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Review

Land Use as a Crucial Resource for Smart Grids—The 'Common Good' of Renewables in Distributed Energy Systems

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Abstract: The energy transition involves transforming electricity supply systems. Smart grids are resilient, polycentric systems consisting of integrated, self-governed Microgrids including distributed energy systems (DES). Renewable energy requires high numbers and a huge variety of infrastructures, requiring large amounts of spaces, including land. Renewable energy flows and land are natural resources. This analysis applies Ostrom's common pool resources (CPR) theory on the sustainable use of ecosystems and natural resources to explore DES as a "common good" with spaces and land as crucial scarce resources. Currently, electricity grids are monocultures with highly centralized and hierarchical governance structures, where the juxtaposition of electricity as public and private good is considered self-evident. The emergence of DES in smart Microgrids is disrupting these monocultures, which is one aspect of the full transformation from current centralized grids towards resilient, integrated Microgrids based on variety and adaptive capacity. The other component of the transformation concerns the essential resource of space. As land and other spaces, such as rooftops, are subject to diverse property regimes, CPR is also applicable for analyzing the required changes in property rights and land-use decision-making. Such changes are necessary to make sufficient space available for the infrastructures of community Microgrids.

Keywords: property regimes; distributed energy systems; distributed energy resources; microgrids; common resources; community acceptance; landscape; social-technical system; cooperative land use

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1. Introduction

Renewable energy (RE) is a natural resource whose sustainable harvesting and use are strongly connected to land use issues [1,2]. Natural resources are always linked to ecosystem functions. This implies that human-made systems for the conversion of energy flows into applicable forms of energy, such as electricity, heavily depend upon ecosystem functions as well. The conversion needs to be reproduced constantly, which implies that fundamentally different kinds of systems are required, because all renewables concern flows of energy instead of stocks, like fossil fuels or uranium that have been built up in geological processes over thousands of centuries.

Transforming energy systems into low carbon or carbon neutral is commonly referred to as the "energy transition". This term applies to the transformation of the structure of the primary energy supply, which requires the fundamental shift from a specific pattern of energy provision to a new state of a complete energy system [3]. As the nature of RE flows like solar radiation, water flows, or wind is fundamentally different compared to conversion based on stocks of fossil, biomass, and uranium, we need a real transition of our power supply systems. This requires a full transformation of these socio-technical systems (STSs). The recognition of the STS character is crucial in transition theory [4,5]. For electricity, this concerns technological change in the production and distribution of electricity, not only new sources of supply, but also setting up new business models, policies, new organizations, and eventually also designing new property regimes. This theoretical elaboration will show that the latter particularly applies to space and land use. The transformation is about doing all things—including the use of space—differently. This is what is usually referred to by the term *radical innovation* [6].

The overall objective is to describe the social innovation required in land use as part of the broader innovation needed for the establishment of electricity systems based on renewable energy (RE). This implies a comprehensive approach that goes beyond mere technological innovation and recognizes the importance of transforming the social, institutional, and regulatory frameworks that govern land use and energy infrastructure development. The core idea is to catalyze a fundamental shift in how land, space, and energy systems are conceptualized, governed, and developed—moving away from centralized, top-down models toward more distributed, participatory, and commons-oriented approaches. Policy decisions to accelerate energy transition will need to be aligned with changes in land-use regimes to enable the development of distributed infrastructure. This requires essential innovation in land use planning. As Gielen et al. [7] conclude, "infrastructure planning early on will be of paramount importance because of its carbon lock-in effect due to long life span and inertia."

2. The Land Use Issue

In transition theory, structural changes are referred to as 'regime shifts' [8]. The origin of radical changes within niches, mostly mere technical innovations, may potentially change the overall socio-technical regimes [9], which includes social innovation [10]. Even in the literature on accelerating the development of renewable energy (RE) in electricity supply systems, such as [7], the social component is hardly analyzed and referred to as creating obstruction and inertia, whereas the dominant frame remains a focus on technology (technological fix) and economics (electricity as a commodity). However, the social side and the land use issue are crucial to energy transitions.

2.1. Distributed Energy Systems

One of the main characteristics of renewables is their high geographical dispersion. Besides this, a sharp increase in infrastructure [11] is needed. The dispersion of the resources sometimes leads to the term "distributed energy resources" (DER). However, the real distribution through human action is, as in the original concept of distributed generation, associated with the actually constructed systems for conversion to electricity and everything that goes with it. These systems are human-made distributed infrastructures, and it is the rapid emergence of these new electricity grids we call *distributed energy systems* (DES).

These DES, as distinguished from natural resources (DER) that also have a different spatial distribution, may essentially grow into inter-connected local or regional *microgrids* with adjacent decentralized governance [12–15]. The trend of upcoming microgrids based on DES is widely recognized as a cornerstone of the emerging 'smart grid' [16]. Importantly, the essence of microgrids is that they can operate independently, although most remain connected to other microgrids and the overall polycentric public grid [15]. The notion of 'polycentricity' [17] reflects the resilience raising from bottom-up approaches instead of centralized, hierarchically imposed ruling [18].

Although most of the literature on DES is technically oriented, the transitions literature fully recognizes the electricity supply systems as STSs. A prevalent trend in social studies on changing electricity systems, however often with limited awareness of technical considerations, is the emergence of renewable energy communities (REC) [19]. Geographically dispersed, community-owned energy systems are widely recognized as a crucial element in the low-carbon energy transition [20]. This runs parallel with the emergence of concepts like energy democracy [21] and community energy [22]. In all these concepts, the notions about environmental justice and energy justice issues come to the fore [23,24]. These are strong determinants of all dimensions of the social acceptance of RE innovation [25].

Community RE seems essential for the active engagement of citizens in the transition to sustainable energy sources [26]. This implies a fundamental transformation: reorganizing ownership of energy, energy infrastructures, and energy systems. Transforming energy system's ownership and the governance framework for energy co-production and distribution in RECs implies a decentralization of social innovation [27]. Current electricity grids are heavily centralist and hierarchical systems, and, combined with usually fairly top-down oriented systems such as spatial planning, the institutional settings for RECs are currently highly obstructive. RECs and microgrid communities become part of a poly-centric power supply system, challenging the currently centralized grids. Besides these socio-technical changes, the most important resource for RE that is becoming scarce is space and land, required for all new infrastructures. This article focuses on land use transformation, as it is key in necessary regime changes in an energy transition towards RE, and the role of community engagement in these changes.

2.2. Outline

This article presents a theoretical survey. A comprehensive literature search was conducted using Scopus and Web of Science to identify all relevant peer-reviewed literature across three main topics:

1. The spatial requirements and land use for geographically dispersed distributed energy systems (DES), and the institutional changes needed to accommodate these.
2. The literature on smart microgrids, end-user activation, and energy communities.
3. The literature on common pool resources, social-ecological systems, and property regimes from the—institutional—perspective of governing socio-technical systems.

The elaboration in this article draws upon fundamental theories on the nature of renewable energy and the pivotal role of space, integrating insights from these sometimes-overlapping bodies of literature. (Section 3). After presenting the research question, it continues with an elaboration of the emergence of microgrids, both as a framework for integrating different RE sources, the increasing role of energy communities, and engaged end-users (Section 4). The theory applied to these STSs of energy coproduction is common pool resources, in which RE is defined as a free available common good (CPR, Section 5), with associated social acceptance issues. As the crucial element of the *coproduction* is the use of land and of other spaces, the consequences of CPR theory are described in an analysis of required changes in spatial and land use decision-making concerning DES infrastructures.

3. Characterizing Renewables

Among the ecosystem functions that are relevant for producing applicable RE are many elements that form necessary conditions for the production of the resources. The nature of those services and resources are determining factors for scarcity for their use by people. The factors include materials required for the infrastructure of power supply systems based on RE. Examples are minerals such as rare earth metals for electronics in devices such as wind turbines and solar panels, minerals for storage devices such as batteries, or devices with materials used for thermal storage. Obviously, the required mining these resources generates huge land use issues all over the world, because of the significant ecological impact of mining as well as associated equity issues [28]. However, the focus of this article is at the other side of the chain: electricity supply.

3.1. The Scarce Resource

The most scarce element in the natural resource of RE-flows is not energy itself. The dominant factor in almost any renewable source is the abundant flow of solar radiation. The prime scarcity factor is available space, sometimes resulting in requiring infrastructures for energy conversion, transmission, storage, and distribution [29]. High shares of renewable energy sources (RES) in the energy matrix is, however, a major challenge due to the low energy density per area unit and the stochastic temporal patterns in which RES are available. Distributed generation for energy supply becomes necessary [30]. This is due to the flow type of energy, in contrast with sink-type like fossil fuels, and the adjacent low energy densities [3]. The enormous spatial demand and the geographical dispersion of all these new infrastructures is making land use the prime issue in establishing low carbon electricity supply systems.

3.2. Space and Landscape

The required space and the implied land use of the electricity transition has been framed in many different ways. For example, similar to the issue of mining, one approach is to look at it in terms of 'energy colonialism' [31,32]. Such studies focus upon the deployment of RE megaprojects in peripheric areas, as well as on the nature of political and market powers applied for such deployments, and associated socio-political inequalities. Indeed, unethical types of land-use for RE do exist [33].

Spatial decisions have been the prime topic in studies of social acceptance processes (SA; Section 4.5) [29]. Energy will likely become the primary driver of landscape transformation in the present century [34]. The key in SA is *justice* [35,36]. Numerous studies on the SA of RE innovation have revealed that the most significant reasons why decision-making on acquiring space for projects, particularly land, fall into the following categories:

1. *Competition on scarce land:* As the resource is limited stakeholders, the most obvious reason for all stakeholders to object against land use for RE is the preferential use for other uses. Conflicts arise [37] when RE projects compete with other uses, such as agriculture, nature conservation, residential areas, other infrastructures, transport, tourism, and the military.
2. *Property rights:* Land use for RE infrastructures often involves leasing or acquiring land. Issues related to land ownership, other bundles of rights, and compensation can arise, leading to conflicts and resistance. Fair and transparent processes for acquisition and the recognition of rights are essential for justice [38].
3. *Ecological impacts:* The location and design of RE projects can have environmental and ecological implications. It generally implies clearing vegetation, affecting wildlife, impact on the soil, and environmental annoyance such as noise or flicker. Mitigating these impacts concerns prudent site selection, design, and environmental compensation.
4. *Perceived landscape change*, which is mostly referred to as "*visual impact*" [11,39]. The physical presence of DES infrastructures significantly alters the landscape. The appreciation of landscape contains four components: the subsurface, the ground level, the image, and the human experience. Visual impact is mainly a combination of the image and the human experience [39,40]. The predominant factor here is the perceived quality of the landscape before it is changed by the construction, but, unfortunately, most visual impact studies continue to narrow it to the visual aesthetics of the infrastructures or, in viewshed analysis, to mere visibility. As the visual impact depends upon the choice of the location, the perceptions on the landscape qualities of the alternative sites in host communities are crucial. Visual impact may become low or positive if the constructions, e.g., PV panels, wind turbines, and storage constructions, are perceived to match with the character of the landscape and fit with the values of the community [11].

Obviously, the process of the SA of all RE-related innovation and projects concerns more than the decision on acquiring spaces for RE infrastructure and adjacent distributed facilities such as transmission or storage. It is about the appreciation of new technologies, perceived risk, policy objectives—e.g., climate change, economic development—the distribution of costs and benefits, and more. In the SA processes, these topics often become entangled or are subject to spillover-effects. For example, objections based on the high expectations of visual impact may translate to beliefs about the lack of benefits or noise annoyance [41]. Furthermore, community acceptance is embedded in several acceptance processes. Although the notion that "public support can influence new technology adoption and deployment" ([42], p. 2019) holds true, acceptance rates among the public can never be considered a proxy for social acceptance, as many other actors are prominent in SA processes and become parties in conflicts, such as between municipalities, municipalities versus developers, and with hierarchical powers [43].

