviewed in Sovacool and Dworkin [33]. In this work, the authors apply six philosophical concepts found in justice theory: (1) human rights, (2) procedure, (3) welfare and happiness, (4) freedom, (5) posterity, and (6) fairness, responsibility, and capacity when studying energy developments. The prohibitive and the affirmative principles proposed by Sovacool et al. [1], by their definition, directly or indirectly encompass justice principles. The prohibitive principle states that "energy systems must be designed and constructed in such a way that they do not unduly interfere with the ability of people to acquire those basic goods to which they are justly entitled" ([1], p. 3). The affirmative principle asserts that "if any of the basic goods to which people are justly entitled can only be secured using energy services, then, in that case, there is also a derivative entitlement to the energy services" ([1], p. 3). As energy services help people attain essential access to goods and other services for human flourishing, a just energy system should ensure that everyone has access to energy sources (affirmative principle) and the ills and benefits of an energy system does not unduly affect anyone in such a way that they lose access to other goods (prohibitive principle).

We utilize this framework to consider renewable energy projects to operationalize energy justice in evaluating RE developments. As justice is a highly debated concept, we use the prohibitive and affirmative principles to frame justice simply as equity and equality of distribution of burdens and benefits and then explore how existing RE scholarship addresses these tenets via five dimensions – geographic, temporal, technological, economic, and sociopolitical. However, going beyond the anthropocentric definition of energy justice, while conducting our research we broaden the scope of energy justice by adding inter-species impacts of RE systems, proposing that a just energy system is also one that also does not endanger species critical for ecological systems to survive, which is important in itself and extremely useful in supporting human life.

The geographic dimension focuses on the spatial allocation of energy services and the costs and benefits associated with them. Uneven energy development that affects one place more than others also involves changes to the ecological and environmental conditions in the area, impacting local communities in ways that can even lead to degradation or even displacement. This section considers RE in terms of the affirmative and prohibitive energy justice principles. In which a just energy system would include characteristics that lessen the uneven geographic impacts associated with energy development projects and improve access to energy to obtain basic needs.

The temporal dimension of energy justice stresses energy systems as an intergenerational issue, where the negative externalities of energy production and use of current generation continue to impact future generations (hence capturing intergenerational ethical obligations). Therefore, this section considers how just RE systems can elicit externalities that prevent or hinder future generation's abilities to obtain their basic goods, either through the provision of fuels or access to energy to satisfy basic goods. Therefore, a just energy system should have characteristics that lead to reduced or negligible impacts on future generations and the ways and means essential for maintained quality of life. Temporal dimensions explore intergenerational and also inter-species energy justice issues, where energy injustices will affect the generations to come who will be impacted by climate change, degraded landscapes, biodiversity loss, air pollution and associated health implications in the future stemming from current energy use.

The technological dimension explores inherent ethical deficiencies of energy systems in relation to their safety, efficiency, reliability, and vulnerability to external security threats. This section considers whether the technical components of the energy system itself have the capacity to reconcile with these principles. A just technical energy system would provide non-interference, reliable, safe, and non-vulnerability with the provision of basic goods. The economic dimension of energy justice mainly concerns the social distribution of energy services and the costs and benefits associated with them. Sovacool et al. [1] point out that energy services should be distributed in such a way that people across social groups can have access to energy that is affordable enough to cover at least the basic requirements to maintain a dignified life. Often the lack of physical access or the costs of energy services prohibits people from accessing its benefits. Therefore, a just energy system addresses both principles by considering RE projects that do not elicit negative economic impacts or cause an imbalance to different economic groups. The sociopolitical dimension of the energy system is closely tied with the economic dimension. A just energy system from the sociopolitical viewpoint would uphold the principles of human rights, democracy, and political process devoid of any dysfunctional nexus between energy producers and the government. A just energy system should also ensure that no social groups are marginalized from or given access to energy based solely on their social status.

