Geography of Innovation and Sustainability Transitions

GEIST Working Paper series

Reconfiguring actors and infrastructure in city renewable energy transitions: a regional perspective

GEIST Working Paper No. 2021(6)

Christina E. Hoicka[*1], Jessica Conroy[2], Anna Berka[3]

[*] Corresponding author (cehoicka@uvic.ca)

[1] University of Victoria, Canada

[2] York University, Canada

[3] Massey University, New Zealand

This article has been peer-reviewed, revised and accepted for publication in Energy Policy:

Hoicka, C.E., Conroy, J., Berka, A.L., 2021. Reconfiguring actors and infrastructure in city renewable energy transitions: A regional perspective. Energy Policy 158, 112544. https://doi.org/10.1016/j.enpol.2021.112544

Reconfiguring actors and infrastructure in city renewable energy transitions: a regional perspective

Christina E. Hoicka*, University of Victoria, Canada
Jessica Conroy, York University, Canada
Anna Berka, Massey University, New Zealand
*Corresponding author: cehoicka@uvic.ca
August 2021

Abstract
Cities as large centres of energy demand and population are important spatially and materially in a renewable energy transition. This study draws on available literature on material dimensions, energy decentralization, and regional approaches to provide a conceptual framework to analyse emerging city renewable energy transition plans for their material- and place-based actor scalar strategies. This framework outlines how the increase in renewable energy provided to cities results in new locations of productivity, interscalar relationships between new and centralized actors, and socio-economic outcomes. We use this to analyse 47 ambitious renewable energy transition plans in densely populated cities. Empirically, this study confirms that, for the most part, regions are important emerging actors in the decentralization of energy systems in a renewable energy transition; that city renewable energy transitions involve the forging of new economic relationships between cities and neighbouring communities and regions, and, as the community energy literature emphasises, that the involvement of a wide range of civic and local actors is important in shaping renewable energy transitions for cities. Further research can investigate how the institutional context is shaping these distinct actor material strategies and emerging interscalar relationships across regions. The socio-economic outcomes, particularly as they relate to new economic relationships between cities and the surrounding region and the re-spatialization of productivity and benefits, should also be examined.

Keywords
Renewable energy transition; cities; decentralization; regional approaches; carbon neutral;

1. Introduction

Transitioning to predominantly renewable energy is understood as an effective strategy to stay within 1.5°C average global temperature rise (IEA, 2017). There is a lot at stake with respect to who benefits from and who is impacted by this transition. A renewable energy transition requires unprecedented investments in distribution systems and new renewable energy supply, the latter estimated to total $22.5 trillion investment by 2050 (IRENA, 2020). The transition to 100% renewable energy is estimated to cost 139 countries $124.7 trillion for 49.9 TW of new installed capacity (Jacobson et al., 2017). At the same time, the liberalization of energy markets has created opportunities for participation in the market by a broader range of actors (Balta-Ozkan et al., 2015; Van Vliet, 2003). In the past four decades, these factors have converged in a societal debate about the reorganisation of energy systems toward more renewable, more distributed, decentralised and heterogeneous than under the fossil fuel era and this has become an important topic of study in both technical and socio-technical literature (Lovins, 1977; Martinot, 2016; McCauley and Stephens, 2017). For example, renewable energy generation can be developed at scale, owned and operated by established utilities and multinationals, or owned and operated by municipalities or community organisations comprised of 'prosumers'. Who controls and owns these projects affects who receives the revenue and benefits, including the type and extent of local economic development, access to affordable energy, and social acceptance - with potentially far reaching consequences in terms of regional socio-economic decline, empowerment of marginalised communities and broader climate change and energy policy stability (Berka and Creamer, 2018; Kelsey and Meckling, 2018; MacArthur and Matthewman, 2018; MacArthur et al., 2020). Moreover, local civic engagement in energy, depending on how it is implemented, can leverage an additional stream of investment that enables the accelerated diffusion of renewable technologies, increased energy awareness and low emission lifestyles (Berka and Creamer, 2018).

Literature on material and spatial implications of renewable energy transitions shows that the nature of a renewable energy transition means that different locations and types of land uses will employ and deploy renewable energy differently, and variably generate new land-use pressures (Poggi et al., 2018; Ramirez Camargo and Stoeglehner, 2018). This is because a transition from high power density fossil fuels and nuclear power to lower power density renewable energy requires more land, presenting not only important technological challenges, but also infrastructural and landscape challenges and changes (Bridge et al., 2013; Pasqualetti, 2012; Smil, 2015). The high energy density and demand of cities adds additional complexity to the spatial challenges associated with renewable energy transitions, and highlights the importance of emerging interscalar relationships. The development of high density urban areas was enabled by energy dense fossil fuels and nuclear power (Owens, 1986, 1986). Cities occupy only two percent of the world's landmass in terms of size, but contribute over 70 percent of global carbon dioxide emissions and consume over two-thirds of the world's energy (C40 Cities, 2019; Wei et al., 2021). Sixty eight percent of the world's population is expected to live in urban areas by 2050 (United Nations, 2018) and global energy demand is expected to grow significantly (IEA, 2017). Due to population density and the built environment, the power density of energy use is highest in cities (Smil, 2015). Although we do not yet have a comprehensive understanding of the material techno-economic implications of renewable energy in cities globally, techno-economic assessments such as Arabzadeh et al. (2020) and Lund et al. (2015) indicate that cities are unlikely to be self-sufficient within their boundaries if they rely on 100% renewable energy. Naumann and Rudolph take this as their starting point to theorise on the implications of renewable energy transitions on rural areas, arguing that "urban energy transitions are simply impossible without rural energy transitions" (Naumann and Rudolph, 2020, p. 97). This is also because while fossil fuels and nuclear are global commodities (Mitchell, 2009), renewable energy is predominantly a regional and local commodity, emphasizing the importance of the region in such a transition. Yet, most studies ignore the interscalar relationships that emerge in energy transitions and that are inherent in regional approaches, instead focussing on bounded local, urban or national levels (Balta-Ozkan et al., 2015).

Because much of the research around energy transitions focuses on the local or on the tensions between traditional versus new actors, and many spatial energy studies focus on a specific scale, we risk losing sight of the potential interscalar relationships and effects of renewable energy transitions. We purport that subnational regional approaches are needed to take into account these interscalar aspects. Ideas about the spatial reconfiguration of social and economic activity and energy consumption and production that will be necessary vary widely, from relocalised and post-material to hyperintegrated, -digital and -mobile (Bauwens et al., 2020; Horst, 2017). This carries with it important implications for the scale of governance, opportunities for deep engagement with consumers, land use patterns, security and resilience outcomes as well as potentially influencing social and equity outcomes in complex ways (Bickerstaff, 2017; Bridge et al., 2013; McCauley and Stephens, 2017; Späth and Rohracher, 2014). Taken together then, decisions around spatial reconfiguration made today will influence the subsequent dynamics of transitions and our capacity for transformation (Bridge et al., 2013). For that reason, it is important to examine the ongoing (re-)distribution of energy related activities across space, the underlying processes that drive these patterns of reconfiguration, and the implications, including inter-spatial implications in the form of spillovers of both costs and benefits (Bridge et al., 2013). Whether one takes a local, urban, rural, or regional perspective on energy transitions, a place-based perspective with a focus on interscalar relationships is argued to be critical to understanding energy transitions, who influences and benefits from transition processes (Balta-Ozkan et al., 2015; Bouzarovski and Haarstad, 2019; Bridge et al., 2013; Bulkeley et al., 2014; Coenen et al., 2021; Creamer et al., 2018). Place-based perspectives are used in a variety of fields, ranging from regional studies, to human geography and community energy, where it is taken to mean the explicit consideration of the local and regional context, including local resources, capacities, the personal and communal identities and diversity of values in the management of environmental decisions, resulting in situated governance strategies (Barca et al., 2012; Bouzarovski and Haarstad, 2019; Coenen et al., 2021; Horlings, 2015; Neumark and Simpson, 2015; Norton and Hannon, 1997).