In community acceptance studies, 'the public' is usually operationalized as local residents, but that is reducing the acceptance process to '*affected residents*' [44,45]. Still, this tends to obscure the internal contradictions within communities itself ([37], p. 22), such as between neighbors on property issues and residents versus second-home owners [43]. Conflicts mostly emerge as *private* or *public RE projects* search for space that communities perceive as their *common property*. Therefore, we should focus on the community acceptance of land use and of land as a crucial resource investment in DES. It is about the co-production of these infrastructures by all actors in the community. The fundamental research question concerns the elaboration of a comprehensive SA process regarding community microgrids with DES: *What institutional changes, with regards to the use of land and other spaces, are needed for the co-production of DES in such microgrids?*

So, we will start with a brief overview of the elements in establishing DES and Microgrids as significant elements in future resilient electricity grids [46].

4. Microgrids

4.1. The Framework of Socio-Technical DES

DES should be recognized as a distinct concept. By their very nature, DES must be interconnected and, therefore, will be implemented in microgrids. All participants, prosumers as well as mere end-users, become members of community microgrids, and these have the potential to become the foundation of smart grids (SGs) [16,47]. Originally, the SG was introduced as a transformation of the electricity grid into an *adaptive complex system* [48,49], with the purpose to integrate DES in a *resilient grid* for the future, whereas the current centralized grid is characterized by instabilities and rapidly decreasing reliability [50]. With the introduction of less uniformity and more flexibility, the SG aims to be self-healing, adaptive, resilient, and sustainable, with the ability to predict outcomes under different uncertainties ([51], p. 2591). It aligns with the socio-ecological system (SES) [52] interpretation of an "*adaptive resource system*", with the resource comprising the natural supply of various carbon-free RE sources. This perspective also aligns with the growing recognition of power grids as ecosystems [50]. Therefore, the concept of smart grid has been developed to use the growing complexity of this STS to enhance its resilience in order to deal with all varieties of end-use, as well as the variations in the input of flow-type resources [47,53], and also to reduce the vulnerability of the grid with regards to natural disasters, e.g., storms or earthquakes [54,55]. The core of the smart grid concept is that, in social-ecological systems, resilience is based on variation, diversity, and adaptive capacity, whereas monocultures, such as the hierarchical central grid, are associated with vulnerability. The resilience is rooted in four fundamental principles (Table 1).

Table 1. Four basic principles of resilient smart grids [16,47,56].

Principle	1st Challenge *	2nd Challenge *	3rd Challenge *
Integration of different RE flows	Varying supply patterns	*Different owners* of *distributed generation*	*Geographical dispersion*
System flexibility	Inflexibility existing central public grids	Acceptance issues of demand response	*Lack of Storage and buffering capacities*
Socio-technological system character	*Central and hierarchical control paradigm*	*Achievement of engaging end-users*	Dominant techno-fix frame
Information and communication technology	*Ownership and control*	Privacy issues	Vulnerability: software and hacking

* *Italics*: Challenges associated with land use.

4.2. Smart Grid Principles

The first principle is the enhancement of the integration of different variable RE sources [57]. Optimal mixes are, to a large extent, determined by the local and regional spatial structures. This concerns the existing land uses and their density, e.g., of residential, commercial, industrial land or public amenities, the distance and availability of transport infrastructures, as well as the temporal patterns of energy demand and supply. This is implies significant spatial requirements, including land-use, as RE is only available in geographically highly dispersed distributed resources by numerous distributed generation units [58]. DES not only provide supply patterns based on dynamic energy flows but also include infrastructures for storage, *demand response* (DR), and integration with other energies (e.g., heat). DES represent a move away from the traditionally rigid centralized grid, that is, with its monocultural design lacking compatibility and mainly dynamic flexibility.

The second principle (Table 1) revolves around *system flexibility*. Essential for self-healing and adaptivity, recovery capabilities have been deemed fundamental for SGs [16,47] overcoming vulnerabilities due to the rigid monoculture of the uniform centralized electricity grid. Acquisition of space is crucial for infrastructures necessary for flexibility.

Recognition of the *STS character* of electricity supply systems is the third principle. Among other things, it implies that RE deployment and flexibility may fall apart when the proposed technologies and infrastructures are not embedded in adjacent innovations in the social determinants of the systems [59,60]. It is about changes in the purposes, the agents who are in control, as well as the tensions between RE and the existing conventional ways of generation, and, hence, about incumbents in existing centralized grids with their vested interests. This not only concerns the infrastructure of the production–consumption chain but also how the greatly increased use of space and land use is organized.

Finally, a factor that is also entangled with the STS-character is that electricity supply becomes integrated with *information and communication technology* (ICT) as a tool to make it all happen. Following early efforts to create RE communities by integrating wind generated power with household demand by demand response [61], ICT is used for the dynamic control of energy flows and capacities of generation, storage, transmission, and end-use. Such combinations of digital control systems are expected to enhance the ability of both customers and utilities to monitor, control, and predict energy usage, thereby facilitating the reliable integration of various generation sources and demands [62,63].

4.3. Energy Communities

All elements within the basic principles of SGs can be valued differently. From the resulting different smart grid definitions [51], for our purpose, we adhere to a comprehensive definition that remains close to the original objective of the SG concept: "a network of integrated microgrids that can monitor and heal itself" ([47], p. 570). These microgrids must be governed and organized, incorporating distributed generation based on renewable sources, along with other necessary elements of flexibility [64] that are required for integrating variable generation, such as storage capacities and demand response (DR) capabilities. As STSs, they need to be organized, which implies the activation of end-users [65], not only in DR to variable power supply but also transforming the passive response to suppliers into active participation as prosumers [66] in installing new grid infrastructure. Eventually, microgrids connect a selected group of prosumers and consumers and other actors engaged in the governance and management of DES, which defines a microgrid 'community' [67,68].

In order to become a microgrid community the infrastructures are coproduced by any form of cooperation [12,15]. The space issue implies that this coproduction also concerns the cooperation of relevant actors in acquiring space [11,69,70], beside the electricity that is co-produced. The community governs and shares the infrastructures and capacities for generating, storing, and distributing energy, facilitating *peer-to-peer* (P2P) delivery of energy within the community's microgrid [71]. Thus, DES microgrids present a targeted approach to implementing community energy systems [72]. The focus is on the technologies and infrastructures combined with the social structures of the production–consumption chain from renewable energy sources to end-users in the community who govern the DES microgrid [67,68]. The fundamental premise of DES in microgrids is that they can be regarded as ecologies, serving resilience and sustainability [15,73]. They emerge and operate STS, as described in Ostrom's SES framework [52,74].

Within the scope of limiting required transmission capacity, required land use for infrastructure, and integrating spatially dispersed renewable generation, several conceptual ideas have been developed. For example, one that has been particularly framed within policy is "Positive energy Districts" [64,75]. The EU's Strategic Energy Technology Plan has aimed at creating 100 positive energy districts (PEDs) in Europe by 2025. PEDs are "energy-efficient and energy-flexible urban areas or groups of connected buildings which produce net zero greenhouse gas emissions." [76]. They are supposed to actively manage the local or regional surplus production of renewable energy. They require the integration of different systems and infrastructures, with "interaction between buildings, the users and the regional energy, and mobility and ICT systems, while securing the energy supply and a good life for all in line with social, economic, and environmental sustainability" [77]. PED is a broad EU frame, but other policy drivers of community energy can be found in EU directives as well, such as the Renewable Energy Directive II (RED II), and with EU definitions of renewable energy communities (RECs) [10,78].

4.4. End Users' Activation

Communities can be defined in various ways [79] with regards to transforming power supply systems. Community members have different roles, acting as consumers and as citizens, so their participation goes far beyond taking part in decision-making [80]. In the consumer role, the question is also about participation: "What are the drivers that enable certain groups of energy users to act together and develop collective solutions for smart consumption and prosumption; and what are the institutional lock-in factors obstructing this?" [81]. For example, a prime factor in the ongoing growth of electrification is the rapid increase of charging electric vehicles (EV). This load is geographically dispersed, and it is also important for the direct utilization of RE-generated power because of its battery buffering capacity. It is separated in charging at home, at private parking places—e.g., for employers or charging stations along the way—and at public parking charging stations. All these places can be included in community microgrids. However, this participation requires the strong commitment and engagement of end-users as well as the electricity retailers.

The engagement goes beyond co-producing the energy system itself. Participation should avoid channeling people into system-defined positions, such as user, clients, beneficiaries, or 'those affected' [26]. In their role of citizens, participation is primarily in decision-making processes about siting infrastructures and acquiring required space. The activation of end-users in the supply–consumption chain has to be accompanied by the empowerment of users in the governance of STS of power supply [82], particularly the empowerment of prosumers [15,66].

The technical criterion for defining microgrids excludes governance and economic aspects, but the latter are pivotal for the observed trends away from centralized electricity system. Currently, focus is shifting towards the business models and organizational designs enabled by local energy provision in microgrids. This shift is made possible through the availability of distributed generation coupled with ICT. It is worth noting that the shift from public (DSO) to common or community models is a socio-political construction, challenging strong path-dependent and locked-in institutionalizations [8,47,83]. This lock-in is embedded not only in legislation and incumbent organizational structures but also in policymaking [84]. It is paradigmatically reinforced by socio-political framing [85] and, as will be discussed (Section 6), these frames also concern fixed patterns in thinking about ownership and the use of land.

4.5. Acceptance Processes

4.5.1. SA of Broad Renewables' Innovation

From the beginning in the 1970s, with mainly wind energy projects, SA problems were mainly linked to location choices, i.e., land use. Fortunately, the NIMBY label, as a disabled concept, has long been reduced to what it is, a policy frame used by developers and policy makers [85]. Currently, most acceptance studies of RE apply approaches that recognize three distinguished levels in decision processes [25]. For *community acceptance* of RE, the backyard-frame has been replaced by theories of place attachment, concern for local identity, and quality of life [86,87]. Explanation for the *market acceptance* and the *socio-political acceptance* of pushing the implementation of contested RE projects or resistance to integration of RE in existing power supply systems can be found in institutional lock-in [83], combined with dominant neoliberal market-driven policy frames [84]. A cornerstone of the lock-in is the current heavily centralized structured and governed grids and adjacent paradigms. An example of centrality is the consideration of the deployment of renewables in "utility-scale solar photovoltaic (PV) and onshore wind" being the cheapest option [88]. Implicitly, such statements neglect the most difficult parts of the innovation, which are the scarcity of space, taking for granted the organization structures of current power supplies in commercially and state-organized companies ('utilities'), and the resulting congestions in SA processes of renewables. Essentially, 'utility' is not a scale, neither of organization nor geography [89]. It is merely a specific type of organizing the provision of public goods, often attributed to private companies. The shift towards the recognition of RE as a manifestation of a *common good* (Section 5) may become pivotal in the transformation of the STS of electricity supply.

Although in the past, Feed-in-Tariffs (FiTs) have served as the most important policy to support community energy projects [90], these are targeting mostly single technologies, e.g., wind or solar, and they do not address issues of transmission, storage, and distribution capacities. Combined with neoliberal state reforms concerning the promotion of unfettered competition by removal of the state's common and social affairs [91,92], this is leading to the decreased social-political and market acceptance of FIT-systems among policymakers and energy sector incumbents. It has triggered a renewal of charging for installed distributed generation capacity or implementing auctions for RE permits [93]. This 'panacea' tends to crowd out communal projects and small developers and implies a heavy market-frame for decisions about location and land use [94]. It triggers perceptions of injustice [95] with a destructive impact on community acceptance. This becomes primarily manifest in decision-making on the acceptance of land use for RE installations and other infrastructure, such as transmission lines. Such effects also highlight the strong dynamics of community acceptance [96], as affected by institutional conditions defined at the social-political level [45]. At all levels of acceptance, decision-making on land-use issues is highly topical (Section 6).

