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Review

An Exploration of the Land–(Renewable) Energy Nexus

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Abstract: The need to understand the connection between land and energy has gained prominence in the calls to opt for renewable energy as part of the climate change mitigation actions. This need derives from the fact that renewable energy resources are site-specific and require rightful access and use of land. The impacts on landscape, land tenure, and land-use patterns of constructing energy facilities are significant, and they may subsequently undermine the authority of local communities. Still, the connection between land and energy is not yet part of integrated development policies and political debates when deciding on renewable energy projects. Therefore, this study critically reviews the land–energy nexus with the aim to understand and explain how the uptake of renewable energy is shaping the land–energy nexus and how renewable energy technologies are evolving and interacting in different regions of the world, particularly in the Global South. Theoretically, the land–energy nexus tends to reflect a dual tension between those who support the rapid expansion of renewable energy projects and those who oppose it due to concerns over land pressure and social impacts. We consider that this contrast is ruled by both the ecological modernization paradigm and the environmental and social justice paradigm, as part of wider environmental and social debates. The study adopts an integrative literature review built on the analysis of existing literature and deductive logical reasoning to create new, exhaustive scientific knowledge focusing on three interdependent dimensions: land requirements and planning policy, environmental impacts, and public opposition, as an informative guidance for future research and policies. The multiple forms of social dispute and agency demonstrate that dominant narratives supporting renewables act as a modern technological fix but provide only a partial solution for the climate and energy crisis. The deployment of renewable energy creates land pressures and spatial patterns of uneven development. These are visible by numerous environmental and social outcomes, which may imperil the sustainability of the investment. Hence, there is the need of a land–energy balance as a new aspect of sustainable development.

Keywords: renewable energy; solar energy; solar PV; solar thermal; wind energy; energy planning; land acquisition; land management; land use; land conflict; rural areas; rural communities; Global South; nexus

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1. Introduction

Achieving sustainable development is the key challenge of the 21st century. Energy is vital for this. With rising critical concerns to meet the energy demand and needs of present and future generations on a global scale and a long-term vision, the exploitation of renewable energy resources and technologies appears to be the one of the most efficient and effective solutions to help shift towards a low-carbon energy system [1–3]. This increasing environmental pressure has made the world's energy landscape change rapidly over the past decades with an expanding deployment of renewable energy projects. Although renewables have proved their significance in reducing air pollution and increasing countries' energy security by decreasing their fossil fuels dependency, it is yet important to take into consideration their dependency on land. The use of renewable energy requires the use of and access to land. In fact, larger areas are needed to collect the incoming energy from

renewable sources such as solar, wind, hydropower, geothermal, and biofuels [4,5]. It is, indeed, more than a simple revolution of the energy sector based on technical innovations; it will also be a complex transformation that will deeply affect economies and societies [6]. Renewable energy development is also triggering a multifaceted dialogue, engendering evolving economic, social, and environmental concerns, and competing pressures at the different scales—from global to local—at which these operate. Such a discourse is more than the apparent choice over siting; it also involves the development and exploitation of renewable energy, with land at the center of many debates [7].

Over the last few decades, countries across the globe have set ambitious targets supporting the widespread development of renewable energy projects, especially for electricity supply, helped along by supportive policies and falling technology costs. Their deployment is part of the actions taken to mitigate climate change and achieve the Sustainable Development Goals adopted by the United Nations in 2015, as energy is the dominant contributor to the global greenhouse gas emissions, accounting for almost 60% of its total [8,9]. Global and regional trends indicate that energy demand will soon be mainly covered by these renewable energy sources. According to the IEA forecast, the global green electricity production is expected to grow by 305 GW each year between 2021 and 2026, which represents an increase of practically 60% when comparing this with the renewables' expansion of the previous five years [10]. Energy and land were always intimately connected. In a powerful, synergetic association, the generation, operation, and use of energy requires land, and simultaneously, the human use of land requires energy. The rise of renewable energy over recent decades and their wide deployment to manage energy needs and consumption have been the root causes of some severe land conflicts, with planning systems and siting processes struggling to deal with complexities of both fundamental and procedural issues [7]. The production of electricity from renewable technologies is characterized by a significant spatial and temporal variability. These resources are site specific: this implies they have a higher potential for disturbing land-use patterns and engendering land-use conflicts than resources that can be more easily relocated such as oil or coal [11]. Renewable energy development also implies the use of larger areas of land per unit of generated power than the traditional nonrenewable energy forms (power density W/m^2) [12,13]. This means that for delivering the same power as fossil fuels, renewable energy is considerably more land intensive. Hence, the means and the ends of this energy transition is a disputed space by conflicting interests, ethics, and future outlooks that will only intensify the global competition for land and beget social conflict [1,14].