This paper brings energy decentralisation literature together (we believe, for the first time) with a second largely separate strand of literature that has embarked on mapping the material and spatial implications of renewable energy transitions, and puts forward a place-based approach that considers both material and decentralization aspects. As such, the first starting point of this investigation is that cities are important spatially and materially as centres of energy demand, and will play an important role in the development of new interscalar relationships that result from the large-scale investment in renewable energy and the spatial reconfiguration that it brings about. Our second starting point is taken from 'place-based' perspectives on socio-technical transitions. This study investigates the narratives used to frame renewable energy transition plans in cities, analysing both the spatial organization of renewable energy and the stakeholders involved. The development of strategic visions and scenarios for decarbonised urban energy systems and their translation into plans is considered an essential first step in identifying the measures and spatial planning implications for cities to meet specific emission reduction goals (Maya-Drysdale et al., 2020). This process involves the collection of baseline emissions and other environmental and social data, the clarification of local energy problems and subsequent development of visions and scenarios to help identify solutions, with plans shaping concrete actions on the ground (Maya-Drysdale et al., 2020). As such, this analysis of emerging energy transition plans in cities presents an important first step in understanding the emerging interscalar relationships in renewable energy transitions.

In what follows we review the literature to summarise current knowledge on the material and spatial implications of urban transitions on the one hand, and the environmental, socio-economic and political impacts and outcomes of various forms of actor engagement associated with energy decentralisation, on the other, pinpointing key knowledge gaps in the literature. We use this to underpin and structure an empirical analysis of the spatial, technological and actor dimensions of energy transition plans in cities (Section 3), and outline our Methodology (Section 4). Section 5 provides an overview of our descriptive results, which we use to identify distinct generic scalar strategies and trajectories that cities are taking. Finally, we discuss the relationship between spatial, technological and actor dimensions and the implications of these factors on the dynamics of energy transitions and its outcomes.

2. Starting premise: a tale of two literatures

2.1 The material and spatial implications of urban energy transitions

It has been estimated that future renewables-based societies will require two or three orders of magnitude more space to secure the same amount of useful energy as existing power arrangements (Smil, 2015), leading to a range of consequences for both land use and technological innovation. The current spatial distribution of economic activity developed under historical relationships between energy, environment and economic production (Bridge et al., 2013). The material spatial and technological challenges of a renewable energy transition can be encapsulated in the concept of power density, which is the amount of energy produced or consumed per unit horizontal area of land or water and is often measured in watts per meter squared: W/m^2 (Smil, 2010). The gap between the high power density consumption of cities and the low power density production of renewables is an important technological challenge of cities transitioning to a substantial portion of renewable energy. The mean power density that urban areas use globally ranges between 10 and 100 W/m^2, and hourly extremes often reach and substantially surpass 1,000 W/m^2 (Smil, 2015, p. 200). Fossil fuels and nuclear power have high power densities, ranging from 100 to 10,000 W/m^2, and in some cases, even up to 50,000 W/m^2 (Smil, 2015), and they can be sited or transported in or near urban areas. In contrast, renewable energy sources have much lower power densities of production, ranging from 0.1 to 500 W/m^2, and production capacities are determined by technology, geographic location and conditions (Smil, 2015).

At present only one city, Masdar City in the United Arab Emirates, is entirely powered by renewable energy, while a number of cities worldwide, ranging from Adelaide (Australia), to Freiburg (Germany), to Rizhau (China) to Rema (Ethiopia) have to varying degrees begun to deploy ambitious amounts of renewable energy (Kennedy et al., 2018). Many other cities have made commitments to transitions to renewable energy and published these as plans as what they currently view as a pathway forward in achieving the most ambitious renewable energy goals. However, to date, there is only a partial understanding of the potential options and impacts of a renewable energy transition for cities. Some studies outline renewable energy technologies particularly suited to cities (IRENA, 2016), but without analysis of the limits of renewable self-sufficiency. Kennedy et al. (2018) point out that the decarbonization of cities depends on their efficiency and electrification, although the technologies required to decarbonise the electricity supply and where they would be located is left exogenous. A shift to renewable energy for cities requires a strong focus on energy conservation and demand side management in order to reduce energy supply requirements that make demands on land use (IRENA, 2016; Schroth et al., 2012). Several studies have investigated the limits of self-sufficient renewable energy production in cities (e.g. Arabzadeh et al., 2020; Lund et al., 2015). Their techno-economic modeling suggests that storage and smart technology are required to increase the share of self-sufficiency of producing renewable energy locally, although none of their case studies achieve 100% renewable energy locally. Several studies conclude that cities require renewable energy production outside of their boundaries, which brings about competing land-use decisions and trade-offs (Poggi et al., 2018; Schroth et al., 2012). In theory, stringent emissions policies at city level may induce the shifting of emission generating activities beyond the city boundary to surrounding regions and beyond. Poggi et al (2018) show that solar and wind technologies in rural areas have both different geographical specificity and different implications for land-use competition with productive agricultural land, wetlands, and forestland. For example, wind is more compatible with preserving productive agricultural land than ground-mounted solar. In the case of solar siting, it has been shown that these trade-offs in land uses can lead to net release of carbon (van de Ven et al., 2021). Therefore, from a material balance perspective, this type of transition creates land-use pressures requiring spatial planning and energy planning to be combined, and careful consideration of land uses and impacts at the regional level (Ramirez Camargo and Stoeglehner, 2018). Rural areas can shift to smart specialization of renewable energy production (Poggi et al., 2018) and become net renewable energy producers (Naumann and Rudolph, 2020; Sasse and Trutnevyte, 2019). This shift would also require construction and maintenance of access roads to wind turbines; buffer zones between areas of human habitation; and extensive transmission rights-of-way to export electricity from sunny or windy areas (for example) to major urban and industrial areas (Smil, 2010).

Although these analyses and case studies have only examined a few cities overall, they indicate that cities, as large demand centres, will play an important role in shaping energy infrastructure and landscape developments in regions. Existing literature analysing the implications of urban energy transitions tends to focus on the material aspects of the transition compared to a city's boundaries, with less attention to the social and political implications, aspects and possibilities of such a transition. Poggi et al. (2018) argue that renewable energy transitions depend on concepts of regional urban systems--rural areas exporting energy to urban areas, forming new economic relationships between them-- and the decentralization of energy decisions.