4.5.2. 'Communities of Interest'

Not only with regards procedural justice in decision-making but also concerning the distributional justice, the issue of how possible local benefits are generated and distributed is relevant. These are interrelated and dependent upon ownership and control over the DES infrastructures [38]. Direct flows of revenues and other generated benefits enhance perceived acceptability and approval, whereas payment to members of the communities of the affected remains problematic as it is based on a flawed approach of the economic compensation of perceived environmental risk [97]. The question of community benefits that is addressed most often is an instrumental one: To what extent might the provision of greater flows of benefits to 'communities of the affected' increase the community acceptance of the development and expedite the decision-making process? [97]. In terms of market-oriented, private, and commercially driven projects, this instrumental approach often leads to considerations about how to create compensation schemes [98]. This neglects the prime cause of unequal distributions. Among affected communities, the perception of justice in land use decisions is primarily informed by property regimes (Section 6.1). It is about the issue of the ownership of RE facilities [99], the allocation and sharing of benefits and damages between stakeholders [100,101]. The most obvious way to let affected communities get their fair share of benefits is not to compensate them but to turn them into 'communities of interest' that define the shape, location, purpose, and governance of their own DES infrastructure. This includes the use of their own resources, and their prime resources are space and land.

4.5.3. Focus on Land Use

Addressing land use issues in a comprehensive and inclusive manner is essential for securing the SA of RE innovations [11]. By understanding and addressing the concerns and interests of local communities, stakeholders, and the environment, it is possible to navigate land use challenges and build a foundation of support for the transition to RE. Although spatial planning systems significantly diverge among most countries, in general, current spatial planning regimes are unfit to deal with RE, often framed as too slow in reaching decisions and unreliable in awarding consent ([102], p. 524). However, this is primarily a developers'—either private or public—perspective, originating from frustration among developers and policymakers. Currently, when land use plans and planning systems are investigated, the conclusions are that these are not positioned to manage the place-based opportunities and impacts associated with RE development, as shown for Canada, for example [103].

In most countries, these systems do not prioritize community needs and concerns with regards to energy, land use, and landscapes [104]. For land, all types of applications for energy infrastructure compete with other forms of land use, and most of these are expressions of values held by community members. As in the co-production of DES in community microgrids, the expressions on the landscape that are connected to different land-uses are twofold. They concern expressions of *productivism*, such as farming, work, production of commodities, extraction of natural resources, and commercial and industrial production. On the other hand, there is *consumptive* use, such as place-based recreation, tourism, cultural heritage, agricultural tourism, and nature protection, including the values of the landscape's scenic character [103]. Based on the validity of the concepts of sense of place and place attachment [105], the prime factor creating complexity is that it concerns expressions that are "in the eye of the beholder" [39,106]. Basically, it also reflects a fundamental principle in the sustainable governance of natural resources and environmental justice [24].

4.5.4. Co-Production of a Natural Resource

As they heavily depend on local geographies, flows of RE like solar, wind, geothermal, marine, or hydro-power may be locally scarce. Nevertheless, as most RE is based on solar energy, it is not scarce, but the required space and land are scarce resources. Hence, the crucial question is how to organize and govern the production and allocation of sustainable electricity supply systems with the tight availability of land.

Currently, our power supply is organized with a high degree of centralism combining public—state controlled—and private—commercial—elements within a strong market frame. This is also the dominant approach to renewables. Many studies describe goods and services produced and delivered in the STS of power supply merely as "public" services (associated with state regulation) or "private" commodities (associated with markets). Unfortunately, even researchers regularly seem to consider this juxtaposition of public and private in power supply as self-evident that even if they investigate local DES communities, they often frame it as "local energy markets" [107]. This way the most fundamental element, that of citizens cooperating in decision-making about their scarce space and land while sharing the capacities to harvest the natural resource of RE, is obscured. Even the basic activity to jointly co-produce such DES remains, in most publications, framed in market terms [85].

5. Common Goods

5.1. Current Public-Private Frame

Within society, markets are not the only way to allocate scarce resources. Some things cannot easily be divided into discrete chunks that, as a commodity, can be sold in a market. These include common-pool resources that might be owned by the community, not an individual, or even may not be owned at all, like solar radiation. Communities may come up with their own rules about who, and when, and how such a shared resource can be harvested.

Energy providers sell their product, electricity, in markets that have been shaped by state legislation. Originally, electricity was completely distributed within separated commercial grids, but in the first half of the 20th century, in many countries, grids became connected, power generation became centralized and was confiscated by the state, building larger centralized monopolistic public grids [108], and electricity provision was considered a "public good" provided by 'utilities'.

In the neo-liberal motivated privatization waves of the 1980s and 1990s, most power generation activities and large-scale production of utilities controlled by public authorities became separated from grid management in private enterprises; however, they were still regulated within heavily centralized public legislation. After this wave of privatization, the generated power became defined as a commodity, a "private good", produced in competition by mostly private companies [109]. Electricity is provided by privatized actors (generators), and the service of distribution is often provided by trading companies, which engage in wholesale purchasing and retail sales. They are using the grid that mostly is still publicly managed, a monopolistic infrastructure, and the connection to it is a "public good" provided by the DSO, a state-controlled grid operator.

5.2. Challenging the Public-Private Frame

The new emerging DES in integrated microgrids form the foundations of the ecology of the new polycentric electricity supply systems [110]. There is a significant role of end-users, partly becoming prosumers, collectively providing a product that classifies as a "common good" instead of the dominant electricity-frame as a commercial commodity. Policy is yet to recognize this potential. The power supply lock-in is not only embedded in sunk costs and vested interests of the existing grid but also in paradigmatic views [56]. Currently, grid managers (DSOs) are legally obliged to connect consumers and to deliver electricity regardless of consumption by others, a typical public service. Most legislation and operational procedures of power supply are still enforcing that prosumers are delivering a market-commodity instead of sharing goods and services that they co-produce [111].

For example, the EU's RED II is an interesting step forward to furthering RE in communities. However, electricity is still considered a private commodity: "Support schemes for electricity from renewable sources shall provide incentives for the integration of electricity from renewable sources in the *electricity market* in a *market-based and market-responsive way*" [EC, art4:2]. Clearly, still mainly defined in market terms is the EU definition of RECs [27] as legal entities based on open and voluntary participation, which are autonomous and effectively *controlled by shareholders* localized close to the renewable energy projects that are owned and developed by that legal entity. Though this emphasizes localized property, it still does not primarily consider the participants as social community as co-producers and *cooperating citizens*, but it continues to define them as a set of individual shareholders and consumers, economic actors operating in a market.

5.3. Institutions

The centralized STS is a regime of which the elements of either public and private goods are firmly defined and laid down in legal regulations. This crucial element of the system's lock-in [83] asks for regime change [8]. The "rules of the game" are challenged, as prosumers take a role in managing the energy flows [112]. Those "rules of the game" ([113], p. 5) and the prevailing habits of thought are the *institutions* that require necessary change to open up centralized uniform electricity grids in order to further DES, including the engagement of communities co-producing those microgrids [68,114].

If we look at the institutional conditions that would create favorable options for the establishment of renewables as a common good, we recognize that these options are generally ruled out deliberatively during the broad movement towards monopolization and nationalization of power supply systems [115]. In the era when electricity became a state controlled public good, it concerned the nationalization of former private initiatives. Local and regional and regional grids were linked into regional governmental utilities under the regime of central national legislation. The privatization of power generation under the emerging neoliberal regime even required stronger central regulation. Competition was introduced, but as large-scale power generation was considered a 'natural' monopoly, the introduction of competition required strong, newly introduced market regulators and uniform market protection rules.

5.4. Common Property Regimes

For *common goods* (Table 2), the concept of co-production is essential [116]. The recognition of co-provision as relevant for RE was the first sign of this new emerging phenomenon in electricity supply [117]. The concept of common goods particularly applies to sustainable harvesting and the use of natural resources, in our case, RE flows. A significant role for ownership and other levels of property is particularly important for the empowerment of end-users [118], as well as the participation and activation of prosumers [22]. Co-production of infrastructure to provide the common good in SES [52] finds its counterpart in the STS of DES microgrids. [15]. Within autonomously operating microgrids, the common infrastructure also requires co-production in terms of cooperation in investments of resources. Within the commercial and market frame, this is recognized as financial investments. Obviously equally important is the investment of the most scarce natural resource related to RE—the contribution of community members to the required space, needed for all infrastructures of generation, storage, distribution, and flexible end-use.

Co-production by prosumers is based on the concept of the shared economy, with common distributed generation and commonly installed and managed storage [119] being shared and delivered peer-to-peer. This implies, also, a certain level of sharing the space for these infrastructures, on land, but primarily as much as possible within buildings, on top of buildings, or integrated in other infrastructures. Most of the devices, such as generation units or storage capacities, as well as the space allocated can either be individually owned (e.g., rooftop PV panels, batteries, or electric vehicles), or they may be commonly constructed and owned (e.g., ground-mounted PV, arrays on rooftops of apartments, enterprises, or public community buildings).

Table 2. Common goods, distinguished from private, public, and 'club' goods ([120], p. 24).

		Substractability of Use	
		High (Exclusive Substraction)	Low (Non-excludable)
Access or exclusion of potential beneficiaries	High: Rivalrous consumption	Private good/service	Common good/service
	Low: No rivalry in consumption	Club/toll good/service	Public good/service

5.4.1. Rights of Access and Withdrawal

The nature of electricity generated and used in DES microgrids as a common good is determined by three characteristics: the resource, access to it, and the substraction of it. The term 'access' describes the right to enter a certain physical property, for example a natural resource like solar radiation or the flow of a river. Obviously, a resource like solar radiation is freely available; however, only in the case where one is able to install an energy conversion installation. This depends on the right to use a certain surface that catches the sun, so this is about space, e.g., the roof of a building, or a parcel of land. 'Substraction' or withdrawal refers to the rights to obtain the products of a resource, in our case, electricity generated within a DES microgrid. This requires connection to that microgrid with a certain capacity, e.g., 6 or 12 kVA for households.

In terms of substractability, electricity is rivalrous. Any kW provided to one end-user cannot be used by another (Table 2, top). However, once the 'right to prosume' is settled for every individual end-user, any prosumer capturing the power of the sun with rooftop panels can do so without excluding other users to do the same. If they share their capacities, they produce a 'club good' (Table 2, low left), but by creating access for other users the electricity within this microgrid it becomes a common good (Table 2, top right). That is, if this is not blocked. In most existing legal arrangements, prosumers are forced to deliver their surplus to electricity companies only—mostly private—via the public grid. That is de facto state coercion to sell your electricity as a private commodity, with associated market rules. Moreover, the availability for an individual consumer is strongly restricted if the electricity is limited to what she can generate. This primarily concerns the exclusiveness of available space. Space is the scarce resource and furthermore subject to competitive functional claims. For that reason, it becomes highly beneficial to cooperate in order to acquire the space needed for the infrastructures. The investment of space by the community members is crucial, and the cooperation to acquire these investments, including land, for the co-production of DES concerns the creation of common value. Located top-right in Table 2, it becomes a common good [121,122].

5.4.2. Governance and Management

All resources, space, financial capital, social capital, capacities of generation, transmission, and storage can be managed in a common system of operation and control. The STS of the smart microgrid corresponds to the concept of SES as the basis of the *adaptive governance* of sustainable natural resource governance [58]. Essential for operating a SES is the collective action at multiple levels opening up the possibilities for self-governance in such systems [17]. The common pool resources theory has, besides the SES-framework, another essential extension, which is the Institutional Analysis and Development (IAD) framework [123], which describes institutional conditions for adaptive governance of SESs. The significance of including the institutional level is twofold, primarily because those institutions should avoid 'panaceas' [17,18], often implying top-down imposed monocultures. Geographical variety among different communities, their distributed energy resources, and, hence, their community microgrids should be fostered. Secondly, geographical contexts also show a wide variety that should be served. The concept of smart microgrids based on locally available RE resources does not only apply in developed countries but is also relevant in the context of developing countries, which sometimes lack existing public electricity grids [124,125].