There is a significant volume of empirical literature concerning the power of renewable energy and their achievement in addressing global warming and fossil fuel phase-out issues, and acknowledging the growing interests of experts and the general public in the subject. However, there is a lack of empirical literature addressing the land footprint of renewable energy production and its potential impacts [14,15]. The pertinence of land requirements for renewables is a prominent topic within a broader concourse, as land availability and accessibility are considered to be a pertinent biophysical constraint that might restrict the achievability of this transition within the current socioeconomic framework. Since renewable energy sources require the mobilization of substantial amounts of land, one can expect a growing number of both tensions and conflicts as a direct consequence of such mobilization efforts. Similar to other land mobilization projects, such tensions and conflicts can reflect the multiple voices of landowners and users and associated sociospatial power rearrangements [16]. Combined, they result in major societal transformations on the one hand, and the need of a better balance in land and energy allocation, as part of a trajectory towards sustainable development, on the other. A quick scan of the literature shows in a scattered form that there is some sort of relation between land (right, use, restrictions, and requirements) variations and the variations of energy requirements. This relation is most visible through the spatial concepts, such as power densities (for each type of energy source). Yet, the specific details (in terms of site specifications, the interaction between certain land management and certain renewable energy choices, the degree of

interdependency and proven correlations) of the land–(renewable) energy nexus are not yet sufficiently clear. This lack of clear relations makes it difficult for practitioners to assess the effects and impacts of their choices. Hence, there is a need for a more elaborate review of the inter-relations. In view of this, the main goal of this article is to understand how the spread of renewable energy is shaping the land–energy nexus, and how the maturing renewable energy technologies are evolving and interacting in different regions of the world. Especially in the Global South, there is a need to understand land concerns, the nature of the challenges that renewables offer for land management, and the responses and reactions which are being made by focusing on these three interdependent themes: land requirements, environmental impacts, public opposition, and planning policy.

The article is structured as follows: First, we introduce the concepts of land and renewable energy, and the construct of the land–energy nexus with its relation to ecological modernization and spatial justice. Second, we describe the used methodology for literature identification, review, analysis, synthesis, and reconceptualization. Third, we review the causes, impacts, and conditions of the land–energy nexus in the context of renewable energy projects based on three main aspects of land: landscape, land use, and land tenure. Fourth, we develop the nature of the challenges that renewables present for land management and the responses and reactions which are being made, focusing on these three interdependent themes: land requirements and planning policy, environmental impacts, and public opposition. Finally, we draw the conclusions and implications for further research.

2. Theorizing the Land–Energy Nexus

The concept of land is multi- and transdimensional. It is simultaneously an environmental unit, an economic asset, a productive resource, a territory, an accommodation, a sense of place, an identity, and symbolic scenery. Sustainable land use refers to the rational development, use, and preservation of land resources based on a particular spatial and temporal context, while adopting appropriate mechanisms and organizational instruments [17]. Making rational choices needs, however, to recognize that land (use) is part of a complex system. In their latest report, the Intergovernmental Panel on Climate Change stated that land provides the principal basis for biodiversity, ecosystems, and human livelihoods and well-being including the supply of food, water, and energy. Human use directly affects more than 70% of the global, ice-free land surface. Land ecosystems and biodiversity are vulnerable to ongoing continuous climate and environmental change and extreme weather events to various degrees. In addition to the complexity of the physical system, there is complexity in the institutional system. The rationality of allocating, regulating, and administration is bound and guided by national and subnational laws, norms, and rules, which are difficult to align [18]. If land management has to contribute to reducing the negative impacts of multiple stressors, including climate change, on ecosystems and societies, it has to be multifunctional and multidimensional. There is additionally a high urgency, as land is increasingly becoming a scarce resource. The global competition among its different uses is becoming acute, and conflicts related to this are becoming more frequent and more complex, thus asserting the need for innovative land management and more efficient planning [19].

Having identified that managing land is already complex, the allocation of land for energy sources specifically is equally complex. It brings another factor into the equation, namely the need to rely on a clear conceptualization of renewable energy, both conceptually and spatially. The International Energy Agency (IEA) defines renewable energy as resources "derived from natural processes" and "replenished at a faster rate than they are consumed". The IEA definition of renewable energy includes the following sources: "electricity and heat derived from solar, wind, ocean, hydropower, biomass, geothermal resources, and biofuels and hydrogen derived from renewable resources" [20]. The booming of renewable energy is at the root cause of the major changes that have been influencing and conditioning the energy policy of several countries over the last decade and it is often neglected that these

projects, such as solar power plants and wind farms, are considerably more land-intensive, and that their siting process and their perception is frequently disputed [7,21]. Together, land and energy represent two major interconnected forces driving anthropogenic, global change. We define the land–energy debate as the diverse views, interests, and principles expressed by the different active voices in the discussion in regard to the expansion of modern renewable energy as part of the climate change mitigation actions and to support a decarbonized economy. This includes both the activities, relations, powering and brokering mechanisms, and co-ordination applied between international institutions, governments, land administrations, environmental organizations, scientific bodies, technical experts and managers, social structures, and local communities.

Due to the expansion of renewable energy projects, scholars utilize different approaches and case studies to categorize the multiple storylines and narratives. The construct of the land–energy nexus is therefore a transdisciplinary construct, emerging from different concourses. Scoones [22] argues that the implementation of renewables, as part of the transformation to sustainability, arises from the junction of technology, market, government, and citizen-led processes, with a focus on the different political dynamics. Huber [23] argues that developments in critical social theory suggest that concerns for a conversion to renewable energy must put space at the focal point of the discussion, as it requires new spatial arrangements and new spatial vision. Wolsink [24] debates that the principal issues connected with effective implementation and execution of policies concern the socioeconomic institutions that are contingent to spatial planning and energy strategy, both informed by environmental policy. Huber et al. [25] suggests that future implementation of renewable energy infrastructures will lead to eventual alterations with current and future land-use, landscape, and related ecosystem services. Within this multifaceted roadmap, the land–energy nexus exhibits a pattern of similar discourses and narratives, suggesting that there exists a dual tension between those who support the rapid expansion of renewable energy projects, and those who oppose particular deployments due to concerns over land pressure and social impacts. Theoretically, we consider this dual tension as embedded in a wider environmental and social debate. As a consequence, the land–energy nexus construct can be specified in relation to two perspectives. The first perspective is rooted in the ecological modernization paradigm, and the second is part of the environmental and social justice paradigm. These two angles undoubtedly enlighten and embody the modern land–energy nexus. Nevertheless, evolving narratives are gradually giving way to new theoretical framework and empirical arguments.