2.2 Energy Decentralization and its implications for traditional and new actors

Energy is governed at multiple scales, including national governments, international governmental and non-governmental organisations, cross-border regional organisations, and by transnational networks of advocacy, quasi-regulatory private bodies, global policy networks, and public–private partnerships (Balta-Ozkan et al., 2015; Goldthau, 2012). Energy centralization describes "the degree to which critical capacity and supply decisions are centralised and co-ordinated by a single body" (Bridge et al., 2013, p. 336). Since the mid-1900's, electricity supply has consisted of distant, large-scale state and utility owned and operated thermal power generation plants (Chick, 1995; Hannah, 1979; Helm, 2004; Lawrence, 2020). These were (and in some countries, still are) predominantly centralized and operated by traditional or incumbent actors, generally state, provincial, or national electricity transmission operators and vertically and horizontally bundled energy utilities. Increasingly, studies examine the extent of shifts from "incumbent" utilities and central decision makers toward new ("niche") actors in the energy sector, with a wider range and larger number of energy producers and prosumers in the provision and management of energy (Avelino and Wittmayer, 2016; Berka and Dreyfus, 2021; Brisbois, 2020a, 2020b; Burger et al., 2020; Burke and Stephens, 2017; Devine-Wright, 2019; Haf et al., 2019; Hoicka and MacArthur, 2018; Judson et al., 2020; Stephens, 2019; Walker and Cass, 2007).

Decentralization involves a shift in technological infrastructure, a rescaling of power generation and decision making on how energy is sited, produced, consumed from centralized actors to a range of new actors, creating opportunities for new stakeholders within the market context (Berka and Dreyfus, 2021, p. 110663). These new actors typically include independent power producers, citizens, households, community organisations and other forms of social enterprise, as well as local authorities (Berka and Dreyfus, 2021; Chilvers and Longhurst, 2016; Kelsey and Meckling, 2018; Sperling and Arler, 2020). Decentralization as engagement of new actors in the energy sector is assumed to enable distribution of benefits such as energy supply resilience, job creation, local economic development and social benefits (Berka and Dreyfus, 2021). It is also seen as providing an opening for social innovations that would enable deep consumer engagement and the transformational and accelerated change that is necessary to meet global climate change targets (Chilvers and Longhurst, 2016; Loorbach et al., 2020; Müller et al., 2011; Ornetzeder and Rohracher, 2013). Importantly, given the size of the investments in energy infrastructure required (IRENA, 2020; Jacobson et al., 2017), the nature and extent of involvement of these new actors will affect who invests and profits, as well as the geography and magnitude of local economic development through the creation of jobs, new investment and business opportunities (Phimister and Roberts, 2012). However, even in areas of the world pursuing the most inclusive energy governance strategies such as Europe, the energy transition will include a blend of both new (niche) and traditional (incumbent) actors (Hoicka et al., 2021).

2.3 The place-based implications of decentralization

To date, energy decentralisation literature has paid little attention to regional context or regional implications of energy decentralisation, with regional perspectives by and large limited to analysing regional multiplier effects and development opportunities (Allan et al., 2016; Phimister and Roberts, 2012), also in the developing world (Alazraque-Cherni, 2008). Similarly, a key criticism of energy transitions studies is that they are place-blind, resulting in simplified dynamics and roles of new ("niche") actors versus traditional ("incumbent") actors and losing sight of processes that are non-hierarchical and relational (Avelino and Wittmayer, 2016; Berka et al., 2020; Bouzarovski and Haarstad, 2019; Creamer et al., 2018; Turnheim and Sovacool, 2020). For example, there is an overemphasis on local, urban, or nationally bounded and discrete studies (Balta-Ozkan et al., 2015; Naumann and Rudolph, 2020). This has led to a call for place-based analysis to understand the actors, processes and relationships involved in shaping energy transitions - whether the scope of analysis is local, urban or regional (Bouzarovski and Haarstad, 2019; Bulkeley et al., 2014; Coenen et al., 2021; Creamer et al., 2018). This includes the acknowledgement of the importance of regions in energy transitions (Balta-Ozkan et al., 2015; Coenen et al., 2021; Nijkamp, 1980), since depending on locally specific contracts, public perception, the energy legacies of local authorities and elected representatives, "a technological decentralisation with small-scale power plants at more sites and in more regions entails a shift of potential democratic control to lower levels, i.e. regions and municipalities, and affects a larger number of them" (Bauknecht et al., 2020, p. 109543). While a plurality of perspectives is encouraged, existing place-based understandings of energy transitions are heterogeneous, without a cohesive conceptual framework to tie the plurality of perspectives together (Coenen et al., 2021). One of the prominent subfields within decentralisation literature that takes a place-based perspective on energy transitions focusses on civic and community participation.

2.3.1 Community Energy

Community energy distinguishes actors as private, public, and communities that are local or networked. This literature has largely focussed on local dynamics, motivations, and impacts, observing local distributed energy as arising from cohesive community networks, as a form of environmental activism and an alternative to energy that is managed and controlled by traditional actors in the form of utility scale, renewable energy projects and/or strongly motivated by local socio-economic needs (Bomberg and McEwen, 2012; Devine-Wright, 2019; Seyfang et al., 2014; Smith, 2005; Walker et al., 2010). More recently, community energy literature has moved to documenting enabling institutional contexts, national level taxonomies for civic energy and country comparative studies (Bauwens et al., 2016; Berka et al., 2020; Creamer et al., 2018; Gorroño-Albizu et al., 2019; Heras-Saizarbitoria et al., 2018; Hewitt et al., 2019; Hoicka and MacArthur, 2018; Kooij et al., 2018; Wierling et al., 2018). Community energy offers a place-based understanding of the forms of engagement between renewable energy production and adjacent communities. In many cases, community energy is used as an umbrella term for "various forms of locally led, collectively owned, and managed energy projects" (Creamer et al., 2018, p. 2) and a concept used to ensure that benefits are local and collective, rather than distant and private, emphasizing the proximity of local citizens to energy activities (Walker and Devine-Wright, 2008). A key concept is therefore 'communities of place' implying "a set of social relationships embedded in a particular locality—the idea of territorial community or community of locality" (Walker, 2011, p. 778) where "identification with a place-based community facilitates participation [..]. A sense of belonging to a particular place is observed to inspire voluntary efforts to develop community renewable energy to generate local benefits" (Creamer et al., 2018, p. 3). Although not all energy projects that involve citizen collectives are local, it is argued that the association with normative goals that are typically collectively negotiated through local networks means that it is often local in practice (Seyfang et al., 2014, 2013). At its core then, community energy literature and practice can be seen as an extension of localist resistance to the social and environmental problems that have emerged from the globalised capitalist economy (Berka, 2018; de Moor, 2013).