The essential elements of CPR theory are eight institutional design principles in the IAD framework that should be considered crucial for the success of sustainable social-ecological systems [120]. The two most relevant for DES and the required space are the following:

- "Congruence between institutions and local conditions" (#2). This, for example, reflects the need for an *optimal fit between RE* infrastructures such as PV or wind turbines, with *the landscape values and needs of the community* [11].
- "Minimal recognition of rights to organize by external government authority and respecting of local rules" (#7). This is about *avoiding all "panaceas"* [18] that tend to produce uniform recommendations that are insufficiently place-based [2].

The consequences of this are far-reaching, in particular for how property rights of land and space should be adjusted to enable DES infrastructure in microgrid communities. We can observe critical conditions for developing STSs of microgrids with DES in the current centrally organized electricity grid that are based on strong legally defined market regimes and publicly managed distribution networks. For common initiatives, there are many systemic obstructions. These can be of two kinds, namely created within the governance system or through physical interventions in the resource system (see below).

The exclusiveness of the energy harvested from flows only concerns the scarcity of available space required for such harvesting. As there are many competitive functional claims for using space, it becomes beneficial for consumers to cooperate as citizens and build energy communities around distributed energy systems. The rapid development of 'smart' in the management of these common systems enables prosumers and consumers increasingly take part in harvesting the natural resources, and, by doing this collectively, they operate in self-organizing communities. Hence, essential questions not only concern how to participate in coproduction [80,116], but also how to organize and govern such collaborative efforts [12,15,126].

6. Investment of Spaces

6.1. Property Regimes and Using Space

6.1.1. Property Regimes: Access

The common sense understanding of a common-property resource is that it is easily assumed to reflect property owned by no one or, alternatively, by the state or the government. However, the reality is that there are many different types of property that imply different grades of control and different modes of exercising that control.

Central to the concept of "common goods" is the idea of property. For electricity supply systems, there are many different forms of ownership, although most of these are primarily linked to the various forms of infrastructures, such as distributed generation, storage, transmission, and distribution. The property and control of these are strongly informed by the property of the spaces that are used, especially land, roofs, and the subsoil.

Within CPR theory, Schlager and Ostrom [127] introduced an ascending series of entitlements, called '*property regimes*', ranging from 'authorized user' to 'claimant' to 'proprietor', and to 'owner' (Table 3). The presumption is that 'owners', for example, of a home with solar PV on a rooftop, or owners of a parcel of land, are not the only resource users investing in their resource systems. At the collective-choice level, their rights of control are shared with several others who hold different degrees of rights.

Table 3. Relevant property positions and associated bundles of rights [127], with RE examples.

Bundles of Rights	Owner	Proprietor	Claimant	Authorized User
Access and withdrawal	X	X	X	Right of way; transmission lines; access to a MG
Management	X	X	Claimed visual impact; 'Sense of ownership'	
Exclusion	X	Permit for ground mounded or rooftop PV		
Alienation	Electricity from E-company's solar plant			

Community members may have individual generation capacity, e.g., solar panels that they own, because they have bought and installed them on the rooftop they own. Alternatively, their rooftop may be used to install collectively owned PV panels. Alternatively, individual or collective PV panels may be installed on shared rooftops, for example, in the case of apartment buildings. Another alternative may be collective panels placed on public or community buildings. In all those cases, the question is whether the 'owners' have all rights, from access to the rooftop to alienation.

Collective-choice property rights include management, exclusion, and alienation (Table 3), besides the access and withdrawal rights that defines the common good's character of RE (Table 2). At first sight, the propriety of a home implies full access for the installation of PV panels on a rooftop, or a storage capacity like a battery or super-capacitor in-home. However, most countries have serious legal claims limiting the access rights, primarily, if one is renting the house but also if the roof is part of an apartment-building with a collective property. There also may be legal restrictions with regards using the rooftop or space within the home to install certain equipment, e.g., for security reasons. The latter also concerns, for example, legal claims for preserving scenic views or the appearance of buildings. Many countries require permits for installing PV panels, which implies that property is partly executed by a municipality or another authority. Further restrictions or outright denial of use (exclusion) may result from the monumental status of buildings, which is a strong restriction for solar power close to demand [128]. Other strong legal claims or proprietor rights may result from the status of ecological valuable land, which can exclude land use rights for ground-mounted PV plants, wind turbines, storage facilities, or even restrict the right of way for transmission lines. Besides access, there are three other 'bundles of rights' that imply restrictions for the rights, particularly those of "owners".

6.1.2. Management

The right to regulate internal use patterns and transform the resource by making improvements. Currently, in most countries, once PV is installed on a rooftop, one may use the power generated for one's own consumption, but for collective use there are strong restrictions. DSOs or energy companies are legally the claimants of excess power. Most countries only allow feed-ins and selling excess power to the public grid.

6.1.3. Exclusion

The right to determine who will have access rights, and how those rights may be transferred. Typically, one can decide to use the roof for one's own solar panels, while others do not have the right to use your roof, unless you allow them to do so. The latter often occurs when power companies are hiring several rooftops in districts for PV installations in order to use the rights to manage and sell the power that has been generated.

6.1.4. Alienation

The right to sell or lease either or both of the above collective-choice rights. In most countries, one is not allowed to deliver electricity generated on rooftops to neighbors, even if they are also owned by those neighbors. That is, there is the legally mandatory claim of the DSO or the energy company to sell it to them. Possibly, this right may change in some EU member states if the RED II directive [78] is translated into national law.

6.2. Property Regimes and Land Use

Crucial issues with regards coproduction and community management and use of RE generated power are about the energy flows and the capacities for generation, transmission, energy management, and storage. Almost any understanding we currently have on the emergence of DES in microgrids is based on the aspects of energy flow and capacity management [129]. Particularly important, but there is hardly insight into how all this infrastructure should be created and where it should be located. This is precisely where a large part of the challenge lies in actually creating this crucial foundation for future smart grids. As space is the prime scarce resource, and all spaces are subject of different properties, the impact of property regimes on the acquisition of required space for all the infrastructures becomes crucial for creating microgrid infrastructures.

According to CPR theory, in the co-production of natural resources like RE-generated electricity in the STS of community microgrids, high levels of self-governance prevail [17]. This implies that current property regimes of space and land-use, which are mainly based on private and public ownership, require fundamental institutional changes to turn them into resources that can be collectively managed and used.

All actors who are relevant in establishing DES-based community microgrids hold different positions (Table 3) in terms of the spatial resources they should bring into the common system. Because land is scarce and has many other functional claims, as much space as possible should be combined with other uses. Primarily, the use of roofs, but wind turbines and ground mounted solar panels, can also be combined with growing crops [130]. As most roofs are privately owned, the input is dependent upon the willingness of the owners who hold exclusive rights of access to invest in RE. At the same time, if their RE-generated electricity can only be applied for self-consumption, this material participation will remain very limited. In reality, the alienation rights of energy companies for the excess power are sometimes combined with taxing schemes. An extreme example is the so-called 'Tax on the Sun'—implemented in different ways in Australia and Spain. It is legislation that tries to restrict the free use of the natural resource, although solar radiation is not rivalrous (Table 2). This obstruction of access to a common good is an effort to enforce the frame of electricity as a public good by legislation, but it does so by narrowly defining electricity as a commercial market good to be sold in the current electricity grid [131]. So far, it has hindered electricity self-consumption, leading to a decarbonization slowdown [132]. All existing property rights regarding electricity, primarily those linked with the rights of the owners of roofs and land, must be reconsidered for implementing favorable conditions for DES in microgrids.

6.3. Reducing Land Use: Buildings

Legal and practical rights may vary, but current regimes in most developed countries for relevant actors and their "bundles of rights" are presented in Table 4. Indeed, most property positions are either determined by private—commercial or civilians—ownership or public—state or local governments—ownership. For common goods, many positions of Table 4 may be challenged by institutional changes to create better conditions for establishing community microgrids. Within community microgrids, several different kinds of actors can become prosumers or have access as consumers.

In fact, resilience in SES or STS is enhanced by avoiding monocultures. Including a variety of actors with varying demand patterns and also varying resources—spaces, financial, and social capital—will enhance resilience [74]. All actors with interests in the resources, space, social, and financial capital should be engaged local authorities in the first place.

Table 4. Distributed Generation & Storage [W2018]: Actors, their Spatial Resources, and Property regimes.

Principle	Generation & Storage Type(s)	Spatial Resource	Property Regime
Individual households	Solar PV Solar collectors --------------------- Small batteries; EV Hot water boilers	Rooftop ----------------------- Indoor	Access, Management, restricted Exclusion
Group of house-owners (e.g., apartments)	Coll. solar PV Solar collectors --------------------- Ind. and coll. batteries; Ind. hot water boilers	Rooftop ----------------------- Indoor	Restricted Access Coll. Management ----------------------- Access; Management
Group of households (rental apartments)	Coll. solar PV --------------------- Small batteries; Hot water boilers	Rooftop ----------------------- Indoor	Lim. Access ------------------- lim. Management

Table 4. *Cont.*

Principle	Generation & Storage Type(s)	Spatial Resource	Property Regime
Co-producing households (different kinds)	Coll. solar; coll. Wind turbines * --------------------------- Ind. and coll. batteries Hot water boilers Coll. thermal storage	Shared land ** Rooftops --------------------- Indoor, shared land Subsoil	Coll. & Ind Access Management Exclusion ----------------------------- Coll. Access Management Exclusion
Communities co-producing microgrids	Collective solar Collective wind * -------------------------- Ind. and coll. batteries Ind. hot water boilers Collective thermal storage	Shared land ** Rooftops: Private and Public buildings ------------------------- Indoor: Public and individual/ shared land/space/ subsoil	Coll. Access Management Exclusion ----------------------------- Coll. Access Management Exclusion
Farmers	Individual solar Indiv. wind * Bio-energy ----------------------------- Hot water/cooling ins. Batteries	Rooftops (home, stables) Indiv. land ----------------------------- Indoor Land subsoil	Access Management Exclusion ---------------- Access Management Exclusion
Natural reserves (ecological values)	Small scale hydro Geothermal -------------------- Pumped hydro Geothermal	Land --------- Land	Limited access Management Exclusion ----------------- Limited access Management Exclusion
Small scale enterprises (e.g., Shops, manufactories)	Solar PV -------------- Batteries Hot water/ Cooling	Rooftops ---------------- Indoor	Access Management limited Exclusion --------------- Access Management Exclusion
Industries	Solar PV Wind * Bio-energy ------------------ Batteries Thermal storage	Rooftops Land ------------------ Indoor Land	Access Management Exclusion ----------------- Access Management Exclusion
Local authorities (incl. public buildings)	Collective solar PV Collective wind * ---------------------------- Collective Batteries Thermal storage	Rooftops Public spaces Land ------------------ Indoor, public spaces, land, subsoil	Collective Access Management Exclusion ---------------- Collective Access Management Exclusion
Local or Regional Grid manager (DSO)	Grid scale storage ***	Grid infra public space (e.g., transformer houses, LV transmission)	Limited Access Management ***

Table 4. *Cont.*

Principle	Generation & Storage Type(s)	Spatial Resource	Property Regime
Not local authorities/ gov. agencies with land	Large scale RE Hydro, solar, wind, geothermal ----------------------------------- Pumped hydro Geothermal storage	Land	Access Management Exclusion ----------------- Access Management Exclusion

* depending on geographical conditions, other RE sources, e.g., geothermal, near shore energy, etc. ** shared land, either rented or owned by community member. *** Storage of different kinds and scales. e.g., currently, DSOs still have control over individual indoor thermal heating; remote readable meters (currently framed as 'smart meters') can be used for controlling consumer/prosumer demand (DSM, demand side management) and generation.