2.1. Ecological Modernization

The ecological modernization perspective reflects the image and the vision of international institutions, national governments, energy corporations, and environmental organizations supporting the development and deployment of renewable energy as one of the most efficient and effective technological answers to tackle climate change and solve energy problems, but also as a chance to promote sustainable business and a decarbonized economy, especially in the rural areas of the involved countries [26,27]. This narrative originates from the ecological modernization paradigm, where environmental protection and economic progress have compatible and nonopposite principles through innovative technologies' development, productivity enhancement, competitive markets, and governmental involvement [1,28]. From this perspective, renewable energy projects are drawing a powerful image of nature and modern technology working together in harmony, and social opposition is generally described as an obstacle in the development of an energy system that is cost-effective, environmentally desirable, and technically reliable [1]. In this sense, land is seen as an economic asset for renewable energy siting and development.

However, literature on renewable energy technologies has also exposed that it is clearly insufficient to generate clean energy depending on economic assets and financial support, and that it is also necessary to deploy the technology within a social context where it will be collectively accepted in its implementation, including its various impacts. Additionally,

in environmental social science research, the main critics of this paradigm have argued that ecological modernization does not redress overall injustices, especially environmental and social injustice [28]. In fact, many scholars have genuinely interrogated these beliefs in regard to their pro-poor effects, acknowledging significant social impacts and risks for local rural livelihoods, especially due to the absence of land-tenure security among the rural population, the weakness of legal systems pledging property and occupancy rights for community members, and the way that land use is considered in energy planning [29,30].

2.2. Spatial Justice

Contrary to the ecological modernization perspective, which is dominated by economic thinking and scientific reasoning, the spatial justice as a second perspective prioritizes sociospatial dialectic values over environmental ones. As a starting point, this perspective advocates a fair, just, and equal spatial distribution of socially valued resources, benefits, and opportunities. Spatial justice in this perspective is both an outcome and a process, and it can furthermore be seen as an evaluative framework that empowers actions that can help achieve sustainability [31]. Spatial justice is the principal morality of social and political institutions and resource management regulations that should be receptive to everyone's need. It conceptualizes the relation between the geographical distribution of goods, resources, and services and its social just/unjust repercussions [32].

From this perspective, renewable energy projects are perceived as drivers of transforming the rural scenery into a large, open-air industrial energy production factory and as leading factors in depriving local vulnerable communities from accessing their land and sustaining their livelihood. The spatial justice framework contributes to the need for a critical analysis of the land–energy nexus, and to the necessity of emphasizing the potential social and spatial consequences over and above simple technological and financial aspects and discloses a more controversial political power of renewable energy and land. This idea additionally emphasizes institutional perspectives towards resource conflict, resulting from competition over ineffectively characterized or inadequately administered real properties. Underneath this reasoning persists the hypothesis of scarcity and inescapable conflicts of interests over resources [33]. A large body of literature describes the causes and impacts of land-related conflicts in countries that have inherited a particularly disparate land ownership allocation scheme [34].

3. Materials and Methods

3.1. Research Approach, Boundaries, and Design

In order to derive a more comprehensive land–energy construct, this study relies on an integrative review design. An integrative review is considered more suitable for the development of new research lines than systematic or semi systematic review methods. This method allows one to assess, critique, and synthesize existing literature to generate new knowledge, frameworks, and perspectives about the reviewed topic. Integrative literature reviews are conducted on dynamic topics to help build a robust body of literature that may comprise inconsistencies or disparities between the literature and the new observations regarding the subject, which are not addressed in the literature [35].

Given this, we apply a review methodology based on an integrative interpretation process of existing documentation and literature, with the aim of rethinking the topic and deriving a novel conceptualization of the land–energy nexus by identifying gaps and opportunities for improvement on existing literature and concepts via extension (update) and/or reconceptualization [36]. It is possible to use one's self-knowledge and understanding on the subject to critically break down, analyze, and synthesize the existing information about various concepts, theories, hypotheses, and frameworks, and deduct unique and innovative reconceptualization of the topic as novel scientific knowledge from the reviewed general facts. Nevertheless, integrative review analysis is criticized for being built in a manner that it is nonconforming to any specific standards and for providing only

a trifling summary of existing studies, making it not truly integrative. This can lead to a lack of rigor as compared to systematic reviews [37].

In order to draw contextual limits and boundaries, we focused mainly on articles and documents which exclusively addressed ongoing research on the land–energy nexus for this literature review. The study's literature was not restricted by any spatial and/or temporal boundaries. This allowed us to gather all available and relevant literature, mainly in the English language. The literature identification process, review, analysis, synthesis, modeling/reconceptualization, and extraction of new scientific knowledge on the topic are described in the next section and summarized in Figure 1 below.