3. RE Through the Lenses of Energy Justice

We organize the results in terms of their closest relevance to the geographic, temporal, technological, economic, and sociopolitical dimensions of energy justice. Each subsection below first highlights the major trends that emerged from our review. The review was compiled based on a systematic search for peer reviewed literature, books, and in some cases reports by government or international organizations reporting empirical research findings on the impacts of RE technology. The Google Scholar database was used and articles published between 2010 and 2017 were included. Initial search terms were based on the dimensions of energy justice used to organize the analysis; additional search terms developed based on the preliminary trends resulting from this initial search. For example, to assess the geographical dimension of RE projects, we targeted articles and reports specifically related to developing nations, with a special focus on the sub-Saharan Africa, Asia, and in other rural areas of the Global South. Articles were searched utilizing key terms such as “RE and developing nations,” “rural electrification,” “energy poverty,” “energy access,” “Africa,” “India,” and “developed versus developing.” To search the literature for the technical dimension keywords like “water impacts of solar/wind/hydro power,” “mining impact of renewable energy” and “ecological impacts of renewable energy” was used. After identifying the trends, specific key words like “wind power impacts on bats” or “water use of Concentrated Solar Power” were used. A similar method was employed when searching for articles in the technological dimension. Keywords in this search included “RE and technology,” “fossil fuel impacts, and health.” For economic dimension, search terms were mainly like “energy poverty and renewable energy” and “renewable energy and energy poverty in developing countries.” Similarly, for sociopolitical dimensions search terms were based on the key themes like “land acquisition renewable energy,” “green lobby and renewable energy”, “public participation in renewable energy decision making” were used.

As the main purpose of this work is to develop an understanding of how RE development is conceptualized in terms of the range of energy justice impacts, the sampling frame focused on sampling for diversity, finding a range of perspectives and trends, rather than a quantitative count of content. Given that we were more interested in finding the range of emerging trends of RE related to energy justice and injustice rather than the number of papers that reported on a thematic area, use of a single database sufficed this purpose, as we could find a broad range of issues covered in the articles selected for review. Delimiting our search between 2010–2017 (even though, for example, lifecycle analysis-based articles of RE technologies have been published since the 1990s) had two purposes. This date range helped focus the review on the impacts of current technology used rather than on older technologies. Moreover, understanding of the impacts of RE have also evolved with time as prices of technologies have fallen, the scale of operation has enlarged, and penetration of RE has made it more or less contested due to socio-political reasons in recent years. In some cases, when recent articles were not available, search periods were extended. Thousands of articles came up in these searches, and articles were selected that reported original research that narrowed down to 20–30 articles for each dimension and numerous articles that address multiple dimensions with a total inclusion of over 200 studies in this review. Each article was analyzed to assess whether RE development aids or attenuates the affirmative and/or prohibitive principles. Articles were also distinguished based on the types of RE systems, either centralized or distributed, where scale plays a role in aiding or attenuating energy justice. Where possible and when possible depending on the availability of literature, we also tried to separate the impacts of decentralized energy systems from the impacts of centralized energy systems. However, it was always not possible due to lack of clarity in the reported research.

3.1. Geographic dimension of justice in renewable electricity

A basic requirement of development is access to energy. As mentioned above, energy is instrumental for human flourishing. Energy influences many quality of life indicators, including access to drinking water, life expectancy, mortality, education, and poverty reduction [34]. A key for improving these indicators is electrification [35]. Currently, 1.2 billion people (about 17%) live without access to electricity whereas 2.7 billion cook by using the traditional biomass, which results in 3.5 million deaths due to indoor air pollution [36]. Lack of electricity has adverse impacts on socioeconomic conditions in developing countries and rural regions of developed countries highlighting the inequitable geographic distribution of energy services [37].

As mentioned above, energy poverty is intertwined with the lack of access to energy and energy services. Populations that are said to live in energy poverty are unable to maintain daily activities that require energy use. Many rural regions and developing nations live in energy poverty due to a lack of affordable energy services, lack of energy infrastructure, or both [26]. Most populations (about 95%) experiencing energy poverty live in sub-Saharan Africa and Asia, with about 80% living in rural regions [36].

Adverse impacts of living in energy poverty include health issues. Many households in developing nations and rural regions rely on renewable energy sources (i.e. biomass) for cooking, which, as noted above, has severe health implications. Problems such as respiratory infections, lung cancer, asthma, and many others arise out the indoor biomass combustion. Many developing nations and rural regions lack access to electrification, which negatively impacts education as many children who attend primary school in these communities do not have access to electricity. Finally, energy poverty can be linked to lackluster development in these communities. Electricity is instrumental for having running water and modern sanitation, which in turn are keys to overall improved health care, high life expectancy, lower mortality, and poverty reduction. It is important to note that traditionally, overall energy consumption was directly linked to economic development. While the direct link has been refuted in relation to developed nations, there is still overwhelming evidence such a connection exists in developing nations where it further linked to reducing overall poverty level [38].

The issue of energy poverty as a function of energy access has been in the purview of several international organizations, including the United Nations, World Health Organization, and International Energy Agency. In addition, various private and public-private partnerships have been contributing to resolving the energy poverty problem. While some studies have suggested large-scale RE installations for electrification in these areas, they may not be suitable for all rural areas and developing regions hindered by a lack of electricity access [39,40,41]. A more pragmatic approach suggests utilizing RE powered mini-grids to provide lighting, heating, clean cooking, and other energy needs of local communities [42,43,44]. Smaller, decentralized RE grids can provide the optimal option for increasing energy access [45,46,47], and many feasibility studies have analyzed the use of RE systems to increase energy access and subsequent well-being in developing nations and rural regions including studies projections for future energy access [48,49,50].