In order to limit the use of land, the priority should be to reduce the distances between generation and end-use with DES and to combine DES with other already existing uses of space. For the built environment, the integration of energy requirements should become self-evident [133], comparable to other functions that are already integrated in the built environment. In developed countries, we do not build houses without freshwater connections, sewerage systems, mandatory minimum entrance of daylight, safety standards, mandatory waste management, etc. In comparison, we need institutional arrangements enforcing the optimal use of space at collective levels in the built environment, for the application of natural energy resources, matching with the physical and social geographical contexts.

For rooftop solar PV and small-scale batteries, households should have almost unrestricted access rights. Currently, most countries apply legal restrictions, e.g., require permits for installing and have regimes of excluding PF. Based on the invalid assumption that visual impact equals visibility, most approaches tend to exclude PVs that would be visible from street levels [134,135]. For shared rooftops or common areas, e.g., apartment buildings as the obvious case of a common microgrid, the owners should have collective access, management, and exclusion rights, not only on their common rooftop but possibly indoor space for collective thermal storage or batteries as well. A wide variety of legal restrictions currently exist, either imposed by governments or by energy providers or DSOs. Sometimes these obstructions are contractually imposed during the project development phase. Occasionally, installation is outright prohibited, based on cultural heritage or the monumental status of houses, and sometimes local authorities hold the right to refuse permits for any other reason, sometimes based on political ideology. Even in case PVs may be installed, exclusion rights to use and maintain the systems and to decide about who else can use their rooftop space are currently mostly restricted.

In rental apartment buildings and districts with substantial rental housing, tenants should have access and management rights to install small-scale solar or batteries on their private spaces. As the owners currently maintain primary control, legal obligations for cooperation with collectives of renters should be introduced. This could be combined with subsidy schemes that are targeted towards rental houses and their low-income renters. For newly constructed buildings and districts, legal obligations for applying all local available options for installing DES should be considered. This balances the tenant's ability to benefit from RE with the owners taking part in the co-production for the overall building infrastructure.

The classic forms of community energy, households and private enterprises cooperating in local communities, may be shaped towards RECs by institutionalizing rules that these groups get collective access, management, and exclusion rights over their shared RE generation, storage, and distribution assets. The investment of their individual private exclusive rights, this facilitates community-owned and operated microgrids that can optimize energy use across multiple households, small enterprises, and possibly local industries. Public space, including roofs as well as land, can be used as well, with local authorities taking part in these initiatives. A so far largely underestimated part of DES is integrating community energy storage, which, in the largely centralized and monoculture of the present energy system, demand socio-technical innovation [136]. Beyond the model of P2P trading establishing a market only among individual end-users [137], they should not only be able to organize P2P delivery of energy but also the collective management of all capacity to establish a distributed system. Additionally, the prime investments in those capacities are based on the invested resources of space. Hence, they should be able to decide on the location and space for the storage capacities, as well as the shared management of them.

6.4. Land Use and Property

The institutional changes described above to further DES infrastructure in order to maximize proximity between generation, storage, and end-use also contribute to limiting the requirements for additional land use and the associated conflicts [138] for even more energy infrastructures, such as transmission lines. Nevertheless, the demand for space in the future smart grid (Table 4) increases so much that new land for DES infrastructure becomes inevitable. This has two sides: first, it cannot be achieved without affecting the current property rights and positions of several actors. Second, because the ownership of land and other applied spaces strongly constitute a gateway to ownership of energy infrastructure on it, it also affects SA processes, because the ownership model of the DES assets, e.g., community, shared, or private, does affect perceived justice and acceptance [35,38,139].

Farmers, local enterprises, and industries generally hold access, management, and exclusion rights over RE infrastructure, not only on their own rooftops but also on their land. Currently, many farmers generate power to feed into the grid or they lease limited areas of land that leave other uses intact, e.g., for wind turbines [140]. Such activities are often private profit-making ventures. The payments to landowners may indirectly help to revitalize rural areas, particularly in cases of areas lacking public property, and where community wind farms are legally banned [141]. However, only landowners tend to benefit, possibly with local distributional justice issues. In some countries, regulations propose to include participation in decision-making for local communities in RE deployment. However, community acceptance of these models often remains low as the communities feel they have certain property rights, e.g., a 'sense of ownership', as 'claimants' regarding major landscape changes [142]. These are not recognized, particularly when the developments are imposed by public or private actors outside the community [143].

The key is to align the property rights with the scale and purpose of the new DES infrastructure of the entire microgrid community. This will likely require a balance between individual, community, and public interests to unlock the full potential of distributed energy resources. This may imply a restriction to the full exclusive rights of landowners, primarily like farmers, but also impose new obligations to use spaces in the built environment.

Local authorities and government agencies should have certain access, management, and exclusion rights over private owners to enforce the cooperation in the establishment of RE, storage, and grid infrastructure. Sometimes, they may be able to achieve this by the input of available public land. Ultimately, this might imply limited expropriation in exchange for the benefits of the DES. There may be other options as well, for example, by land exchange and consolidation models, such as those applied during the 1950s for the defragmentation of parcels to establish large-scale agriculture [144].

6.5. Collective Systems: Collective Rights

The collective rights allow the community to make decisions about spaces, locations, system design, infrastructures, operations, and energy sharing/trading among participants. Crucial, according to Ostrom's IAD institutional design rules (Section 5.4.2), is that they control over the use of space, buildings, and land without interference or without private or public obstructive powers dominating their DES. This 'self-governance' includes identifying optimal locations for RE projects and for storage facilities of different scales to achieve maximum community acceptance. Therefore, these infrastructures should fit to the landscape, match with the social characteristics and values of the community, in the eyes of the beholders, including the merit they see for the local and regional economy [145]. The 'objectification' of landscape in hierarchical planning, such as the use of 'visibility' as a proxy for 'visual impact', is part of the centralized approaches in the deployment of renewables [11].

Exclusion rights let the community control and set the conditions for who can participate and access the shared infrastructure, within a legal framework that prevents rules of exclusion in order to prevent the establishment of 'club goods' (Table 2) or a 'private good'. These two options may possibly happen in case the exclusion rights of landowners unrestrictedly prevail. Besides the institutional changes in electricity supply, such as unobstructed and uninterrupted P2P delivery within microgrids [12,15,71,137], important institutional changes with regards land use concern the following:

- Aligning property rights of land and other spaces with the scale and purpose of the energy infrastructure.
- Enabling collective ownership and decision-making for community-scale projects, including the land and space used for it.
- Preserving individual control, without interferences like taxing, over private property for smaller building-level systems.
- Giving strategic control to collective capacities, including the land and space of the infrastructures, with engagement of public authorities for larger, public grid-integrated infrastructure.

This implies that energy communities should have strategic planning and coordination power with regards to energy facilities. This implies the commitment of local authorities far beyond the usual 'tokenism' forms of consultancy that prevail in most planning systems [146,147]. Existing institutional rules in planning systems create many obstructions to access, management, and exclusion rights for acquiring the space for comprehensive projects that integrate distributed resources by implementing DES infrastructure. Currently, even private rural landowners have to apply very creative initiatives against the current averse regulatory frameworks [141].

Local authorities should also use certain 'proprietor' rights to facilitate the acquisition of land for community DES infrastructures. The engagement of local or regional authorities may also help to design and implement a good governance structure for the microgrid, to ensure community benefits and mediate in potential conflicts. The sites for collective generation, storage, and distribution facilities become 'commons', i.e., shared lands, but an option could be that these become places where local authorities execute proprietor rights on behalf of the coordination of land acquisition. Local governments should design their zoning rules, building codes, and other policies to support the integration of DES infrastructures of communities within their territory, whereas, currently, most rules create impediments.

6.6. Space and Land as Resource Investments

All constructions of PV, wind, geothermal, and storage like batteries, superconductors, or heating on private property should be welcomed as investments of spatial resources, either rooftops or land. Hence, local governments should fully facilitate access, management, and some exclusion rights to help individual households, businesses, and other actors invest these spatial resources. Local authorities face several key challenges in coordinating the integration of DES within their jurisdictions [147]. Existing jurisdictional boundaries may need to be redefined, which mostly requires institutional changes at the national legislative level, for example, as national implementation of the EU's RED II requirements for RECs.

A special reason for the involvement of local authorities might be to prevent distributional injustice [24,72] by ensuring equitable access to the benefits of DES, such as reduced energy costs and improved resilience. By participating, local authorities are able to prevent the emergence of DES-generated electricity as a 'club good' instead of a 'common good' (Table 2). They could ensure access for those who are not able to invest as prosumers, because they lack the essential resources of finances or space. These are primarily lower-income households, house renters, and marginalized communities, more broadly. As the hybrid polycentric smart grid is built upon integrated and fairly self-governing microgrids, this is a typical task for national policies to cover, possibly with adjacent programs to support those end-users who lack resources to take part in the establishment of DES microgrids.

7. Conclusions

Well-designed transition policies consider energy system characteristics and encompass energy supply and demand. Land and energy are both among our most precious resources, and the manner and extent to which they are exploited contributes to climate change [7]. The energy transition largely means a transformation of the STS of electricity supply towards smart grids, a resilient polycentric system of integrated self-governed microgrids based on DES as close to consumption as possible. This way, as much renewable sources as possible are applied, while reducing the land use for large transmission systems.

In terms of transition, the core task is to figure out how currently dominant sociotechnical regimes might be dislodged and replaced and how new configurations might become mainstream [146]. Still, in most efforts for sustainable development, community engagement, and above all community action, is an important strand in innovation, but this social innovation remains largely neglected [147–149]. Underestimating the importance of social innovation also applies for the conceptual thinking about smart grids, microgrids, and distributed generation [56]. New ways of engaging communities are also innovation, and this also applies to RE and DES. It is social innovation [10,70].

The only way to engage end-users—industry, small businesses, and households alike—is to make them part of the transition. Several options exist that have so far only been tried sporadically and, unfortunately, often under unfavorable institutional conditions. Predominantly, most 'engagement' models are defined as 'participation' in decision-making about projects initiated from private and public perspectives. Within existing institutional frameworks, such as the structure of the electricity supply dominated by the public-private dichotomy, and the spatial planning systems serving developers and policy frameworks, engagement usually remains stuck at levels framed "largely in terms of exacerbated rhetoric and misleading euphemisms" [150]. Fundamentally, options beyond consultation and other 'tokenism' [150] should become mainstream. Some examples include:

- Abandoning all forms of "invited participation" [149], in current RE policies considered as a way to ameliorate or anticipate social conflict on energy projects. This model of enforcing community engagement on developers, and this 'participatory reflex', tends to end in typical "tokenism", damaging trust [80,97]. Following [149], it should be self-organized participation, which implies participation by 'communities of interest'.
- The key element of 'Activated Users' in smart grids must be combined with 'energy citizenship' concepts. The common good of DES must be co-produced and self-governed [15,52]. This implies a turn to 'communities of interest' in which prosumption is a viable and practical pathway to engage more actively with the energy system. Such material participation can co-produce diverse modes of engagement and participation [147,151]. It is more important to have legal conditions that produce equal opportunities of material participation for all, instead of continuing the current institutional and neo-liberal limitations of participating in common DES.
- RE policies, even if claimed to be designed for future smart grids, tend to be dominated by paradigms that still view electricity supply systems as centralist monocultures [56]. However, panaceas, one-size-fits-all policies, must be avoided in favor of flexible and adaptive regimes [152]. This also applies to any 'silver bullet' measures that continue to dominate RE policies as well as land property regimes [2], such as auctioning RE permits and other terms informed by economic modeling of RE as a private good.

- Institutional legal conditions need to be established, which give status to RECs. These are still generally and vaguely defined in the EU's RED II, but for this, in accordance with CPR theory for energy communities, a *special legal status needs to be created.* This would allow them to act as an independent actor within the energy domain as well as in spatial planning as a common 'proprietor' [127,153].
- Beyond the private good model of investing in RE and DES, legal and other institutional frameworks must be transformed in order to recognize land and space as a prime resource for investing in the common good of DES infrastructures. This implies redefining the frames of land property regimes and abandoning old frames of decision-making about space for RE, such as top-down imposed 'mandatory search areas' for solar PV (tending to exclude wide areas) or distance rules for wind turbines [154]. For example, by defining a leading role for the legal entity mentioned in the previous bullet, for taking the lead in decisions about space.