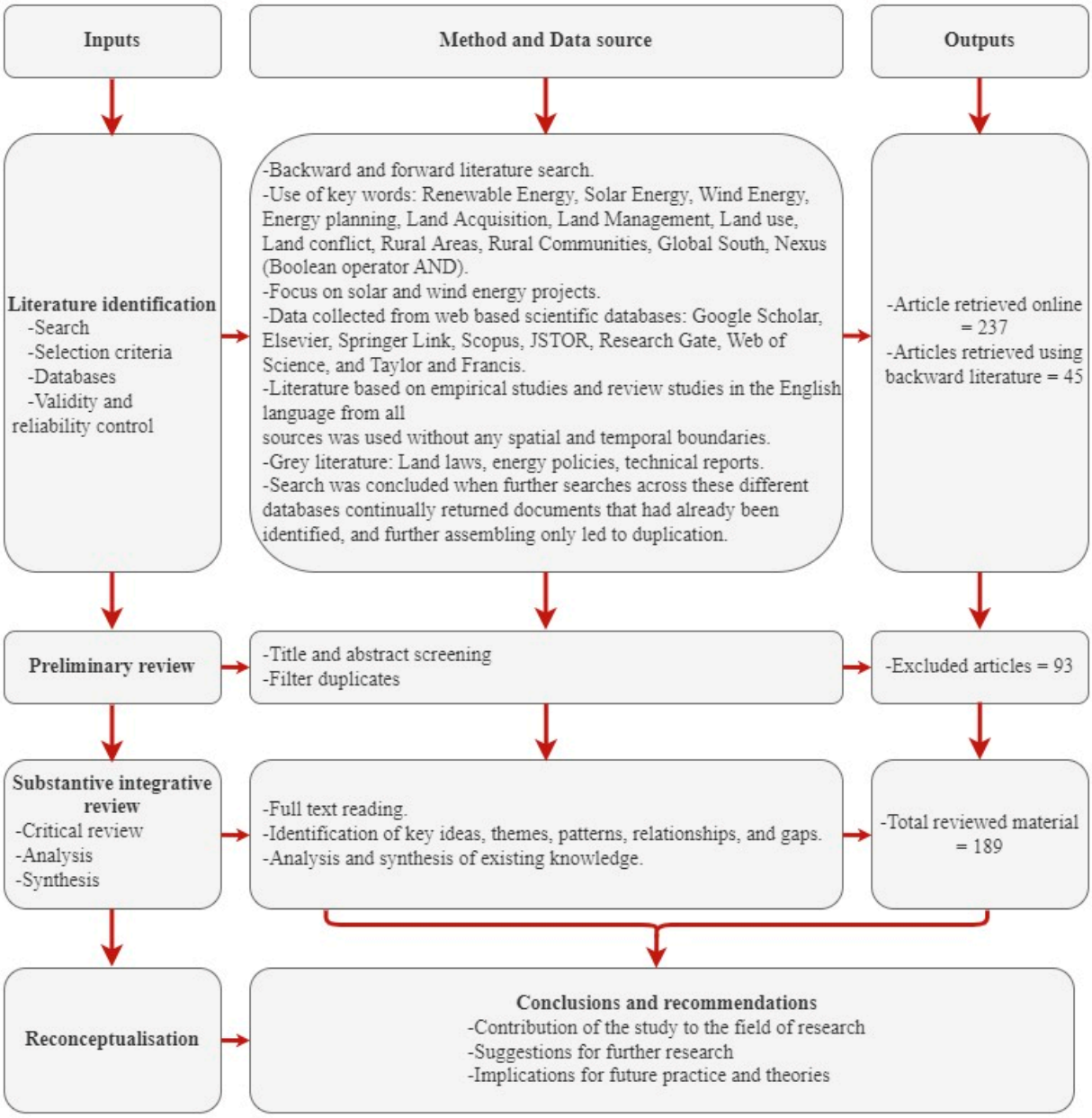

Figure 1. Research process and design overview.

3.2. Data Sources and Research Methods

For the systematic literature search, we used the following individual key words: renewable energy, solar energy, wind energy, energy planning, land acquisition, land management, land use, land conflict, rural areas, rural communities, Global South, nexus. We also used their combinations in different scientific repositories: land acquisition for

renewable energy in the Global South, land management for renewable energy in the Global South, impact of renewable energy on rural communities, land conflict and renewable energy, impact of renewable energy on land use, land management and energy planning for renewable energy, energy planning in the Global South, etc.

We collected all the data from the following scientific databases: Google Scholar, Elsevier, Springer Link, Scopus, JSTOR, Research Gate, Web of Science, and Taylor and Francis. Additionally, we coupled these data with online grey literature (published and open-access, noncommercial reports and documents from various governmental and nongovernmental institutions (IRENA, IPCC, World Bank, IEA, UN . . .)). Across these diverse databases, we also employed various synonyms of the keywords and their combinations. This helped us access a larger volume of scientific papers and documents on the subject. Then we checked the validity, authenticity, and credibility of the results. We concluded the search when further inquiries across these different databases constantly returned previously identified and selected documents and only led to duplication [35,38]. We considered the identified and selected documents for this study to be providing a holistic view of the research topic and encompassing its multiple aspects. We started the review of these documents by reading the titles and the abstracts. This led to the elimination of some manuscripts either because they were beyond the scope of research or due to duplication. After this step, we maintained 144 documents in total for the detailed and critical full-text reading. During the full-text reading, we identified to which extent the documents argued and analyzed the topic and disclosed key ideas, missing gaps, resemblances, comparisons, and contradictions, to be able to conceptualize the research problem and the objectives. We also used the backward spider literature search [37,39] to identify additional relevant citations and references that were tracked down to their initial sources for identification and review. This brought 45 more additional documents to make a total of 189 documents accepted for critical reading and review analysis, covering a time period from 1984 to 2021. The critical reading and review analysis for this study have helped us define the implications of the new comprehensive scientific knowledge to the existing literature, highlight the research boundaries and limitations, and make suggestions and recommendations for future research directions.