Seventy percent of India’s population lives in rural areas, making up twenty-five percent of the world’s poor population [51]. Therefore, India serves as a preliminary case study and a major driver for energy access studies, in light of the affirmative energy justice principle [52,53]. Similar studies have been conducted in sub-Saharan African nations [54,55,56]. Additionally, several studies have been conducted assessing the progress and success of energy access initiatives in rural regions in India [57], with a majority of projects focused on solar PV RE technologies [52,58,59]. These studies provide continuing evidence in support of decentralized RE powered micro-grid systems versus large-scale RE utility projects. Specifically, rural electrification in India provides many benefits, including improved education, increased employment, improved health, and an overall reduction in poverty [60]. In studies in the African context, most researchers address optimal ways to increase energy access, through international development funds, clean energy programs, and rural electrification initiatives [48,49,61]. Within the geographical dimension, common topics include addressing energy poverty in terms of health, education, drinking water, and overall poverty.

This review found a dearth of information surrounding RE projects in the context of the geographical dimension of justice through the prohibitive principle lens. Rural communities are especially impacted by conventional energy systems, and energy planning and policy must balance the inequitable distribution of impacts and access across geographical scales. Large-scale standalone RE projects may not have the capacity to solve all rural energy scarcity problems (other than basic lighting services), as appliances and methods of heating and cooking differ from urban and rural areas, especially in energy poor remote communities [62,63,64]. Therefore, large-scale RE may have limited scope in mitigating energy poverty-related justice issues in rural and remote communities. However, smaller decentralized RE powered microgrid systems maybe provide a more appropriate solution. In addition, such projects can aid in developing communication infrastructure, commerce, health, education, and mobility in rural areas [65–72]. The affirmative principle is also addressed.

Most articles focus on rural regions in developing nations of sub-Saharan Africa and India. Researchers acknowledge RE technology's capacity to improve existing conditions of energy poverty in these regions, using indicators such as better drinking water, education, health, and reduced poverty levels. In terms of the global geography of poverty, RE development offers a key tool for addressing energy injustice by both providing energy access and mitigate the environmental harms associated with energy provision. There is a lack of research surrounding energy poverty issues and rural regions in developed nations. While this problem may not be as prominent compared to some least developed regions, it is still important to acknowledge access and affordability to energy in these regions as well.

3.2. Temporal dimension of justice in renewable electricity

The prohibitive principle illustrates how transitioning to RE is justified in the face of climate change from greenhouse gas emissions, resource scarcity, pollution, increasing water stress, and how the impact on other species all of which is essential for current and future generations ability to acquire basic goods. Based on the affirmative principle, our review also included articles on the scope of RE to be able to provide for essential electricity needs for the future generations. Applying the prohibitive and affirmative principles of RE justice involved reviewing existing literature and examining the designs and structures of RE systems that can unduly interfere with future generations ability to acquire essential goods and access to energy services. It is important to recognize here that conclusive results on the capabilities or restrictions of RE to provide future generations with essential goods and services cannot be determined entirely at present time as such impacts can only be evaluated at a future date; currently we can only predict some of the temporal impacts with much certainty. Elaborating further, the current dominant energy system, which utilizes fossil fuels can negatively impact future generations' ability to obtain basic goods and services, particularly under changed climate conditions as a result of GHG emissions and depleted natural resources leading to intergenerational injustices [73,74,75]. Therefore, shifting energy production to renewable resources can significantly decrease the climate-impacting GHG emissions from power generation [76], saving future generations from the increased likelihood of catastrophic climate events. Other positive externalities of RE include the positive impacts on public health from reduced atmospheric pollution levels [77,78]. As a result of this shift, future generations can benefit from clean water and air required which are two of the essential life sustaining basic good. By reducing the climate impacts of fossil fuels, RE can significantly further energy justice potential based on prohibitive principle. When compared with fossil fuels, RE systems can be comparatively low on emissions, yet RE systems are structural realities that are becoming increasingly common; like any other system of production, RE development entails the use of nature as a source and a sink. Therefore, the energy justice potential of RE in its temporal dimension must thus be explored holistically. The cumulative effect of a large RE sector on some environmental goods and services critical to human welfare can limit future generations' ability to access basic goods. Like other energy technologies, the proliferation of RE to meet future energy demands will have GHG emissions in manufacturing, installation and operation and differ in terms of materials used in manufacturing and construction, technology, location, and climate conditions, yet such emissions are less when compared with fossil fuels.