Space, and particularly land, is the prime scarce resource required for RE sources, in particular, when calculated for the extension of our current ways of electricity consumption and production [155]. For harvesting and sustainable use of RE to become a cornerstone in sustainable development, innovation and community action to establish microgrids are crucial. For the energy transition, it becomes inevitable to also transform our ways of attributing space and land for energy purposes. Just like the flows of RE, land is a natural resource, but of a different kind. It is scarce and subject to many different property regimes. Because of the 'common good' character of RE and the completely problematic property regimes for space and land, CPR theory becomes an obvious approach for analyzing the required socio-technical regimes around RE, and land must be adapted. Conflicts over land use for RE often emerge as private or public RE projects search for space that communities perceive as their common property. Hence, for enhanced SA, social acceptance, the currently existing models of energy provision—framed as 'private commercial' or 'state-controlled public'—are challenged (Table 2).

Microgrids, in all conceivable forms, are STSs in which DES, through joint management of generation, storage, and distribution capacity, and mutual supply—P2P—of the 'common good' electricity, is established. All infrastructures of that DES need space, and that implies that it is mainly about how the regime of the claim on the fundamental source, space and land, is established. Thus it becomes inevitable to reconsider all our institutions and ways of thinking around the distribution and exercise of property rights. This is needed in order to make space available, with as much use as possible of spaces other than land, for joint use in a common system of carbon-free electricity supply. In this article, some suggestions for the transformation in thinking about property, based on the classification of properties as 'bundles of rights' [127], have been made. As the recognition of RE as a common good currently remains only a new paradigm, still challenging the dominant frame of electricity as private and/or public good, the transformation in land use and property regimes for space and land is still virtually unexplored territory. We need to start reconsidering the dominant frames very quickly, because the scarcity of space is the most pressing problem [3] in the transition to a carbon-free energy supply.

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References

1. Plieninger, T.; Draux, H.; Fagerholm, N.; Bieling, C.; Bürgi, M.; Kizos, T.; Kuemmerle, T.; Primdahl, J.; Verburg, P.H. The driving forces of landscape change in Europe: A systematic review of the evidence. *Land Use Policy* **2016**, *57*, 204–214. [CrossRef]
2. Meyfroidt, P.; De Bremond, A.; Ryan, C.M.; Archer, E.; Aspinall, R.; Chhabra, A.; Camara, G.; Corbera, E.; DeFries, R.; Díaz, S.; et al. Ten facts about land systems for sustainability. *Proc. Nat. Acad. Sci. USA* **2022**, *119*, e2109217118. [CrossRef]
3. Smil, V. *Making Sense of Power Densities*; MIT Press: Cambridge, MA, USA, 2015.
4. Rotmans, J.; Kemp, R.; Van Asselt, M. More evolution than revolution: Transition management in public policy. *Foresight* **2001**, *3*, 15–31. [CrossRef]

5. Geels, F.W. From sectoral systems of innovation to socio-technical systems: Insights about dynamics and change from sociology and institutional theory. *Res. Policy* **2004**, *33*, 897–920. [CrossRef]
6. Henderson, R.M.; Clark, K.B. Architectural Innovation: The Reconfiguration of Existing Product Technologies and the Failure of Established Firms. *Adm. Sci. Q.* **1990**, *35*, 9. [CrossRef]
7. Gielen, D.; Boshell, F.; Saygin, D.; Bazilian, M.D.; Wagner, N.; Gorini, R. The role of renewable energy in the global energy transformation. *Energy Strategy Rev.* **2019**, *24*, 38–50. [CrossRef]
8. Geels, F.W. Regime resistance against low-carbon transitions: Introducing politics and power into the multi-level perspective. *Theory Cult. Soc.* **2014**, *31*, 21–40. [CrossRef]
9. Geels, F.W. Disruption and low-carbon system transformation: Progress and new challenges in socio-technical transitions research and the Multi-Level Perspective. *Energy Res. Soc. Sci.* **2018**, *37*, 224–231. [CrossRef]
10. Hewitt, R.J.; Bradley, N.; Baggio Compagnucci, A.; Barlagne, C.; Ceglarz, A.; Cremades, R.; McKeen, M.; Otto, I.M.; Slee, B. Social innovation in community energy in Europe: A review of the evidence. *Front. Energy Res.* **2019**, *7*, 31. [CrossRef]
11. Wolsink, M. Co-production in distributed generation: Renewable energy and creating space for fitting infrastructure within landscapes. *Landsc. Res.* **2018**, *43*, 542–561. [CrossRef]
12. Gui, E.M.; MacGill, I. Typology of future clean energy communities: An exploratory structure, opportunities, and challenges. *Energy Res. Soc. Sci.* **2018**, *35*, 94–107. [CrossRef]
13. Von Wirth, T.; Gislason, L.; Seidl, R. Distributed energy systems on a neighborhood scale: Reviewing drivers of and barriers to social acceptance. *Renew. Sustain. Energy Rev.* **2018**, *82*, 2618–2628. [CrossRef]
14. Farrelly, M.A.; Tawfik, S. Engaging in disruption: A review of emerging microgrids in Victoria, Australia. *Renew. Sustain. Energy Rev.* **2020**, *117*, 109491. [CrossRef]
15. Wolsink, M. Distributed energy systems as common goods: Socio-political acceptance of renewables in intelligent microgrids. *Renew. Sustain. Energy Rev.* **2020**, *127*, 109841. [CrossRef]
16. Marris, E. Upgrading the Grid. *Nature* **2008**, *454*, 570–573. [CrossRef] [PubMed]
17. Ostrom, E. *Governing the Commons: The Evolution of Institutions for Collective Action*, 2nd ed.; Cambridge University Press: Cambridge, UK, 2015.
18. Nordman, E. *The Uncommon Knowledge of Elinor Ostrom: Essential Lessons for Collective Action*; Island Press: Washington, DC, USA, 2021.
19. Mihailova, D.; Schubert, I.; Burger, P.; Fritz, M.M. Exploring modes of sustainable value co-creation in renewable energy communities. *J. Clean. Prod.* **2022**, *330*, 129917. [CrossRef]
20. Brisbois, M.C. Powershifts: A framework for assessing the growing impact of decentralized ownership of energy transitions on political decision-making. *Energy Res. Soc. Sci.* **2019**, *50*, 151–161. [CrossRef]
21. Szulecki, K. Conceptualizing energy democracy. *Environ. Politics* **2018**, *27*, 21–41. [CrossRef]
22. Walker, G.; Devine-Wright, P. Community renewable energy: What should it mean? *Energy Policy* **2008**, *36*, 497–500. [CrossRef]
23. Bickerstaff, K.; Bulkeley, H.; Walker, G. (Eds.) *Energy Justice in a Changing Climate*; Zed Books: London, UK, 2013.
24. Schlosberg, D. Theorising environmental justice: The expanding sphere of a discourse. *Environ. Politics* **2013**, *22*, 37–55. [CrossRef]
25. Wolsink, M. Social acceptance revisited: Gaps, questionable trends, and an auspicious perspective. *Energy Res. Soc. Sci.* **2018**, *46*, 287–295. [CrossRef]
26. Lennon, B.; Dunphy, N.; Gaffney, C.; Revez, A.; Mullally, G.; O'Connor, P. Citizen or consumer? Reconsidering energy citizenship. *J. Environ. Policy Plan.* **2020**, *22*, 184–197. [CrossRef]
27. De Vidovich, L. Niches Seeking Legitimacy: Notes about Social Innovation and Forms of Social Enterprise in the Italian Renewable Energy Communities. *Sustainability* **2024**, *16*, 3599. [CrossRef]
28. Hall, N.; Lacey, J.; Carr-Cornish, S.; Dowd, A.M. Social licence to operate: Understanding how a concept has been translated into practice in energy industries. *J. Clean. Prod.* **2015**, *86*, 301–310. [CrossRef]
29. Lamhamedi, B.E.H.; de Vries, W.T. An Exploration of the land–(renewable) energy nexus. *Land* **2022**, *11*, 767. [CrossRef]
30. Camargo, L.R.; Valdes, J.; Macia, Y.M.; Dorner, W. Assessment of on-site steady electricity generation from hybrid renewable energy systems in Chile. *Appl. Energy* **2019**, *250*, 1548–1558. [CrossRef]
31. Batel, S.; Devine-Wright, P. Energy colonialism and the role of the global in local responses to new energy infrastructures in the UK: A critical and exploratory empirical analysis. *Antipode* **2017**, *49*, 3–22. [CrossRef]
32. Sánchez Contreras, J.; Matarán Ruiz, A.; Campos-Celador, A.; Fjellheim, E.M. Energy Colonialism: A Category to Analyse the Corporate Energy Transition in the Global South and North. *Land* **2023**, *12*, 1241. [CrossRef]
33. Tran, T.H.; Egermann, M. Land-use implications of energy transition pathways towards decarbonisation–Comparing the footprints of Vietnam, New Zealand and Finland. *Energy Policy* **2022**, *166*, 112951. [CrossRef]
34. Nadaï, A.; van Der Horst, D. Introduction: Landscapes of energies. *Lands. Res.* **2010**, *35*, 143–155. [CrossRef]
35. Gross, C. Community Perspectives of Wind Energy in Australia: The Application of a Justice and Community Fairness Framework to Increase Social Acceptance. *Energy Policy* **2007**, *35*, 2727–2736. [CrossRef]
36. Yenneti, K.; Day, R.; Golubchikov, O. Spatial justice and the land politics of renewables: Dispossessing vulnerable communities through solar energy mega-projects. *Geoforum* **2016**, *76*, 90–99. [CrossRef]
37. Eichenauer, E.; Gailing, L. What Triggers Protest?—Understanding Local Conflict Dynamics in Renewable Energy Development. *Land* **2022**, *11*, 1700. [CrossRef]