4. Results

In this section, we present the results that emanated from the literature review. The section focuses on how the spread of renewable energy in rural areas of the Global South are shaping the land–energy nexus. It also presents our findings on the causes, impacts, and conditions ruling land-management decisions for renewable energy projects in the context of developing countries.

The main causes motivating the growing prominence of renewable energy sources across the world are principally their optimistic ecological footprint and their continuing promotion of sustainable economic development. The main causes motivating the growing prominence of renewable energy sources across the world are principally their optimistic ecological footprint and their continuing promotion of sustainable economic development. Renewable energy is indeed not only helpful for reducing dependence on traditional fossil fuels but also for improving energy security, lowering greenhouse gas emissions, tackling global warming, and achieving sustainable development [40]. In the Global South, renewable energy is being advocated as a potentially significant lever for rural growth and development, providing a new source of jobs and revenue, affordable electricity, and community empowerment. In most of these countries, governments have invested substantial amounts of public money to assist and encourage renewable energy development. Rural areas tend to be sparingly inhabited and have largely available and easily accessible land. Additionally, with abundant sources of renewables they consequently attract a larger investment associated with green energy deployment [40,41]. The International Renewable Energy Agency has established an optimistic plan, according to which clean electricity generation from renewable energy is expected to grow from 25% in 2017 to 85% in 2050 [42].

The International Energy Agency has also stated that all the world's countries have at the minimum one bountiful renewable energy source and many countries have several resources [10].

The major impacts of this renewable energy expansion are, on one hand, a broader access to clean and affordable energy, which removes a considerable impediment to socioeconomic and human development. On the other hand, the development of technology, such as equipment that enhances the efficiency of energy production and research in intelligent design, is progressing rapidly. Costs of renewable electricity have also dropped distinctly over the past decade, motivated by technological advancement, economies of scale, competitive supply chains, and better developer experience [40]. The continuing technological progress in the renewable energy sector has demonstrated how effective and cost-competitive these technologies currently are compared to conventional generation technologies. This has resulted in the rapid deployment of many renewable energy technologies, especially solar and wind power [43]. Supported by economic incentives, solar and wind technologies dominated the market in the last decade, and their implementation still expands rapidly.

The main conditions under which the expansion of renewable energy technologies is largely driven are the evolving global energy policies and institutional frameworks: countries are setting ambitious renewable energy targets and enacting support policies. Evolving land policies are also playing a role in this transition by sustainably and responsibly facilitating land acquisition for governments or private parties and stakeholders to acquire land for renewable energy infrastructure projects and by addressing land tenure and governance issues in connection with such projects [44]. However, most scholars emphasize that to further promote the adoption of renewable energy, the social barriers must be overcome: global perceptions of renewable energy have shifted considerably, and the social responses to the development of these projects are highly variable globally, and it requires a lot of time investment to decide how to address social issues such as negative reactions and conflicts due to the opposition to and nonacceptance of renewable energy projects by local communities [43]. The most commonly referenced explanations behind this are: a weak development rate, an unbalanced distribution of costs and local benefits, and an absence of sufficient communication and satisfactory consultation of local residents by developers.

5. Discussion

Renewable energy technologies are, to some authors, the magic bullet to achieving environmental sustainability [45]. Their role in reducing greenhouse gas emissions has become a broadly discussed national debate, but less consideration and recognition has been given to other impacts of these technologies. Notably, renewable energy production has an extensive repercussion on land, a key theme in national and local policies, and political, environmental, and social questions surrounding the development of these projects [46].

In our literature review, scholars have mostly tackled these three main aspects of land shaping the land–energy nexus: landscape, land use, and land tenure.

5.1. Renewable Energy and Landscape

Globally, landscape possibilities and concerns are central focus points in the current energy transition debate. These aspects are reflected in a twofold concept, combining a territory and an image [47]. Several researchers, such as Ellis et al. [27], Pasqualetti [11], Devine-Wright et al. [48], and Carlisle et al. [49], argue that the more strongly people feel attached to their landscape, the more likely they are to oppose interventions for aesthetic reasons. Sociospatial connections to the landscape thus play a crucial role when changing landscapes. Communities may dread a loss of their heritage landscape and cultural patrimony. This generates an eventual conflict potential as energy production is made more visible, thus changing the common image of energy as an unthought-of commodity and suggesting an industrialization of rural space.