Expansion of RE will likely increase the demand for mineral resources including gold, copper, aluminum, lithium and other metals used for manufacturing RE systems components [79–82]. The growth of the RE industry can stress readily available metal ore deposits, making metal extraction costly and energy intensive [80,83] potentially impacting the availability and affordability of these resources for other purposes in the future. Additionally, metal mining comes with a host of negative environmental externalities, which is likely to have negative intergenerational justice consequences. These impacts are less clearly defined by the scale of RE development (either large-scale centralized RE projects or a large number of decentralized RE projects) than by the material used in a specific technology and the source of that material [83].

Many energy projects require significant water resources [84]. Climate change will severely stress water resources in many parts of the world, leading to water scarcity for many communities [85,86]. This will also impact some forms of RE production as well, specifically HE [87,88]. Water use in RE projects is technology specific [89,90]. In the case of SE, water is used for cleaning dust from solar installations [91] and suppressing dust in the area surrounding a facility [89].

Water use is particularly high in certain technologies like concentrated solar power plants that require water for cooling. If wet cooling or hybrid cooling methods are used, the quantity of water utilized is often higher than in thermal coal and natural gas power plants [92–95]. However, results differ when dry-cooling technologies or synthetic nitrate in place of mined nitrates salts are used, and studies suggest that SE saves water [78,96]. Therefore, to assess the water needs of SE, the particular form and scale of the technology used are of critical consideration, with water impacts lessened in large-scale centralized projects with dry-cooling alternative methods or decentralized grid connected systems.

WE, on the other hand, has limited water needs and has a significant edge in water use when compared with conventional hydrocarbon-based electricity production. Therefore, WE can mitigate water scarcity-related problems in water-stressed areas [97–100]. HE also has a high water footprint due to the water consumed or evaporated during electricity production [101,102,103]. However, the footprint differs based on local climate differences and structural specifications of the HE facilities [104] and the ecosystem benefits of reservoir water serving multiple purposes [105].

RE developments interact with other drivers of the global environment to have intergenerational effects on water resources that are critical to sustaining human life and on landscape-level impacts such as biodiversity. Preserving biodiversity for future generations is critical due to its known and as of yet unknown benefits arising out of having a healthy and diverse gene stock [106]. Research suggests that RE developments have mixed impacts on biodiversity [107–112]. Several studies report WE projects’ adverse impacts on birds and bat populations as they collide with the blades of the wind turbine [107,113–120]. Bats provide critical ecosystem services [121,122] and have a very slow rate of reproduction that limits their population recovery [123]. Some studies have suggested that offshore WE installations may be detrimental to marine ecosystems [124,125], yet further research is required for a definitive conclusion [126]. Although limited in definitive and conclusive results, some studies have also evaluated the impacts of displacement of other species from suitable habitats due to land acquisition for WE, raising concerns regarding large scale WE development [110,111,127–130].

The biodiversity impacts of SE have not been studied rigorously enough to come to definitive conclusions [110]. Yet many researchers have pointed to the environmental impacts of solar energy like altered microclimates over SE projects and land fragmentation creating barriers for free movement of wildlife [110,131–134]. Others point to the impacts of transmission lines on biodiversity [135,136]. SE also offers opportunities for mixed land use through agro voltaic development, where land is used for both energy and agricultural purposes [137].

In the case of HE, river flows are critical to ecosystems [138], and any alterations of the river flow can impact aquatic ecosystems [139]. Like other forms of RE, studies have identified different negative biodiversity impacts of large HE projects [140–143]. Therefore, the scale of the dams and their impacts on local ecosystems being prominent elements for consideration of the justice dimensions of HE development [144,145,146]. On the other hand, small HE projects can be operated without large dams and their subsequent negative ecological impacts, yet considerable research is required to understand the true ecological impacts of a large number of small HE projects required to meet energy demands adequately [147,148].

To explore the affirmative principle of energy justice in the temporal dimension, we analyzed how RE can meet essential electricity requirements of the future generation. In 2030, the projected end-use energy demand worldwide would be 17 trillion watts (TW) [149]. Researchers project that the large-scale expansion of wind, hydro, and solar energy technologies required to meet the future energy demand worldwide is possible economically and technologically but would require social and political impetus [6,7,8].