Likely a result of its strong normative orientation, the local or community energy literature has been criticized for overstating the power and agency of community organizations, and for not taking into account the multi-scalar relationships and dependencies between civil society actors of different locations, the private sector and the state, as well as potentially underplaying the role of civic networks and social relationships that extend beyond specifically place-based networks (Becker and Kunze, 2014; Berka et al., 2020; Bouzarovski and Haarstad, 2019; Creamer et al., 2018). For example, *communities of interest*, where a regional or national network of investors invest in a renewable energy project, are widespread, but may focus on benefits secondary to the local community and be funded by a variety of private or public funds. They may be largely market or incentive driven and therefore more "standardized and scalable" than *communities of place* models (Baigorrotegui and Lowitzsch, 2019; Bauwens and Devine-Wright, 2018; Hicks and Ison, 2018; Maruyama et al., 2007; Walker, 2011). In addition, 'community as actor', referring to bodies of local decision making, such as local government and local authorities, is also an important actor in rescaling and decentralization (Walker, 2011). Municipalities as local governments play a variety of roles in facilitating community energy and energy decentralisation more generally, ranging from brokering projects, facilitating route to market, investing and encouraging through the use of planning and incentives.

3. Conceptual framework: Regional Perspectives on city actor-material strategies

Regional perspectives are now challenging approaches that are locally, urban, or nationally bounded and discrete (Balta-Ozkan et al., 2015; Naumann and Rudolph, 2020), highlighting the important gaps and debates in our understanding of how an energy transition will occur, who is affected, and the transitions to new spatially located economic activities and socio-economic outcomes. Although regional analysis of energy transitions was proposed as early as 1980 by Nijkamp (1980), spatial analysis and regional approaches are only recently gaining prominence in analysing low carbon and renewable energy transitions, encompassing a plurality of perspectives of energy transitions in, of, and by regions (Coenen et al., 2021). These perspectives argue the importance of the regional and spatial differentiation in renewable energy transitions with respect to land-use, infrastructure, new localizations of smart specialization and agglomeration of firms in support of renewables, particularly in rural areas; the coordination of a wider range of actors in the energy system across the region; and the resulting socio-economic impacts (Balta-Ozkan et al., 2015; Foray, 2014; Müller et al., 2011; Naumann and Rudolph, 2020; Nijkamp, 1980; Poggi et al., 2018; Ramirez Camargo and Stoeglehner, 2018).

Many city energy studies have tended to leave impacts on surrounding regions exogenous, and there are no systematic reviews or frameworks that set out the full range of regional implications associated with city energy transitions. However, there are some key studies and findings that can help us indicate appropriate areas and methods of analysis. Drawing both on existing regional perspectives and building on the literature review set out in 2.1 and 2.2, we can expect city renewable energy transitions to affect the following regional dimensions, discussed below in turn.

Table 1: Regional impact dimensions of city renewable energy transitions

Dimension	**Impact**
Regional Land use	New land use for renewable energy production.
	Trade-offs and spatial constraints in the use of peri-urban land.
Regional Infrastructure	Infrastructural investments to overcome network constraints and build in flexibility mechanisms.
Spatial agglomeration and smart specialisation of firms	Regional co-ordination of complementary development of capabilities within specific fields, technologies and sub-systems necessary to materialise city energy transition plans.
Actor involvement	Which actors are involved inside the city and in neighbouring communities within the wider region and extent of participation.
Socio-economic outcomes	Actor involvement shapes spatially differentiated income and employment effects and the (perceived) distribution of costs and benefits influences social acceptance.

3.1 Regional Land-use

A renewable energy transition for cities will have material effects on the surrounding region, leading to trade-offs in land-uses that have social and environmental consequences. As discussed in Section 2.1, urban areas will rely on the surrounding region, communities and rural areas for the materialization of renewable energy transitions (Naumann and Rudolph, 2020; Poggi et al., 2018). This requires new land-uses for renewable energy, leading to trade-offs and spatial constraints in the use of land for cultural, environmental, and social outcomes and impacts (Poggi et al., 2018; van de Ven et al., 2021), requiring spatial planning tools for energy transitions (Ramirez Camargo and Stoeglehner, 2018).

3.2 Transformation of Regional Infrastructure

Regional approaches emphasise spatial differences in infrastructure implementation, such as network constraints and new locations of power generation. The transformation of infrastructure underlying renewable energy transitions is tied into regional land-use changes. Increasing the share of renewable energy technologies on an energy system requires technological upgrades and investments towards flexible local distribution systems globally (Martinot, 2016) and new investments in transmission systems (Clack et al., 2020). Regional approaches are argued to be critical to consider the coordination of activities at the regional level to find flexible solutions to avoid sub-optimal results (Balta-Ozkan et al., 2015). For example, the uptake of energy efficiency varies by locational characteristics (Morton et al., 2018), which impacts the supply demand balance in locations differently. The rapid diffusion of solar photovoltaics in a particular location without flexibility or complementary renewable sources can lead to the "solar duck curve" and system instabilities (Krietemeyer et al., 2021). These types of changes can lead to infrastructure and network constraints or opportunities, requiring new and spatially differentiated investments in transmission and distribution systems (Balta-Ozkan et al., 2015).

3.3 Regional Agglomeration of Firms and Smart Specialization

Regional approaches highlight how spatial structure is important to the function and development of regional economies (Parr, 2014) and emphasize the importance of regional specialization and competitiveness (Foray, 2014). Regional urban systems approaches are concerned with how the urban centre and other surrounding centres in a region relate to each other with respect to location and demographics of economies (Burger et al., 2014). The regional urban systems approach addresses competition versus complementarities, the level of regional coordination and cooperation between centres within the urban system, and the spatially organized behaviour of individuals, households and firms (Burger et al., 2014). In creating productivity, urban centres may rely on "borrowed size" in which urban agglomeration effects are not limited to the city's physical boundaries, spilling over into smaller surrounding communities that then have a higher productivity than would be expected. At the same time, surrounding communities in the regional urban system may also rely on "borrowed function" advantages that result from the greater accessibility of services, labour, and physical spatial spillovers of functions from larger cities (Camagni et al., 2016). The benefits of borrowed size and function in regional urban systems is about considerations beyond simply the proximity of agglomeration economies, but to also include consideration for how networks between actors and firms are functioning and what their impacts are (Camagni et al., 2016).

Renewable energy transitions require the emergence of clusters of innovations (Hoicka et al., 2021), which requires underlying supporting innovation systems (Coenen et al., 2018) and new spatial agglomerations of firms (Balta-Ozkan et al., 2015; Jaegersberg and Ure, 2017). Rural and urban areas can have complementary specializations. Urban areas will require specialization in flexibility, efficiency and conservation, as well as renewables suited for dense urban landscapes (Hoicka et al., 2021). By shifting to smart specialization in renewable energy, rural areas can expand on the main functions and services they offer from agriculture and landscape to include the net export of renewable energy to urban centres (Naumann and Rudolph, 2020; Poggi et al., 2018). These new complementary specializations would alter regional urban systems dynamics between urban centres and surrounding communities. Camagni et al. (2016) describe how in a regional urban system, the urban centre would benefit from the "borrowed size" of the surrounding communities and regions, and the surrounding regions would benefit from "borrowed functions" from the city.