Blaschke et al. [50] introduce the notion of "energy landscapes" as being the established correlation between the physical characteristics of energy commodities and their spatial footprints, on the one hand, and the outlook of individuals regarding these energy commodities and how these projects are being integrated into the landscape on the other hand. It is the places where people and renewable energy technology meet [51–53]. Pasqualetti et al. [11] unveil the nature of the challenges for the implementation of renewable energy projects such solar, wind, and geothermal in the United States, Scotland, and Mexico. They argue that communities are perceiving landscape change as a persistent imminence. Frolova et al. [54] point out that renewable energy technologies have altered both the landscape and the land use. Principally, wind farms and solar power plants drastically change the visual identity of the landscape by adding forms of industrial and artificial components to it. Such landscape alterations present a source of conflict with local communities who feel personally or socially affected in their landscape identification. Cicia et al. [55] point to the relevance of this identification aspect when local residents were asked for their preference for either wind, solar, biomass, or nuclear energy. However, despite the fact that the preference of a type of renewable energy depends on the inhabitants' attributes and aspects, Delicado et al. [47] find that there are always occupants who cannot acknowledge whatever type of renewable energy is designated, even when the project is vital to the local community. In the literature, one of the most renowned opposition movements by nearby residents to the siting renewable energy is known as the not-in-my-backyard syndrome (NIMBY). Dear [56] defines NIMBY as the protectionist position and the oppositional strategies adopted by community groups facing an unwanted development project in their neighborhood. Originally used for wind turbines, now other studies also conceive the perception of other renewable energy facilities as a NIMBY phenomenon, such as Bell et al. [57], who demonstrates NIMBY by showing how residents tending to accept renewable energy when it does not affect themselves but do not want it in their neighborhood. Overall, landscape change is at the heart of the renewable energy spread and its impact should be considered as part of spatial and energy planning. Criteria such as environment conservation, environmental compatibility, cultural heritage, and preservation of biodiversity and natural ecosystems need to be integrated adequately within the energy transition through strong landscape protection policies to minimize the impacts of renewable powerplants [58,59].

5.2. Renewable Energy and Land Use

With its rapid developing economy and increasing electrification rate, the growing energy demand in countries of the Global South are resulting in an escalating competition for land resources to supply sufficient food, water, and energy [60]. It is apparent that land is becoming a scarce resource, and as a consequence, exploiting renewable energies is clearly recognized as a new competing use for land in rural areas, resulting from the need for energy, the need for food, the need for urbanization, and the need for preservation of natural resources, forests, and agricultural lands [61].

The ultimate land-use challenge for siting and developing renewable energy is that they are site-specific and have high land requirements due to their low surface-power densities when compared to other nonrenewable electricity generation sources, such as nuclear, coal, fuel, oil, or natural gas, which represent concentrated and compact deposits of energy [13]. For example, the average power density of nuclear power plants is comfortably above 100 W/m^2 as opposed to solar power plants with approximately 5.7 W/m^2, and just 0.9 W/m^2 for wind farms [46]. The surface power density metric becomes a powerful indicator for comparison of renewable and nonrenewable industrial energy sources, which calculates the total amount of electricity production obtained per unit of earth surface area used by different energy systems and is measured in W/m^2 [62]. It allows one to compare different renewable energy sources, their energy yield potentials, and their respective land requirements. Its values vary with geographic and topographic attributes, installation scale, and technology [61]. As a result, renewable energy infrastructures commonly call

for a greater land footprint than nuclear or fossil fuel plants to produce the same amount of power. Renewable energy development is impacting land use at several stages of the project, including site preparation, on-site construction, and upcoming expansion. Electricity production from renewable resources also entails the construction of power-line corridors, roads, service buildings, and other infrastructure that are a part of any power development, extraction, or transmission project [63]. Geometrically, these linear land-cover features fit more with industrial and urban land-use patterns, and are less compatible with rural land-use patterns, englobing agriculture, rangelands, and forest lands. Power-line corridors and roads may occupy only a relatively small area, but the cutting of vegetation and topographic reworking in these corridors cause fragmentation of vegetation and rural settlement patterns, and can have large and cumulative effects on land use and land rights [64].

These land-use requirements are sequentially significant regardless of the selected renewable energy source because land-use decisions can be among the most contentious social issues and can contribute to political and economic friction among rural communities, where land is perceived to be more available [14,46]. Indeed, these land-use decisions encompass competing interests, values (clean energy production, landscape conservation, local development, job opportunities, etc.), spatial justice and profit distribution (benefits allocation to local communities and project developers, grievance mechanisms handling negative impacts and damages . . .), and rights (change in land rights, responsibilities, restrictions, etc.) [46].

Geographic research focuses on location and locational interdependencies. In light of this, the research makes a link between renewable energy site location and development. As part of this discourse, associated land-use conflicts are inherently more in common with these resources than with those that can be moved around more readily such as oil or coal [11,65]. Attention to certain other renewables has been picking up in recent years, including solar and wind energy development for their potential for disturbing land-use patterns [4]. The implementation of renewable energy projects has added a series of difficulties for land-use planning, including the increasing rate by which projects are being implemented, the slow drafting of proper national planning policies, and the ethical dilemmas for local decision makers torn between competing national interest and local concerns [7,66]. Nonhebel [5] and Capellán-Pérez et al. [14] question whether sufficient land is actually available to meet global, national, or regional electricity demands when having to rely fully or partially on wind, water, and solar electricity sources [67]. Others explore possibilities and opportunities to deal with the spatial impacts of renewable projects. In these discourses, the central question is how to create a multifunctional use of space, and how can one make use of multiple and simultaneous land use offered by these technologies. Examples of such findings are: agrophotovoltaics which allow the combination of agricultural activities with solar power production on the same site and at the same time, thus increasing land-use efficiency; rooftop solar power systems which can be mounted on roofs or facades of existing buildings and structures and therefore do not need to occupy new land surface; or reusing fallow or degraded land for renewable energies for a certain period of time whilst restoring the land for agricultural purposes [68]. Fritsche et al. [69], Dale et al. [63], and Poggi et al. [70] expand this discussion by formulating socially oriented national energy strategies, policies, and frameworks which could be more effective than the current ones. In their views, green energy planning needs to be aligned with social and spatial justice concerns at the local level. This would, however, also require that the development of renewable energy projects is simultaneously supporting sustainable land use, adequate rehabilitation and resettlement provisions, and proper compensatory mechanisms for all the affected and potentially affected, which can result in enhanced trust in public institutions and promote social approval of the implemented projects.