Therefore, our review and analysis regarding whether the RE projects aid or attenuate the prohibitive principle of energy justice in the temporal dimension found RE has many positive externalities furthers the prohibitive principle., i.e. RE on in the temporal dimension has the potential to drastically reduce the negative impacts currently experienced by conventional energy systems. This will allow populations to obtain goods and services with decreased harm caused by shifting to RE systems. However, the overall beneficial effect is partially offset by a few major negative externalities. Although these negative externalities may be of less consequence when compared with the impacts of negative externalities of fossil fuels, exploring alternative options to reduce these negative externalities should be a priority for socially just RE transition. Not surprisingly, recent research has moved in this direction, aiming to find technological options that can counterbalance some of the negative impacts. For example, constructing solar PV modules on agricultural land where shade adapted crops are cultivated can maximize land use and reduce competition for land [150,151,152]. In addition, covering HE reservoirs with floating photovoltaic (PV) arrays reduces water loss from evaporation and overheating of the PV cells [153]. Through the affirmative principle lens, RE projects increase access to energy based on the nature of these systems: utilizing renewable resources. Future generations must have the ability to obtain basic goods and services. Through a continued reliance on non-renewable resources, these future generations ability to obtain goods and services may be jeopardized. Research also suggests that altering wind turbine speed with marginal annual power loss can have significant impact in reducing bat mortality in nighttime operations [154,155]. Other researchers have found that altering colors of the wind turbine [156], type of turbine used, the location of the wind farm [157] matter in increasing the negative impacts of WE on ecological systems. At best, the energy justice potential of RE in temporal dimensions is work-in-progress and coming to definitive conclusions requires further research and many of negative externalities can be solved with proper planning, implementation, and management.

3.3. Technological dimension of justice in renewable electricity

The technological dimension of energy justice highlights inequities stemming from safety, reliability, security, and vulnerability shortcomings ingrained in certain energy technologies. Significant technological innovations are constantly advancing to allow for further exploration, mining, and extraction of existing energy sources to meet growing energy demands. The quest for meeting these demands resulted in the creation of the largest machine, the U.S. electrical grid [158]. This is a centralized fossil fuel-powered system that aims to provide affordable and reliable energy. This system also produces many negative externalities, including but not limited to pollution, land degradation, health effects, and climate change impacts [159,160], impacting its safety and reliability. Most national economies rely on the centralized fossil fuel-based electrical grid to provide essential energy services. Therefore due to its interconnected nature, an electrical grid failure has the potential to impair economic and social functions in the event of a power outage [161,162,163]. Therefore, secure and reliable electricity supply is called into question. This section focuses on how existing studies and projects utilizing RE technologies have addressed the safety, security, reliability, and vulnerability of RE technologies using the prohibitive and affirmative energy justice lens.

As mentioned above, a significant negative externality associated with traditional energy technologies comes in the form of GHG emissions. While fossil fuel power plants produce GHG emissions throughout the entire lifecycle of the technology (extraction of resource to combustion of fuel), emissions related to RE technology are limited to the manufacturing, installation, and maintenance stages [164]. Additionally, externalities differ for each RE technology. For example, HE results in habitat disruption and microclimate changes. WE include noise pollution, land aesthetic impacts, and avian and bat mortality. SE can require a significant amount of land. However, most negative externalities associated with RE technologies can be mitigated [165]. Alternatively, RE technology benefits tend to outweigh the burdens. RE technologies generally do not produce emissions through operation and use, resulting in overall decreased GHG emissions. Global welfare and increased employment are found to correlate with increased adoption of RE technologies. Some studies have shown that the RE development has a more significant positive effect when the technology is produced locally [166].

Scholars and technical experts agree that the continued use of fossil fuel energy technologies is no longer necessary to meet society's electrical needs because of advances in renewable energy source technologies [42,167,168]. Most RE technologies produce no emissions during use and have a well-established ecological balance sheet [169–171]. The technical community also supports a direct solution to address the technical vulnerability of the electrical grid: distributed generation and microgrids [172,173,174]. Based on this, this review aims to determine how RE technology addresses emission reduction (safety), reliability and efficient energy operations, and decreased vulnerabilities to energy generation.

Many technical and feasibility studies have analyzed the use of RE technologies that can replace fossil fuels through the prohibitive justice lens. Several articles review a decentralized RE system approach [175,176,177]. These reviews consider utilizing RE technology as a cost-competitive alternative to centralized generation technologies through off-grid or micro-grid systems power by renewables, yet there is often no mention of utilizing a decentralized RE technology as a security and reliability measure. Most original research articles gear towards RE technology development design and measure optimal RE technology installations that function to reduce costs along with decrease emissions as a matter of public health [178,179]. Therefore, the safety component is addressed. However, the majority of research focused on the context of core nations considers RE technologies at a centralized, the utility scale, to ultimately shift away from traditional fossil fuel based energy sources but not to change the scale of energy technology development [180,181]. Some research uses applications and models to project and understand how policies work in conjunction with advancing technologies to influence the diffusion of renewables at the centralized level [41,182–185]. Few look at RE technology applications in both the centralized and decentralized designs [186,187], yet these findings conclude that decentralized RE technology designs can be integrated into the grid with optimal policies and communication systems.