3.4 Actors involved in each location

Across studies that take a regional approach or view cities as part of a regional urban system in a renewable energy transition, there is agreement that decentralization of energy related decisions to the the public, and to locally, and regionally scaled actors is a permitting factor for regional renewable energy transitions (Balta-Ozkan et al., 2015; Bauknecht et al., 2020; Müller et al., 2011; Poggi et al., 2018; Ramirez Camargo and Stoeglehner, 2018) and that borrowed size and functions depend on how networks between actors and firms are functioning (Camagni et al., 2016). For example, in order to leverage the benefits of the energy system, such as tax and employment, across the range of public and private institutions, there needs to be concerted and coordinated action that builds on pre-existing relationships (Balta-Ozkan et al., 2015, p. 506) and that can generate legitimacy and public support for renewable energy developments (Müller et al., 2011). Regional renewable energy self-sufficiency, a scenario that may constitute less energy generation capacity than a scenario involving energy export to cities, depends on "administrative and civil society actors to initialize and develop projects at the local level, ensure their acceptance and support by the regional population and implement the project in collaboration with relevant actors." (Müller et al., 2011, p. 5800). The land-use conflicts and trade-offs that are inherent to rural areas in renewable energy transitions makes municipal participation critical to land use planning processes (Poggi et al., 2018). For civic actors, contestations around energy issues often occur in rural areas (Naumann and Rudolph, 2020) and social acceptance of renewable energy is increased with open decision-making and regulatory processes that meaningfully engage local people and distribute costs and benefits fairly (Rand and Hoen, 2017). As such, spatially locating centralized and decentralized actors and resources involved in energy infrastructural development and planning is a helpful first step in better understanding the implications of an energy transition.

3.5 Socio-economic outcomes

Regional approaches emphasise spatial differences in socio-economic outcomes (including income and employment effects, equity, empowerment) in relation to ownership and economic activity. Taking together the implications of city renewable energy transitions both in terms of the spatial aspects of material changes, and associated financial and institutional arrangements will alter and shape place-based relationships amongst a range of actors involved in the transition. This will shape outcomes such as locations of economic development, and the distribution of control, costs and benefits among actors. These issues are important to address at the regional scale because renewable energy transitions can exacerbate or improve regional inequalities and inequities between core and periphery (Balta-Ozkan et al., 2015; Golubchikov and O'Sullivan, 2020; Sasse and Trutnevyte, 2019). For example, renewable energy transitions can help to revitalize poorer regions and offer emancipatory potential for rural areas (Balta-Ozkan et al., 2015; Müller et al., 2011; Naumann and Rudolph, 2020; Poggi et al., 2018). Energy development can contribute to reversing rural deprivation, improving the attractiveness of peripheral areas for immigration, and create positive spillovers towards infrastructure and public services such as transportation, schooling and healthcare, further supporting a positive regional identity and attractiveness (Müller et al., 2011). Muller et al. (2011) warn that these potential benefits have been overlooked due to lack of robust insight into the value creation for regions and that local level participation is critical in managing inevitable conflicts. Therefore, how infrastructure development is implemented has important economic implications. Sasse and Trutnevyte (2019) found that in producing renewable energy, least cost solutions favoured fewer productive locations in a region, while a more equitable approach to allocating renewables by population or demand can lead to higher electricity generation costs. They argue that due to its widespread applicability, the technology that increases regional equity is solar PV (Sasse and Trutnevyte, 2019). However, a wide variety of community energy models now exist and some of these enable communities of interest to benefit from distant and large-scale renewable energy developments, suggesting that socio-economic outcomes are not just a function of which technology is deployed, but also the business models and ownership arrangements used to finance and deliver them.

In summary, a regional approach with a focus on decentralized energy decisions is more likely to capture the important societal implications of renewable energy transitions of cities and provide decision makers with knowledge towards more equitable approaches.

4. Methods

4.1 Objectives & study context

The objective of this study was to map out the material and spatial aspects of a renewable energy transition, as well as the stakeholders who are involved directly in renewable energy generation in relation to the city. As only one city (Masdar City in the United Arab Emirates) has achieved 100% renewable energy backwards-looking studies will yield little information at this time. However, emerging energy plans will influence the subsequent decisions, impacts and dynamics of transitions. Because energy transition plans frame and guide concrete actions on the ground, they provide an opportunity for forward-looking analysis. An initial first step to a place-based analysis of the impacts and implications of a renewable energy transition for cities is to identify which cities are pursuing ambitious renewable energy futures to map out in relation to the city, and who is involved in specific decisions and plans as they relate to energy siting and control. The focus of this study is on spatially and energy dense cities with ambitious renewable energy goals, because this is where we are likely to see significant material regional implications.

4.2 Data collection

The initial sample of cities plans was gathered between January and July 2020, through websearch from scholarly articles, research, and advocacy organizations working on the interface between environmental issues, climate change, renewable energy, energy, and/or cities. Thirty organisations listed in Supplementary Materials were determined to provide relevant information in the form of lists of locations with 100% renewable or carbon neutral goals. Some organizations provided direct links to 100% renewable energy or carbon neutrality plans, while others simply identified the localities in question. From this we identified 639 potential cities with public goals for renewable energy. Eighty-one potential cities were removed because they did not meet the first criteria for being a city at the lowest tier/level of government responsible for planning. For example, potential cities were removed if they were found to be neighbourhoods, regions, provinces, prefectures, districts, villages, networks of municipalities, research centres, resort towns, townships, counties, states, countries, islands, or a planned developments of new cities. Given the focus on energy dense cities, this list was narrowed by selecting locations with high energy density of demand (W/m^2) and high population density within the area representing the lowest level of local government responsible for planning. The cut-off thresholds used were cities with a population size and density of or above 100,000 and 200 persons per square kilometer respectively, based on definitions for 'city' and for 'urban' by Atlas of Urban Expansion (Angel et al., 2016) and the United Nations Demographic Yearbook 2018 (UN DESA, 2019). According to the Atlas, there is "near universal agreement that a settlement of 100,000 people or more constitutes a city" (Angel et al., 2016). Density is a recurring quantitative determinant of 'urban', with density criteria ranging from a minimum of 200 to 500 persons per square kilometer (UN DESA, 2019). This resulted in an initial sample of 276 cities.

Information on renewable energy goals was collated for the 276 cities in the form of an adopted plan or document that directly mentions the goal and steps toward achieving it. These were identified using searches within a city's internal search engine, Google searches on the page of the city's official website and any associated websites. For each city identified, all documents that were directly related and part of city energy plans were collated and included for the content analysis, including progress reports, implementation documents, and utility reports or internal documents. For example, for Helsinki, Finland, we included the website from the municipally owned utility, Helen, because the webpage was directly linked to, and an important part of, the Helsinki City's plan for carbon neutrality.