38. Hogan, J.L. Why does community ownership foster greater acceptance of renewable projects? Investigating energy justice explanations. *Local Environ.* 2024; *in press*. [CrossRef]
39. Wolsink, M. Planning of renewables schemes: Deliberative and fair decision-making on landscape issues instead of reproachful accusations of non-cooperation. *Energy Policy* **2007**, *35*, 2692–2704. [CrossRef]
40. Ioannidis, R.; Koutsoyiannis, D. A review of land use, visibility and public perception of renewable energy in the context of landscape impact. *Appl. Energy* **2020**, *276*, 115367. [CrossRef]
41. Pedersen, E.; Larsman, P. The impact of visual factors on noise annoyance among people living in the vicinity of wind turbines. *J. Environ. Psychol.* **2008**, *28*, 379–389. [CrossRef]
42. Boudet, H.S. Public perceptions of and responses to new energy technologies. *Nat. Energy* **2019**, *4*, 446–455. [CrossRef]
43. Frantál, B.; Frolova, M.; Liñán-Chacón, J. Conceptualizing the patterns of land use conflicts in wind energy development: Towards a typology and implications for practice. *Energy Res. Soc. Sci.* **2023**, *95*, 102907. [CrossRef]
44. Aitken, M. Why we still don't understand the social aspects of wind power: A critique of key assumptions within the literature. *Energy Policy* **2010**, *38*, 1834–1841. [CrossRef]
45. Wolsink, M. Social acceptance, lost objects, and obsession with the 'public'—The pressing need for enhanced conceptual and methodological rigor. *Energy Res. Soc. Sci.* **2019**, *48*, 269–276. [CrossRef]
46. Boche, A.; Foucher, C.; Villa, L.F.L. Understanding microgrid sustainability: A systemic and comprehensive review. *Energies* **2022**, *15*, 2906. [CrossRef]
47. Wolsink, M. The research agenda on social acceptance of distributed generation in smart grids: Renewable as common pool resources. *Renew. Sustain. Energy Rev.* **2012**, *16*, 822–835. [CrossRef]
48. Amin, M. Toward self-healing energy infrastructure systems. *IEEE Comput. Appl. Power* **2001**, *14*, 20–28. [CrossRef]
49. Amin, S.M.; Wollenberg, B.F. Toward a smart grid. *IEEE Power Energy Mag.* **2005**, *3*, 34–41. [CrossRef]
50. Bakke, G. *The Grid—The Fraying Wires between Americans and Our Energy Future*; Bloomsbury: New York, NY, USA, 2016.
51. Dileep, G. A survey on smart grid technologies and applications. *Renew. Energy* **2020**, *146*, 2589–2625. [CrossRef]
52. Ostrom, E. A general framework for analyzing sustainability of social-ecological systems. *Science* **2009**, *325*, 419–422. [CrossRef] [PubMed]
53. Kojonsaari, A.R.; Palm, J. The development of social science research on smart grids: A semi-structured literature review. *Energy Sustain. Soc.* **2023**, *13*, 1. [CrossRef]
54. Chen, C.; Wang, J.; Qiu, F.; Zhao, D. Resilient Distribution System by Microgrids Formation After Natural Disasters. *IEEE Trans. Smart Grid* **2016**, *7*, 958–966. [CrossRef]
55. Shi, W.; Liang, H.; Bittner, M. Data-Driven Resilience Enhancement for Power Distribution Systems Against Multishocks of Earthquakes. *IEEE Trans. Ind. Inform.* **2024**, *20*, 7357–7369. [CrossRef]
56. Wolsink, M. Conceptualizations of smart grids–anomalous and contradictory expert paradigms in transitions of the electricity system. *Energy Res. Soc. Sci.* **2024**, *109*, 103392. [CrossRef]
57. Ipakchi, A.; Albuyeh, F. Grid of the future. *IEEE Power Energy Mag.* **2009**, *7*, 52–62. [CrossRef]
58. Lasseter, R.H. Micrograds and Distributed Generation. *Intell. Autom. Soft Comput.* **2010**, *16*, 225–234. [CrossRef]
59. Geels, F.W.; Smit, W.A. Failed technology futures: Pitfalls and lessons from a historical survey. *Futures* **2000**, *32*, 867–885. [CrossRef]
60. Norouzi, F.; Hoppe, T.; Elizondo, L.R.; Bauer, P. A review of socio-technical barriers to Smart Microgrid development. *Renew. Sustain. Energy Rev.* **2022**, *167*, 112674. [CrossRef]
61. Wolsink, M. Wind power for the electricity supply of houses. *Neth. J. Hous. Environ. Res.* **1987**, *2*, 195–214. [CrossRef]
62. Liang, X.D. Emerging power quality challenges due to integration of Renewable Energy Sources. *IEEE Trans. Ind. Appl.* **2017**, *53*, 855–866. [CrossRef]
63. McDaniel, P.; McLaughlin, S. Security and privacy challenges in the smart grid. *IEEE Secur. Priv.* **2009**, *7*, 75–77. [CrossRef]
64. Guasselli, F.; Vavouris, A.; Stankovic, L.; Stankovic, V.; Didierjean, S.; Gram-Hanssen, K. Smart energy technologies for the collective: Time-shifting, demand reduction and household practices in a Positive Energy Neighbourhood in Norway. *Energy Res. Soc. Sci.* **2024**, *110*, 103436. [CrossRef]
65. Guo, Y.; Bose, S.; Tong, L. On robust tie-line scheduling in multi-area power systems. *IEEE Trans. Power Syst.* **2018**, *33*, 4144–4154. [CrossRef]
66. Parra-Domínguez, J.; Sánchez, E.; Ordóñez, Á. The prosumer: A systematic review of the new paradigm in energy and sustainable development. *Sustainability* **2023**, *15*, 10552. [CrossRef]
67. Eklund, M.; Khalilpour, K.; Voinov, A.; Hossain, M.J. Understanding the community in community microgrids: A conceptual framework for better decision-making. *Energy Res. Soc. Sci.* **2023**, *104*, 103260. [CrossRef]
68. Warneryd, M.; Håkansson, M.; Karltorp, K. Unpacking the complexity of community microgrids: A review of institutions' roles for development of microgrids. *Renew. Sustain. Energy Rev.* **2020**, *121*, 109690. [CrossRef]
69. Rosen, J.; Painter, G. From citizen control to co-production: Moving beyond a linear conception of citizen participation. *J. Am. Plan. Assoc.* **2019**, *85*, 335–347. [CrossRef]
70. Voorberg, W.H.; Bekkers, V.J.; Tummers, L.G. A systematic review of co-creation and co-production: Embarking on the social innovation journey. *Public Manag. Rev.* **2015**, *17*, 1333–1357. [CrossRef]

71. Tushar, W.; Yuen, C.; Saha, T.K.; Morstyn, T.; Chapman, A.C.; Alam, M.J.E.; Hanif, S.; Poor, H.V. Peer-to-peer energy systems for connected communities: A review of recent advances and emerging challenges. *Appl. Energy* **2021**, *282*, 116131. [CrossRef]
72. Knox, S.; Hannon, M.; Stewart, F.; Ford, R. The (in)justices of smart local energy systems: A systematic review, integrated framework, and future research agenda. *Energy Res. Soc. Sci.* **2022**, *83*, 102333. [CrossRef]
73. Parag, Y.; Ainspan, M. Sustainable microgrids: Economic, environmental and social costs and benefits of microgrid deployment. *Energy Sustain. Dev.* **2019**, *52*, 72–81. [CrossRef]
74. McGinnis, M.D.; Ostrom, E. Social-ecological system framework: Initial changes and continuing challenges. *Ecol. Soc.* **2014**, *19*, 30. [CrossRef]
75. Nguyen, M.T.; Batel, S. A critical framework to Develop Human-Centric Positive Energy Districts: Towards Justice, Inclusion, and Well-Being. *Front. Sustain. Cities* **2021**, *3*, 691236. [CrossRef]
76. Krangsås, S.G.; Steemers, K.; Konstantinou, T.; Soutullo, S.; Liu, M.; Giancola, E.; Prebreza, B.; Ashrafian, T.; Murauskaitė, L.; Maas, N. Positive energy districts: Identifying challenges and interdependencies. *Sustainability* **2021**, *13*, 10551. [CrossRef]
77. Urban Europe. Positive Energy Districts. Available online: https://jpi-urbaneurope.eu/ped/ (accessed on 27 May 2024).
78. Krug, M.; Di Nucci, M.R.; Caldera, M.; de Luca, E. Mainstreaming community energy: Is the renewable energy directive a driver for renewable energy communities in Germany and Italy? *Sustainability* **2022**, *14*, 7181. [CrossRef]
79. Walker, G. The role for 'community' in carbon governance. *WIRES Clim. Chang.* **2011**, *2*, 777–782. [CrossRef]
80. Chilvers, J.; Longhurst, N. Participation in transition(s): Reconceiving public engagements in energy transitions as co-produced, emergent and diverse. *J. Environ. Policy Plan.* **2016**, *18*, 585–607. [CrossRef]
81. Robison, R.; Skjølsvold, T.M.; Hargreaves, T.; Renström, S.; Wolsink, M.; Judson, E.; Pechancová, V.; Demirbağ-Kaplan, M.; March, H.; Lehne, J.; et al. Shifts in the smart research agenda? 100 priority questions to accelerate sustainable energy futures. *J. Clean. Prod.* **2023**, *419*, 137946. [CrossRef]
82. Biresselioglu, M.E.; Demir, M.H.; Solak, B.; Savas, Z.F.; Kollmann, A.; Kirchler, B.; Ozcureci, B. Empowering energy citizenship: Exploring dimensions and drivers in citizen engagement during the energy transition. *Energy Rep.* **2024**, *11*, 1894–1909. [CrossRef]
83. Seto, K.C.; Davis, S.J.; Mitchell, R.B.; Stokes, E.C.; Unruh, G.; Ürge-Vorsatz, D. Carbon lock-in: Types, causes, and policy implications. *Ann. Rev. Environ. Resour.* **2016**, *41*, 425–452. [CrossRef]
84. Johnstone, P.; Stirling, A.; Sovacool, B. Policy mixes for incumbency: Exploring the destructive recreation of renewable energy, shale gas 'fracking', and nuclear power in the United Kingdom. *Energy Res. Soc. Sci.* **2017**, *33*, 147–162. [CrossRef]
85. Wolsink, M. Framing in renewable energy policies: A glossary. *Energies* **2020**, *13*, 2871. [CrossRef]
86. Vorkinn, M.; Riese, H. Environmental concern in a local context: The significance of place attachment. *Environ. Behav.* **2001**, *33*, 249–263.
87. Devine-Wright, P.; Howes, Y. Disruption to place attachment and the protection of restorative environments: A wind energy case study. *J. Environ. Psychol.* **2010**, *30*, 271–280. [CrossRef]
88. IEA International Energy Agency. Renewables 2022: Executive Summary. 2022. Available online: https://www.iea.org/reports/renewables-2022/executive-summary (accessed on 21 June 2024).
89. Hernandez, R.R.; Easter, S.B.; Murphy-Mariscal, M.L.; Maestre, F.T.; Tavassoli, M.; Allen, E.B.; Barrows, C.W.; Belnap, J.; Ochoa-Hueso, R.; Ravi, S.; et al. Environmental impacts of utility-scale solar energy. *Renew. Sustain. Energy Rev.* **2014**, *29*, 766–779. [CrossRef]
90. Busch, H.; Ruggiero, S.; Isakovic, A.; Hansen, T. Policy challenges to community energy in the EU: A systematic review of the scientific literature. *Renew. Sustain. Energy Rev.* **2021**, *151*, 111535. [CrossRef]
91. Springer, S. Neoliberalism and Geography: Expansions, Variegation, Formations. *Geogr. Compass* **2010**, *4*, 1025–1038. [CrossRef]
92. Batel, S. Research on the social acceptance of renewable energy technologies: Past, present and future. *Energy Res. Soc. Sci.* **2020**, *68*, 101544. [CrossRef]
93. Del Río, P.; Linares, P. Back to the future? Rethinking auctions for renewable electricity support. *Renew. Sustain. Energy Rev.* **2014**, *35*, 42–56. [CrossRef]
94. Grashof, K. Are auctions likely to deter community wind projects? And would this be problematic? *Energy Policy* **2019**, *125*, 20–32. [CrossRef]
95. Simcock, N. Exploring how stakeholders in two community wind projects use a "those affected" principle to evaluate the fairness of each project's spatial boundary. *Local Environ.* **2014**, *19*, 241–258. [CrossRef]
96. Küpers, S.; Batel, S. Time, history and meaning-making in research on people's relations with renewable energy technologies (RETs)–A conceptual proposal. *Energy Policy* **2023**, *173*, 113358. [CrossRef]
97. Cowell, R.; Bristow, G.; Munday, M. Acceptance, acceptability and environmental justice: The role of community benefits in wind energy development. *J. Environ. Plan. Manag.* **2011**, *54*, 539–557. [CrossRef]
98. Määtä, S. Community-developer collaboration and voluntary community benefits in Scotland: Are community benefits a gift or compensation? *Energy Policy* **2024**, *191*, 114164. [CrossRef]
99. Crawford, J.; Bessette, D.; Mills, S.B. Rallying the anti-crowd: Organized opposition, democratic deficit, and a potential social gap in large-scale solar energy. *Energy Res. Soc. Sci.* **2022**, *90*, 102597. [CrossRef]
100. Goedkoop, F.; Devine-Wright, P. Partnership or placation? The role of trust and justice in the shared ownership of renewable energy projects. *Energy Res. Soc. Sci.* **2016**, *17*, 135–146. [CrossRef]