While both fossil fuel based and RE technologies produce GHG emissions in their lifecycle, RE technology and infrastructure can decrease GHG emissions and consequential adverse health impacts, and some existing studies do examine the technological dimensions of RE that contribute to its energy justice contribution through the prohibitive justice lens [39,41,175,186,188,189]. These researchers acknowledge the detrimental impacts of current energy technologies on the environment and human health and that RE technologies pose a viable solution to address mitigation and reduction in harm to health from fossil fuel based energy technologies.

This analysis suggests that there is currently a narrow discussion and study of RE technologies through the prohibitive lens in existing research and policy scholarship; i.e. the ability of RE to provide safe, efficient, reliable and non-vulnerable electricity. Only a handful of articles mention RE technology through prohibitive energy justice lens, and those that do acknowledge RE technology's capacity to provide safe power: reduced GHG emission that present harm to humans. This suggests an area for further research into other technological dimensions of RE that relate to energy justice, including the capacity of RE to change the influence of vulnerability on the existing electrical grid, the impacts on land use through the prohibitive lens, and to ultimately provide an understanding of RE technologies viability as an efficient, safe, and reliable energy source. The affirmative principle potential of current RE technological remains inconclusive. Authors address RE technological systems as they relate climate related impacts through GHG and in terms of issues of scale. However, there is much room left for discussing issues of safety, security, vulnerability, and reliability as they relate to RE technological capacity in providing access to energy.

3.4. Economic dimension of justice in renewable electricity

Cheap and abundant energy generated from fossil fuel resources is often linked to the rapid increase of economic prosperity witnessed in the last three centuries [190,191]. Energy is necessary for human beings to access goods and services to which they are justly entitled. Yet in many parts of the world including developed nations and more so globally peripheral countries, energy deprivation arising out of affordability and access inequalities challenges human flourishing [192,193,194]. Energy poverty can contribute to or aggravate income poverty, time poverty, and can curtail social progress [195,196,197]. Moreover, energy generation and distribution fall under the primary economic activities of a nation and most fossil fuel energy production systems are owned and operated by a small number of citizens in any country who disproportionately enjoy most of the profits of the sector [1]. To assess how RE projects follow the prohibitive and affirmative principle in the economic dimension, this section focuses on assessing existing scholarship regarding how RE development has addressed and can address energy poverty and deprivation issues resulting from expensive electricity prices and how diversifying energy portfolios has affected energy affordability.

Energy poverty arises when people are unable to maintain or sustain their socially and materially essential and customary daily activities due to lack of energy [30]. This can occur due to a lack of affordable energy (fuel poverty) or access to energy infrastructure (energy poverty) [30], or a combination of both [26]. One way of solving energy poverty problems is through large-scale RE projects to diversify national energy portfolios so that energy infrastructure is accessible to all. One way of doing so is to construct large-scale RE projects must be in areas that would benefit from low-cost access to the grid or low initial costs of construction, transmission, and distribution Historically, to be cost-competitive with conventional forms of electricity production, such projects were made possible by government subsidies, making them hard to implement in poor countries [39,40,62,198,199]. However, some studies have pointed out that large-scale stand-alone RE projects may not have the capacity to solve all rural energy scarcity problems (other than basic lighting services) as appliances and methods of heating and cooking differ from urban and rural communities [62–65]. This problem can be solved to a large extent by household, community-level, and other distributed RE projects in such a way that energy services are delivered to fulfill local needs [65–70,200].

Many technical and feasibility studies have analyzed cost-competitiveness (vis-à-vis centralized systems) of decentralized WE [40,200], SE [59,200,201], micro HE [59,202], and hybrid renewable energy systems [47,203,204,205]. Several studies identified numerous obstacles in enabling RE to solve energy poverty. Some suggest that the cost of RE systems is the principal impediment to adoption at the household or community-levels [206,207]. Others suggest lack of awareness, change-adverse consumer behavior, market failures, technical and institutional problems and regulatory support as the main barriers [22,207–215]. Community characteristics and the entrepreneurial abilities of community members can also slow down RE uptake where richer and more well-connected communities can opt for renewable energy technologies than poorer communities [216–219]. These limiting factors may not be inherent in the technology itself, but demonstrate that considering technologies in terms of their justice impacts requires attention to the social and situational contexts in which technologies are developed.