The sample was narrowed down further by identifying whether the plan was adopted (110), in process (25), drafted (14) or not found (i.e. as of yet undrafted or not available to the public yet) (193). Only adopted plans were selected for further analysis. These plans offered four levels of ambition, from (1) most ambitious to (4) least ambitious, categorised as follows:

1) 100% renewable energy city-wide - this was classified as the most ambitious as it includes use of renewable energy for all energy carriers and uses across the city.
2) Carbon neutral city-wide - Carbon neutrality addresses all types of energy used in a city, although potentially less ambitious as it allows the use of offsets, allowing the purchase of credits for greenhouse gas reductions from a third party.
3) 100% renewable electricity city-wide- Electricity-only related goals were considered less ambitious as electricity currently competes with other energy carriers, making up a 20% share of final energy consumption globally in 2017 (IEA, 2019)
4) 100% renewable energy, 100% renewable electricity, or carbon neutrality applied to city-operations only - these plans cover emissions under the direct control, influence, and

responsibility of the local government. City operations make up a small portion of overall energy use and emissions in cities.

To focus on as close to 100% renewable energy transition as possible, only the two most ambitious city-wide levels were analysed:

- *100% Renewable Energy* in which the annual amount of total energy consumed within an area is provided by renewable energy (Sierra Club, 2016) including buildings, transport, heating, cooling, and waste.
- *Carbon Neutral* in which the net greenhouse gas emissions associated with the city are zero (Plastrik and Cleveland, 2018) by combining carbon reduction/mitigation measures and carbon offsets (European Parliament, 2019)

This narrowed the sample to 47 plans spanning 5 continents: 29 in Europe including the UK, 17 in North America, 2 in Asia, 1 in Oceania and 1 in Africa. Between January and July, 2021, an additional search across these 47 cities yielded additional documents which were added to the sample. The population densities, size and plan ambition are described in Figure 1 and 2.

Figure 1: City plans by ambition, population density and size.

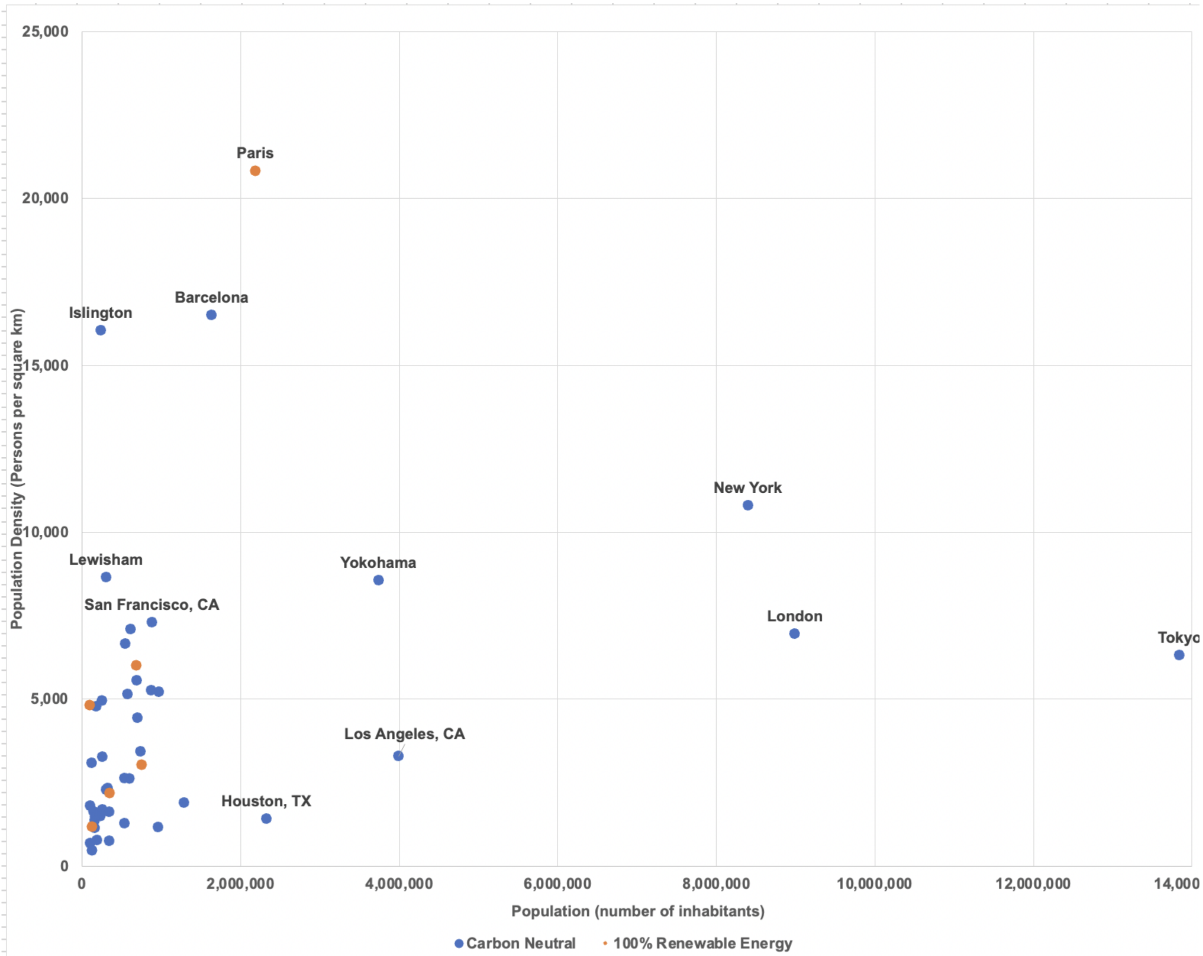
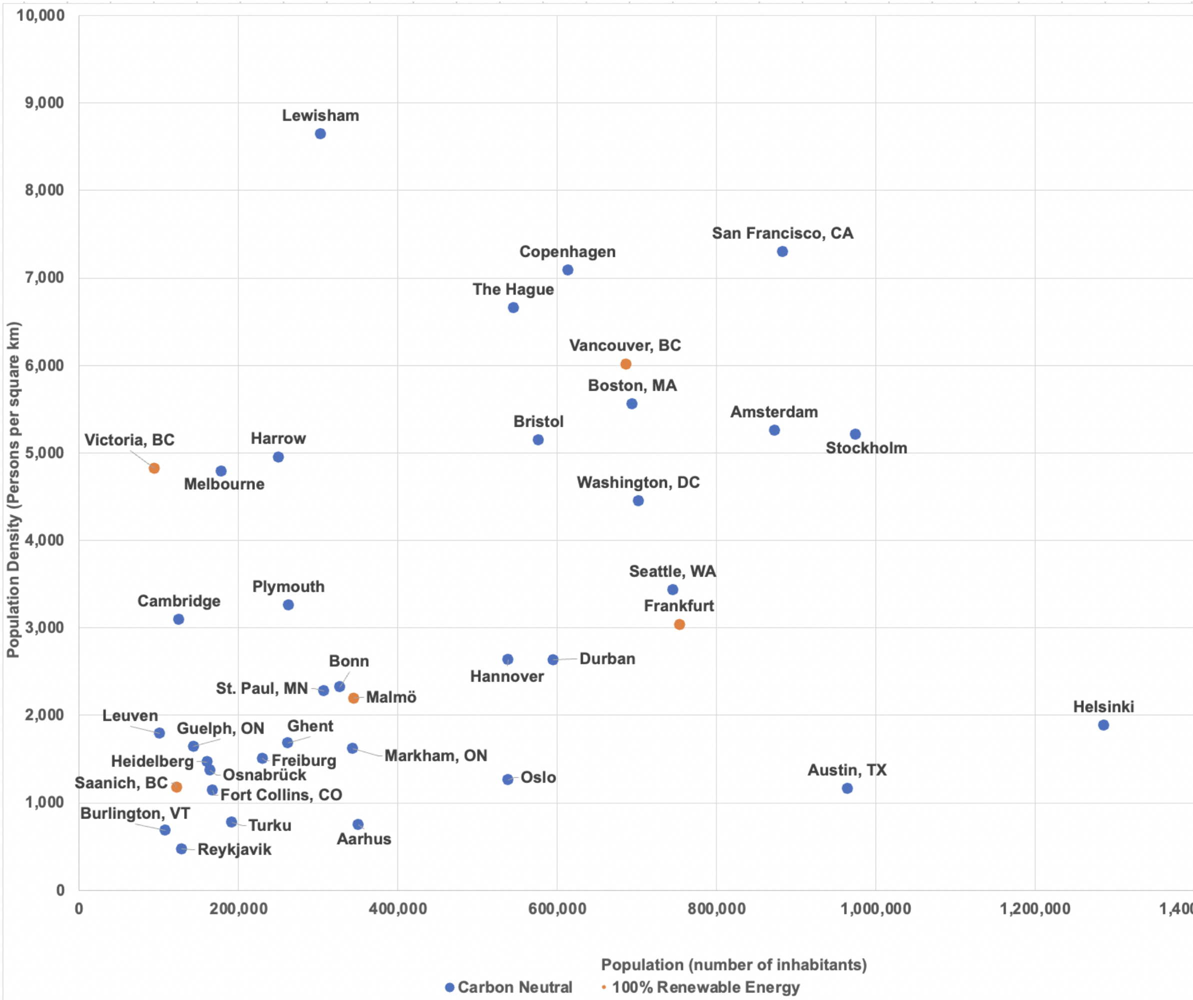