101. Wüstenhagen, R.; Wolsink, M.; Bürer, M.J. Social acceptance of renewable energy innovation: An introduction to the concept. *Energy Policy* **2007**, *35*, 2683–2691. [CrossRef]
102. Ellis, G.; Cowell, R.; Warren, C.; Strachan, P.; Szarka, J.; Hadwin, R.; Miner, P.; Wolsink, M.; Nadaï, A. Wind Power: Is There A "Planning Problem"? *Plan. Theory Pract.* **2009**, *10*, 521–547. [CrossRef]
103. Calvert, K.; Smit, E.; Wassmansdorf, D.; Smithers, J. Energy transition, rural transformation and local land-use planning: Insights from Ontario, Canada. *Environ. Plan. E Nat. Space* **2022**, *5*, 1035–1055. [CrossRef]
104. Taghikhah, F.R.; Taghikhah, M.; Marshall, J.P.; Voinov, A. Navigating the community renewable energy landscape: An analytics-driven policy formulation. *Appl. Energy* **2024**, *362*, 123007. [CrossRef]
105. Lewicka, M. Place attachment: How far have we come in the last 40 years? *J. Environ. Psychol.* **2011**, *31*, 207–230. [CrossRef]
106. Lothian, A. Landscape and the philosophy of aesthetics: Is landscape quality inherent in the landscape or in the eye of the beholder? *Landsc. Urban Plan.* **1999**, *44*, 177–198. [CrossRef]
107. Lezama, F.; Soares, J.; Hernandez-Leal, P.; Kaisers, M.; Pinto, T.; Vale, Z. Local Energy Markets: Paving the Path Toward Fully Transactive Energy Systems. *IEEE Trans. Power Syst.* **2019**, *34*, 4081–4088. [CrossRef]
108. Hughes, T.P. *Networks of Power: Electrification in Western Society, 1880–1930*; John Hopkins University Press: Baltimore, ML, USA, 2008.
109. Joskow, P.L. Comparing the costs of intermittent and dispatchable electricity generating technologies. *Am. Econ. Rev.* **2011**, *101*, 238–241. [CrossRef]
110. Blasch, J.; van der Grijp, N.M.; Petrovics, D.; Palm, J.; Bocken, N.; Darby, S.J.; Barnes, J.; Hansen, P.; Kamin, T.; Golob, U.; et al. New clean energy communities in polycentric settings: Four avenues for future research. *Energy Res. Soc. Sci.* **2021**, *82*, 102276. [CrossRef]
111. Plewnia, F. The Energy System and the Sharing Economy: Interfaces and overlaps and what to learn from them. *Energies* **2019**, *12*, 339. [CrossRef]
112. Zafar, R.; Mahmood, A.; Razzaq, S.; Ali, W.; Naeem, U.; Shehzad, K. Prosumer based energy management and sharing in smart grid. *Renew. Sustain. Energy Rev.* **2018**, *82*, 1675–1684. [CrossRef]
113. North, D.C. *Institutions, Institutional Change and Economic Performance*; Cambridge University Press: Cambridge, UK, 1990.
114. Wirth, S. Communities matter: Institutional preconditions for community renewable energy. *Energy Policy* **2014**, *70*, 236–246. [CrossRef]
115. Unruh, G.C. Understanding carbon lock-in. *Energy Policy* **2000**, *28*, 817–830. [CrossRef]
116. Alford, J. The multiple facets of co-production: Building on the work of Elinor Ostrom. *Public Manag. Rev.* **2014**, *16*, 299–316. [CrossRef]
117. Watson, J. Co-provision in sustainable energy systems: The case of micro-generation. *Energy Policy* **2004**, *32*, 1981–1990. [CrossRef]
118. Geelen, D.; Reinders, A.; Keyson, D. Empowering the end-user in smart grids: Recommendations for the design of products and services. *Energy Policy* **2013**, *61*, 151–161. [CrossRef]
119. Roberts, M.B.; Bruce, A.; MacGill, I. Impact of shared battery energy storage systems on photovoltaic self-consumption and electricity bills in apartment buildings. *Appl. Energy* **2019**, *245*, 78–95. [CrossRef]
120. Ostrom, E. *Understanding Institutional Diversity*; Princeton University Press: Princeton, NJ, USA, 2009.
121. Acosta, C.; Ortega, M.; Bunsen, T.; Koirala, B.P.; Ghorbani, A. Facilitating energy transition through energy commons: An application of socio-ecological systems framework for integrated community energy systems. *Sustainability* **2018**, *10*, 366. [CrossRef]
122. Jonas, A.E.G.; Shepherd, S.; Wahud, S. The smart grid as commons: Exploring alternatives to infrastructure financialization. *Urban Stud.* **2019**, *56*, 1386–1403.
123. Ostrom, E. Background on the institutional analysis and development framework. *Policy Stud. J.* **2011**, *39*, 7–27. [CrossRef]
124. Gollwitzer, L.; Ockwell, D.; Muok, B.; Ely, A.; Ahlborg, H. Rethinking the sustainability and institutional governance of electricity access and mini-grids: Electricity as a common pool resource. *Energy Res. Soc. Sci.* **2018**, *39*, 152–161. [CrossRef]
125. Ngoti, I. Institutional arrangements and sustainable maintenance management of community-based mini-grids in Tanzania. *Energy Res. Soc. Sci.* **2024**, *15*, 103632. [CrossRef]
126. Sousa, T.; Soares, T.; Pinson, P.; Moret, F.; Baroche, T.; Sorin, E. Peer-to-peer and community-based markets: A comprehensive review. *Renew. Sustain. Energy Rev.* **2019**, *104*, 367–378. [CrossRef]
127. Schlager, E.; Ostrom, E. Property-Rights Regimes and Natural Resources: A Conceptual Analysis. *Land Econ.* **1992**, *68*, 249–262. [CrossRef]
128. Lucchi, E. Renewable energies and architectural heritage: Advanced solutions and future perspectives. *Buildings* **2023**, *13*, 631. [CrossRef]
129. Hirsch, A.; Parag, Y.; Guerrero, J. Microgrids: A review of technologies, key drivers, and outstanding issues. *Renew. Sustain. Energy Rev.* **2018**, *90*, 402–411. [CrossRef]
130. Jamil, U.; Hicley, T.; Pearce, J.M. Solar energy modelling and proposed crops for different types of agrivoltaics systems. *Energy* **2024**, *203*, 132074. [CrossRef]
131. Fausto, F.J.; Gunkel, P.A.; Skytte, K.; Bergaentzle, C.; McKenna, R. Designing taxes and tariffs for electricity systems with complex flexible actors. In Proceedings of the 16th International Conference on the European Energy Market, Ljubljana, Slovenia, 18–20 September 2019; IEEE: Piscataway, NJ, USA, 2019; pp. 1–6.

132. Tomasi, S. The (Non) impact of the Spanish "Tax on the Sun" on photovoltaics prosumers uptake. *Energy Policy* **2022**, *168*, 113041. [CrossRef]
133. Adil, A.M.; Ko, Y. Socio-technical evolution of decentralized energy systems: A critical review and implications for urban planning and policy. *Renew. Sustain. Energy Rev.* **2016**, *57*, 1025–1037. [CrossRef]
134. Florio, P.; Peronato, G.; Perera, A.T.; Di Blasi, A.; Poon, K.H.; Kämpf, J.H. Designing and assessing solar energy neighborhoods from visual impact. *Sustain. Cities Soc.* **2021**, *71*, 102959. [CrossRef]
135. Ioannidis, R.; Mamassis, N.; Efstratiadis, A.; Koutsoyiannis, D. Reversing visibility analysis: Towards an accelerated a priori assessment of landscape impacts of renewable energy projects. *Renew. Sustain. Energy Rev.* **2022**, *161*, 112389. [CrossRef]
136. Koirala, B.P.; van Oost, E.C.; van der Waal, E.C.; van der Windt, H.J. New pathways for community energy and storage. *Energies* **2021**, *4*, 286. [CrossRef]
137. Gorbatcheva, A.; Watson, N.; Schneiders, A.; Shipworth, D.; Fell, M.J. Defining characteristics of peer-to-peer energy trading, transactive energy, and community self-consumption: A review of literature and expert perspectives. *Renew. Sustain. Energy Rev.* **2024**, *202*, 114672. [CrossRef]
138. Neukirch, M. Grinding the grid: Contextualizing protest networks against energy transmission projects in Southern Germany. *Energy Res. Soc. Sci.* **2020**, *69*, 101585. [CrossRef]
139. Bauwens, T.; Devine-Wright, P. Positive Energies? An Empirical Study of Community Energy Participation and Attitudes to Renewable Energy. *Energy Policy* **2018**, *118*, 612–625. [CrossRef]
140. Goldberg, Z.A. Solar energy development on farmland: Three prevalent perspectives of conflict, synergy and compromise in the United States. *Energy Res. Soc. Sci.* **2023**, *101*, 103145. [CrossRef]
141. Copena, D.; Simón, X. Wind farms and payments to landowners: Opportunities for rural development for the case of Galicia. *Renew. Sustain. Energy Rev.* **2018**, *95*, 38–47. [CrossRef]
142. Warren, C.R.; McFadyen, M. Does community ownership affect public attitudes to wind energy? A case study from south-west Scotland. *Land Use Policy* **2010**, *27*, 204–213. [CrossRef]
143. Späth, L. Large-scale photovoltaics? Yes please, but not like this! Insights on different perspectives underlying the trade-off between land use and renewable electricity development. *Energy Policy* **2018**, *122*, 429–437. [CrossRef]
144. Haldrup, N.O. Agreement based land consolidation–In perspective of new modes of governance. *Land Use Policy* **2015**, *46*, 163–177. [CrossRef]
145. Sirnik, I.; Sluijsmans, J.; Oudes, D.; Stremke, S. Circularity and landscape experience of agrivoltaics: A systematic review of literature and built systems. *Renew. Sustain. Energy Rev.* **2023**, *178*, 113250. [CrossRef]
146. Shove, E.; Walker, G. CAUTION! Transitions ahead: Politics, practice, and sustainable transition management. *Environ. Plan. A* **2007**, *39*, 763–770. [CrossRef]
147. Seyfang, G.; Smith, A. Grassroots innovations for sustainable development: Towards a new research and policy agenda. *Environ. Politics* **2007**, *16*, 584–603. [CrossRef]
148. Moss, T.; Becker, S.; Naumann, M. Whose energy transition is it, anyway? Organisation and ownership of the Energiewende in villages, cities and regions. *Local Environ.* **2015**, *20*, 1547–1563. [CrossRef]
149. Cuppen, E. The value of social conflicts. Critiquing invited participation in energy projects. *Energy Res. Soc. Sci.* **2018**, *38*, 28–32. [CrossRef]
150. Arnstein, S.R. A ladder of citizen participation. *J. Am. Inst. Plan.* **1969**, *35*, 216–224. [CrossRef]
151. Ryghaug, M.; Skjølsvold, T.M.; Heidenreich, S. Creating energy citizenship through material participation. *Soc. Stud. Sci.* **2018**, *48*, 283–303. [CrossRef]
152. Ostrom, E. A diagnostic approach for going beyond panaceas. *Proc. Nat. Acad. Sci. USA* **2007**, *104*, 15181–15187. [CrossRef] [PubMed]
153. Heldeweg, M.A.; Saintier, S. Renewable energy communities as 'socio-legal institutions': A normative frame for energy decentralization? *Renew. Sustain. Energy Rev.* **2020**, *119*, 109518. [CrossRef]
154. Zaunbrecher, B.S.; Ziefle, M. Integrating acceptance-relevant factors into wind power planning: A discussion. *Sustain. Cities Soc.* **2016**, *27*, 307–314. [CrossRef]
155. Lovering, J.; Swain, M.; Blomqvist, L.; Hernandez, R.R. Land-use intensity of electricity production and tomorrow's energy landscape. *PLoS ONE* **2022**, *17*, e02700155. [CrossRef]