Apart from addressing energy poverty related to physical access, RE should also be assessed in terms of its impact on electricity prices or fuel poverty, which determine the extent to which a person can access energy services. Some authors have pointed out that currently producing electricity from RE resources is not always cost effective and in some cases it raises electricity prices, making energy access unaffordable to the economically marginalized [220–225]. This, in turn, affects the rate of RE adoption [210], as well as the preferences for adopting particular RE technologies [226]. The cost of RE is often disproportionately borne by residential, commercial, and small-scale industrial consumers rather than energy-intensive industries [227] as the former are often unable to retrofit with energy efficient appliances [228]. In addition, several studies also have shown that people with higher income are willing to pay more for RE [229,230,231]. Therefore, fuel poverty arising from affordability-related issues remains a concern worldwide, as large income inequalities exist both in developed and peripheral nations [231]. Others have refuted the claim that RE development results in electricity price increases [232] or have proposed that greater policy involvement is required to align demand and supply, hence stabilizing prices [233,234]. Therefore, there is considerable debate in how switching to RE affects energy affordability issues in the short and long run and policy contexts matter in recognizing the energy needs of different segments of society.

This analysis suggests that although there are multiple opportunities in RE development to attain energy justice potential in the economic dimension, much attention is needed to develop the social, political, and economic contexts in which these technologies are embedded to develop economically just RE systems. Some authors address the prohibitive principle by considering RE system pricing impacts on adoption levels. Additionally, researchers address the potential for disproportionate RE adoption to impact pricing for other consumers negatively. However, there is still room to explore the negative economic impacts of RE systems fully. The affirmative principle is highly prevalent as many authors discuss energy and fuel poverty. While RE is seen as a solution to mitigating these issues that are currently experienced due to fossil fuel powered energy systems, there is still need to explore how RE may function to perpetuate energy and fuel poverty issues. The potential for RE to increase access to energy services depends on the political, technological, and geographical elements involved in development, and the potential for RE to increase economic affordability of energy services is largely depended on the existing economic and policy contexts that shape the organization of energy systems and resultant energy pricing [235,236]. In other words, RE technology may not inherently cause an increase in energy prices making energy unaffordable; rather it is largely about the how the energy market operates. Therefore, without significant changes in the social and political setup within which energy markets operate, the energy justice potential of RE in facilitating energy access and affordability in the economic dimensions remains inconclusive.

3.5. Sociopolitical dimension of justice in renewable electricity

The growth of the RE sector is contingent upon the construction of associated infrastructure. RE also requires significant research and development investment. Energy infrastructure development is a high-cost enterprise, making it susceptible to a variety of risks [1]. Profit maximization motives underlining such significant investments require being protected from shocks external to the system like sociopolitical upheavals based on resistance to such developments. Such resistances can result in political suppression and persecution, as well as human rights abuses. Just energy systems can create avenues where such problems are minimized—when inclusive processes or procedural justice enable democratic participation resulting in coexistence of profit maximization and equitable distribution of benefits. Therefore, this review examines existing research to assess how RE systems are addressing or failing to address the prohibitive and affirmative principle in the sociopolitical dimension of energy justice.

Scholars have pointed out that transitioning from high energy density fossil fuels to low energy density RE technologies requires a lot of land, which may result in struggles for land rights [237,238,239]. Using case studies, some scholars point out that such property transfers to often large and foreign investors for utility scale RE development deliver no or little benefit to local communities [198,199,240]. Meanwhile, these communities have strong cultural, economic and environmental ties to their land. The distribution of benefits from RE development based solely on the socio-politics of land ownership and access can even lead to social and economic marginalization [240,241,242]. Such impacts can unjustly restrict people from acquiring goods and services falling under their rightful entitlements. Popular discourses of environmental benefits of RE can snub the voices of the rural periphery where land is cheap for constructing RE projects [241]. Several marine renewable energy projects have also limited the access rights of coastal and indigenous communities in different countries dependent on the marine resources [243]. There are also instances where renewable industry lobbies have strongly impacted energy policies [244], which may not always favor all stakeholders [245]. Therefore, these cases show that if not properly implemented, RE projects can create injustices based on the prohibitive principles at times working at the interest of large corporations.