Figure 2: City plans by ambition, for population density up to 10,000 persons/KM² and up to 1,000,000 inhabitants.



4.3 Content Analysis

The plans were analysed using content analysis, which is widely used to systematically determine the presence of themes or concepts in qualitative data and has been used elsewhere to analyse elements of local energy plans (St. Denis and Parker, 2009; Tozer, 2013; Tozer and Klenk, 2019; Wyse and Hoicka, 2019). Coding categories were determined on the basis of the conceptual framework outlined in Section 3 and open coding was also used as some emergent categories were added during the coding process (Babbie, 2008). First, the type of Energy Source was coded (Table 2) in relation to its location and scale in relation to the city (Table 3). The plans were also checked for flexibility and energy efficiency strategies taken by cities, because they are important mediating factors for the amount of renewable energy production required. The four types of innovations checked for included 1) conservation and energy efficiency; 2) electrification; 3) design (e.g., compact urban design); and

4) flexibility such as storage, demand response, and smart technologies and grids (Supplementary Materials).

A second stage of coding was used to identify the actors involved (Table 4), in relation to the scale of decentralization and where they are located in relation to the city (Table 5). Actor types distinguish between civic, public, private, and partnerships to be able to analyse and distinguish engagement of actor types at different scales and extent of civic participation, as well as distinguish between incumbent centralized energy systems that may be public-private partnerships, private corporations, or publicly owned. Scales of decentralization were identified by mapping out the spatial or institutional scale associated with actors involved (Table 5). Table 5 distinguishes in the first place between 'local to the city' in question, and regional, representing the surrounding region and neighbouring communities to the city. This is because regional approaches are concerned with firm behaviour at various scales, and location, agglomeration economies and regional actors, such as the regional authority, neighbouring communities and rural areas. Depending on the context, the actors who traditionally control energy systems may operate at the sub-national (i.e., state, provincial, multi-state, multi-province), national or even international scales. While these are distinct institutional scales, for purposes of this study we consider these actors to generally be involved in centralized activities , and these scales were amalgamated into one combined "centralized" category (Table 5).

Taken together these three scales allow us to capture the range of issues presented by decentralization, regional approaches, and community energy in support of place-based perspectives. This coding, while simple, allows us to start to unpack place-based actor involvement in the development of new and changing interscalar relationships that will result from the large-scale investment in renewable energy and the spatial reconfiguration that it brings about. While we recognise that energy transition plans are tentative and subject to change, and that the development and implementation of the energy plan itself is important, the focus of this study was to analyse the narratives and solution framing embedded in these plans. As such, only the actors who were mentioned to be directly involved in energy generation, whether through regulation, control of systems, investors, etc., were considered in this coding.

Table 2: Types of Energy Sources

Source Category	Examples
Bioenergy	Biofuels Biogas Biomass Renewable Natural Gas
Fossil Fuels	Compressed Natural Gas Natural Gas Liquified Natural Gas Coal Oil
Geothermal	Geothermal
Hydropower	Hydropower / Hydro electricity
Nuclear	Nuclear
Renewable	Renewable Energy / Renewable Electricity
Solar	Solar PV Rooftop Solar PV Concentrated Solar Power Solar Thermal/ Solar Heat/ Solar Hot Water Rooftop Solar Thermal
Waste/Process	Waste Heat / Excess Heat / Industrial Heat Waste to Energy District Steam Process Heat Heat or Cooling from Sea Water
Wind	Wind
Not Specified (NS)	Not Specified

Table 3: Energy Source Scale and Location in Relation to the City

Scale	**Examples**
Local	Energy produced inside the city
Region	Produced in a neighbouring community or the surrounding region
Existing energy system	Energy received from the existing power grid or energy system.
Location Not Specified (LNS)	No indication of location offered in document

Table 4: Actor Types

Actor Types	Definition
Civic	Residents, citizens, individuals, community organizations, not for profits
Public	Government, local authority, regulatory bodies, public sector organizations, publicly owned utilities
Private	Firms, financial institutions, private utilities
Partnerships	some combination of civic, public, private

Table 5: Scale of Decentralization

Spatial or Institutional Scales of Actors	**Definition**
Local	The stakeholder is located within city's boundaries, such as a resident, local organisation, or the City itself.
Regional	The stakeholders are located in the regional area. These could be regional authorities, residents, local businesses, or neighbouring communities.
Centralized	Actors operating at sub-national, national, international that traditionally control the existing energy systems. The actors that operate at sub-national scales, that could be provinces, states, or multiple provinces and states. International actors operate in countries outside the city and sometimes multiple countries (e.g., the European Union). This could include cities in other countries.