5.3. Renewable Energy and Land Tenure

Land tenure patterns act as a significant bond between the system of political power, social structure, and economic interactions within depopulating rural communities. A large body of literature describe causes and impacts of land-related conflicts in countries with rooted unequal land ownership allocation patterns [34], and the negative impacts of the latest surge in large-scale land acquisition in rural communities have received considerable attention from scholars in recent years [71–75].

In the rural context, economic analyses suggest that poverty has a strong connection with land tenure, and land plays a determining role in defining the conditions of social capital [74]. Geographers and spatial analysts, on the other hand, posit that land tenure is a driving factor of land-use change [76]. In recent years, the solid association of land and energy has gained prominence in the ongoing debate, mainly in a regional and local context, particularly because renewable energy generation is more land intensive due to their low power density and has a significant impact on land tenure by reason of the land acquisition process, a problem that is not really considered focal to national policies and local debates enclosing renewable energy project development [77]. Indeed, the implementation of renewable energy has been responsible for a global rush for land within the last years. This is referring to the practices of large-scale and long-term land acquisitions by governmental administrations or private investors, and consequently, causing major changes in land use patterns and land rights [72]. The arguments regarding the impacts and the outcomes of these land deals are controversial: energy corporations have pointed out significant economic opportunities in the different concerned countries, especially in their rural poor, even though they have also recognized considerable risks for rural livelihoods [74].

Weak land tenure systems and regulations tend to favor renewable energy project developers rather than communities in developing countries. In rural communities, land acquisition processes by public authorities or international investors to build wind farms or solar power plants are directly causing the loss of access rights to pasture and water points for this land's primary users, such as subsistence farmers, pastoralists, or indigenous people, thus denying them access to resources that sustain their livelihoods and foster their cultural identities [78,79]. Prominent calls therefore exist for policy and legislative reforms which change the ongoing hierarchical top-down approaches to land acquisition practices for renewable energy projects to a system which advocates dialogue as a key tactic to acquire land, as well as one which has reliable mechanisms for fair and prompt compensation [44]. Likewise, a more firm, rigorous, and transparent land-tenure policy would be a crucial first act in empowering these communities, protecting their rights, and enabling them to negotiate with local representatives and external investors. Froese et al. [80] and Yenneti et al. [32] are also claiming that development projects should respect existing land tenure and access and occupation rights, also when these are undocumented and unregistered for customary and common properties. Further requirements include transparent negotiation processes, reasonable profit sharing between impacted community members, investors, project developers, and the local government, as well as ensuring sustainability, guaranteeing livelihood restoration, and respecting the local land policies [81]. While an increasing number of studies currently focus renewable energy impacts on land tenure from mitigation aspects, academic studies relating renewable energy impacts on land tenure from adaptation aspects still remain on the sideline, and it needs further investigation. Thus, there is an urgent need to study how land tenure induces people's vulnerabilities in the face of the deployment of renewable energy projects and influences their endeavors to adaptation.

5.4. Reconceptualization of the Impacts of the Land–Energy Nexus: Engendering a Social Gap

A common idea in both academic and grey literature is that land is the fundamental cause of conflict, mainly due to it scarcity. From this perspective, the hypothesis is that limited and valuable land is consistently conflict-prone and sensitive to contending interests and allegations [34]. Many social science researchers have studied community responses

to renewable energy over recent years and helped explore and identify the factors and procedures leading to local acceptance and/or opposition, as well as the main impacts, outcomes, and benefits for local communities [57,81–83]. However, most of the social science literature on renewable energy and communities mainly discusses acceptance and resistance aspects, participation and engagement processes only throughout the planning stages, and prior construction. No real focus is given to the construction phases or the operation and maintenance phases of these projects [47]. Scholars have also identified how several programs, legislations, and policies have been promoted by different countries and institutions to facilitate the deployment of renewable energy and to encourage the research and development of this technology, through utility regulations and various financial aids, as a mean of achieving sustainability. However, policymakers are increasingly confronted with disputes over social and environmental issues regarding these projects and are searching for new instruments and procedures for integrating land planning and energy planning. Tailoring innovative policies to address the conflicts that arise in the context of this energy transition is crucial to ensuring the sustainability of these investments [84–86]. Numerous cases of opposition to large-scale wind farms and solar power plants provide evidence to the difference between the supportive public opinion for renewable energy projects at a national scale and the opposing community opinion to these projects at a local scale [1,43,80,87]. Since solving dilemmas between the renewable energy companies and the local communities is a hard chore, many facilities are either operating in the face of conflict or resulting in canceled projects [24,88].