However, some studies have found that alternative models like community-based RE projects can mitigate these concerns and, thus, help to facilitate just energy transitions. It is possible where organizational structures allow for non-constrained participation of local community members in RE projects and who can enjoy all the benefits of the projects whilst navigating the risks with the use of local knowledge [246,247]. Community scale RE projects has wider local sociopolitical support and participation. This attributed to local distribution of project benefits, more stringent protection of local natural resources, as well as elevated community spirit and community identity and stakeholder agreeing to projects that are inclusive and follow democratic decision-making processes [230,248–255]. Though these results are encouraging, the existing institutional and organizational barriers continue to pose concern regarding the increase in public participation in RE projects [256–260]. These studies show that community owned and operated energy generation by default may not ensure community participation and how energy projects construction and design can prohibit people's ability to access basic goods and services may largely depend on how the projects are organized and developed.

What emerges from the above discussion is that although large-scale RE projects can lead to sociopolitical injustices especially regarding land rights, smaller-scale RE development such as community energy projects can further the prohibitive principle by virtue of inclusive participation, collective ownership, and community empowerment. In other words, the prohibitive principle is addressed to the extent that RE systems potentially cause negative sociopolitical impacts through land use disputes. The affirmative principle is not discussed in this dimension. This dimension leaves space for further exploration into how RE can either improve or decline the quality of participation, ownership, social stratification, and community empowerment. These represent only a handful of factors surrounding RE ability to impact access to basic goods and services. Therefore, the scale of development matters significantly more than the particular technology for promoting sociopolitical energy justice. The advantage of RE technology is the ability to develop projects at local scales and to shift ownership models to promote participation and community benefit sharing. These benefits are themselves based on the technological aspects of RE, which allow for such flexibility in the scales of development [261].

4. Conclusion

Ethical issues of justice are central to understanding energy choices and energy impacts. The current generation of humans living on the earth arguably has an obligation to overhaul ways and means of producing energy to alternative low-carbon emitting resources to benefit future generations who do not yet exist [28]. Further, social and economic systems are based on energy systems, and renewable electricity can create new opportunities but also jeopardizes existing stabilized systems. Yet these ethical considerations fail to provide a systematic lens for conceptualizing and evaluating the justice components of energy systems in terms of decision making, access, and impacts; these are the purview of energy justice.

Review of existing work on renewable electricity technology development illustrates that energy injustices spanning temporal, economic, sociopolitical, geographic, and technological dimensions are all apparent in the context RE development and use. However, despite the numerous studies that point to dimensions of energy justice in RE development, very few of these studies are explicitly framed in terms of energy justice. Yet studies often offer evaluative conclusions including recommendations for policy or future research. This work would arguably benefit from an explicit grounding in energy justice concepts and systematic use of an energy justice framework to frame analysis and anchor recommendations. There are multiple tradeoffs to consider when ensuring justice, but in general terms, energy system planning and policies can be formulated to aid in solving persistent problems like social inequality, marginalization, and environmental damage rather than perpetuating them. This review aims to identify how the dimensions of energy justice are discussed in terms of RE; future research must grapple with the tradeoffs among impacts across dimensions.

Further, the review illustrates that some components of RE development that are arguably essential to realizing its justice potential are relatively absent in the literature. Specifically, in the technological dimension, the safety and reliability benefit of distributed RE technology is overlooked, indicating a possible avenue for a productive research agenda in the future. Utilization of an energy justice framework can help identify gaps in the literature and potential research silos in which key questions are not yet being asked, and significant impacts of RE development are not yet being explored.

Review of existing scholarship RE demonstrates that, apart from the intergenerational climate change benefits, other dimensions of energy justice are not inherent to RE. Rather than being inherent in the technology itself, many of the justice implications of RE technology development are related to choices regarding the technology, including choices regarding scale, locational siting, and organization of ownership. In general, RE development that involve distributed rather than centralized technologies, are sited to avoid ecologically or culturally significant landscapes, and are designed with community involvement is more likely to have positive implications for energy justice. One specific consideration is the impact of electricity technology on water resources; water is extremely vital, given the inevitable future of water scarcity due to climate change, so water intensive RE development is likely to create temporal injustice.

The energy justice framework used herein provides a valuable tool for assessing the justice implications of electricity choices. One potential weakness in the use of dimensions as an organizational tool is that they necessarily involve some overlap and some ambiguity in demarcation; the dimensions are not isolated in reality and thus cannot be entirely isolated in conceptualization and application. However, areas of overlap can provide for fruitful consideration of intersecting impacts or social intersectionalities across dimensions that deserve particular attention. While there are certainly other ways of conceptualizing energy justice [262,263], the framework used here provides a concrete tool for assessing both the energy justice potentials of technology and the avenues available for future research given gaps in how these potentials are articulated in the literature. As this review demonstrates, particular technological choices do not inherently align with specific justice implications and there is still more work to be done to understand regarding the energy justice potential of renewable energy technologies.

Conflict of Interest

All of the authors declare no conflicts of interest in this paper.

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