Solar and wind power are the most described as sources of conflict with affected local communities. Literature on wind farms and solar power plants' implementation in the Global North [89] supports the narrative that the lack of trust can trigger resentment, create conflicts, and eventually delay a project's timeline, even when the renewable energy facility is described as environmentally friendly. Yenneti et al. [32] emphasize that the acquisition and appropriation of land for solar energy megaprojects can prevent vulnerable communities from accessing their main sources of livelihood and escalate their precarious situation. Their susceptibility is also linked to their weak land rights, high dependence on agriculture and pastoralism, and low literacy skills. Thus, failure to implement equitable and lawful land acquisition procedures is a key factor in exposing the vulnerability of these marginal communities, intensifying their precariousness conditions, and weakening their trust in administrative system. Brannstrom et al. [79] discuss that the "imposition" of these projects without fair and proper compensation or mitigation may cause conflicts between local people and the different investors and planners promoting renewable energy projects due to the prioritization of technical issues of efficiency and energy quality over social considerations, such as human attachment to place, cultural landscape, and resource-based livelihood disruption. Appropriate mechanisms need to be put in place to avoid accumulation by dispossession and safeguard transparency in land acquisition through proper compensation schemes and resettlement strategies at the very least. Since the loss of land assets can really be traumatic and distressing, compensating the affected persons with fair and prompt payments or with alternative land could be redeeming. The government could adopt transparent procedures when resorting to land acquisition, allowing affected communities to understand precisely why and how each surrendered land parcel was selected [32]. Such conditions could moderately be the starting point for achieving spatial justice in the context of renewable energy projects. Nikas et al. [90] argue that community involvement is essential for judicious, adequate, and effective policymaking for the introduction and acceptance of alternative energy. Delicado et al. [47] show that it is necessary to continuously investigate changes in awareness not only at the planning stage but also at the operational stage. Moreover, we can possibly highlight a disparity between the local communities' expectations concerning economic and social benefits and advantages, and the actual positive repercussions deriving from renewable energy exploitation. While the dominant political discourse on renewable energy advantages tends to accentuate the

economic outcomes for these communities, local populations tend to perceive a situation that falls short of their expectations [82].

Understanding how communities can live and adapt in close proximity to these renewable energy structures and assessing their advantages and disadvantages can generate pertinent inputs for regulating spatial planning procedures, preventing negative impacts, and ensuring environmental and social justice to achieve sustainability [47]. Wüstenhagen et al. [91] argue that giving importance to social acceptance is critical for the installation of renewable energy within a community, and this was broadly undervalued in the 1980s when such policy programs were first established. This neglect extended until the 1990s due to an elevated degree of public support for renewable energy technologies. D'Souza et al. [92] also point out that converting local community initiatives into more supportive policies and improving stakeholder consultations would affect the social acceptance of renewable energy projects in rural communities in Australia. Overall, scholars have analyzed numerous cases of community responses to renewable energy facilities in North America and Europe. However, literature about acceptance and/or opposition to renewable energy, as well as their main impacts and benefits in developing countries that are characterized by dominant social disparity, economic inequality, immature environmental governance, lack of political power, and poor access to justice, is growing but still limited [79].

6. Conclusions

As outlined in this article, the deployment of renewable energy increases the possibilities that claims and conflicts in relation to land arise, which in turn may lead to patterns of uneven development for rural regions worldwide. Change in land use and land ownership is connected to local land acquisitions for renewable energy projects. This has divergent environmental and social outcomes, which may imperil the investment's sustainability. In order to be sustainable, the investment should be socially responsible, environmentally conscious, and economically feasible. Additionally, it should ensure rural development opportunities, provide supporting programs for poverty alleviation, and thus generate economic prosperity and environmental protection in the long term. The current dominant narratives that support renewables as modern technological fixes provide a partial solution for the climate and energy crisis. A number of them are, however, gradually questioned by various forms of social protests and organizations. In fact, even when modern technologies tend to indeed generate solutions for particular climate and energy problems, social and spatial problems arise when these changes do not sufficiently align with appropriate economic and social transformations. The challenges of such transformation are how to persuade social organizations into adopting newly revised and improved land management strategies inducing human welfare, equal rights, transparent governance, and justice in the context of the renewable energy deployment. From this discussion, we derive that the land–energy nexus originates from the links between ecological modernization and spatial justice. These links are visible and observable in three dimensions: landscape, land use, and land tenure. It is along these dimensions that one should evaluate how and where the maturing and varying renewable energy technologies are interacting across the world, especially in the Global south, and assess the nature of the challenges that renewables present for land management and the responses which are being made, by focusing on these three interrelated themes: land requirements and planning policy, environmental impacts, and public opposition.

Further research should focus on developing conflict-sensitive approaches to the implementation of the renewable energy projects in rural areas using a qualitative pragmatist approach and focusing on the concepts of land tenure, energy planning, and community autonomy. This will imply local context analysis, identification and recognition of all legitimate formal and customary land rights and rights holders early in the project development process, more community inclusion and participation, and conduction of a comprehensive analysis of the upcoming prospective impacts and repercussions of the planned project.

When approaching the present expansion of renewable energy from a pragmatist perspective, new insights will clear up the land implications and the socioenvironmental repercussions of such deployment at the local scale. Attention to these challenges and solutions may create an improved image of the project and reduce land-related conflicts and high-profile injustices caused by renewable energy deployment.

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