5 Results

5.1 Material Strategies

Figure 3 depicts the material aspects of cities transitioning to renewable energy, including the types of energy sources produced locally, regionally, from the existing energy system and for locations not yet specified. Where some types of renewable energy have multiple types of associated technologies, for example, solar can be photovoltaic, rooftop, ground mounted, concentrated, thermal, etc., each type mentioned in the plan was coded for separately. The results show that for energy produced locally within the city, the broadest range is solar, followed by waste energy and process heat, and bioenergy. Solar and waste energy and heat are all particularly well suited renewable energy technologies for dense urban areas (IRENA, 2016; Stremke et al., 2011). Wind energy, geothermal and hydropower and unspecified renewables had a smaller share, in part due to fewer technology sub-types, and in part because resource potential is more location specific and technology less ubiquitously deployable, and in the case of wind less suited to dense urban areas. As expected, energy coming from the region is predominantly made up of wind as rural areas are able to match the land uses required for wind energy production (Pasqualetti, 2012; Smil, 2015). Energy coming from the existing grid as unspecified renewable energy aligns with leaving the decarbonization of the energy system exogenous from the decisions that cities make.

Figure 2: Material strategies of a renewable energy transition for cities

Legend: NS= not specified, LNS = location not specified

All cities were found to be pursuing all four types of innovations(conservation/ efficiency, electrification, flexibility and design) necessary to reduce the amount of energy required and the requirements for self-sufficiency and land-use requirements.

Figure 4 depicts the location of energy production that the cities in the sample intend to rely on. All cities except for Cambridge UK included renewable energy plans without specifying a location or the type of renewable energy technology. The largest subset in the sample (n=19) plan to rely on energy from local and regional locations as well as the existing energy system. A smaller number (n=16) plan to rely on renewable energy produced locally and from the existing energy system. A smaller number of cities have only identified local sources of renewable energy (n=6) or identified local and regional sources of energy (n=6).

Figure 4: Location of Renewable Energy Production for Cities

Legend: Existing = Existing energy system

5.2 Actor Material Strategies

The actor scalar strategies of the city plans are shown in Figure 5, depicting the type of actors and associated scales that were found in the plans to be directly involved in energy development. The relative size of chart components indicates the range of involved actors identified for all cities at that scale. Not surprisingly, most actors identified were operating locally within the city, followed by actors operating at centralized scale, and then the regional scale. In all three scale categories, the dominant types of actors identified were public. At the local scale, the second most predominant actor type was civic, and the third most dominant actor type private, this was reversed for the centralized and regional scales which had a wider range of private over civic actors.

Figure 5: Actor scalar strategies across the sample

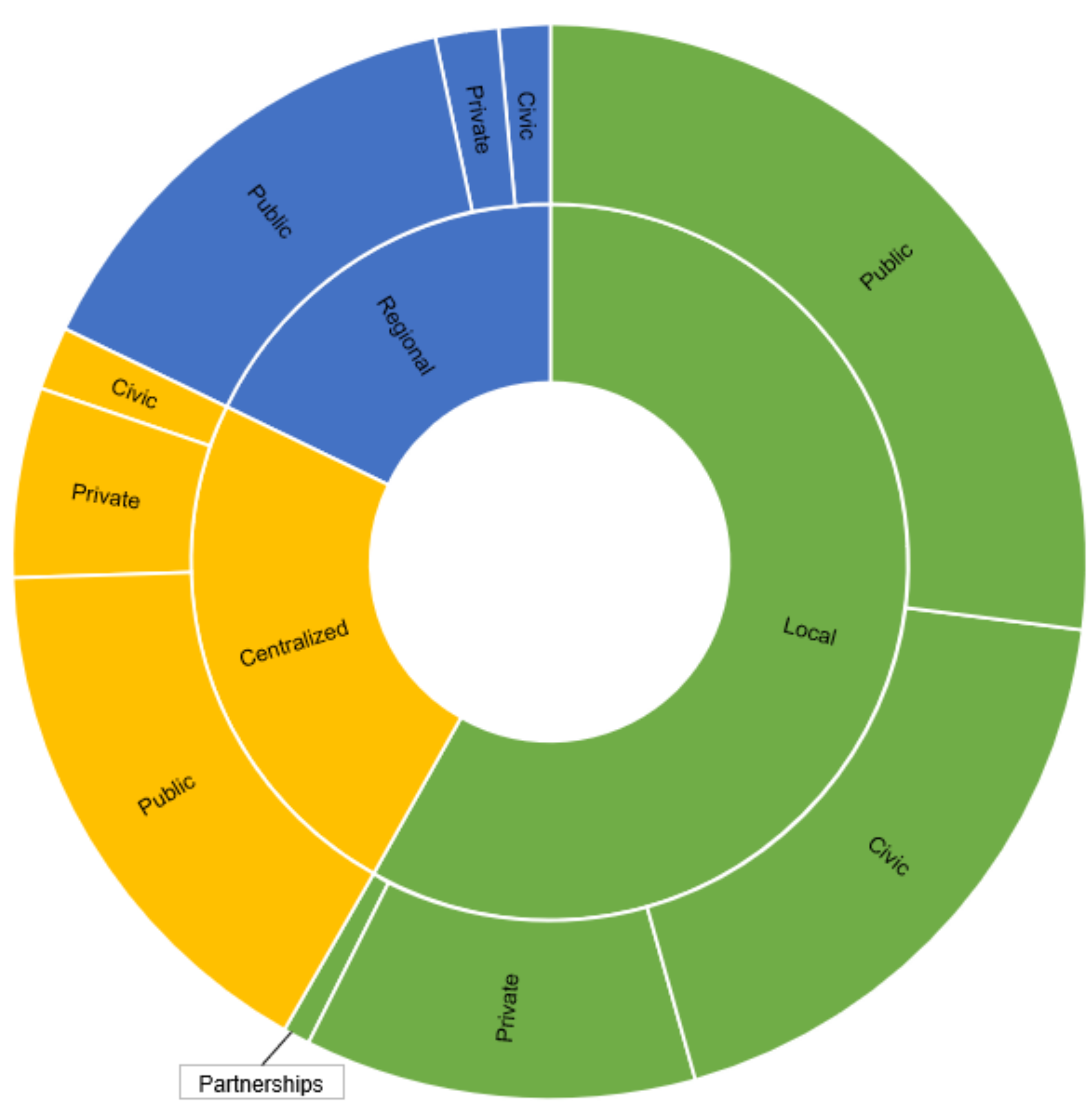


Figure 6 identifies the combinations of actor scales for each city. The largest subset of cities combine local, regional and centralized actors in their transition plans (n=20). This is followed by a subset of cities that rely on local and centralized actors in their plans (n=13), followed by local and regional (n=7), and local only (n=7).

Figure 6: Actor Material strategies by city

Table 6 shows how the proposed location of energy generation for the most part lines up with the actor material scale, although there are exceptions. For example, two plans proposed mainly local energy generation, although they have regional and centralized actors involved in activities to procure renewable energy. These plans aim to acquire support from actors at various scales (regional, sub-national, national or multinational) through renewable energy standards or targets that affect the plan. Five cities, The Hague, Islington, Tokyo, Vancouver and Oslo, have not procured energy from regions yet, however, their plans indicate that they are engaging with regional actors to do so. For example, Vancouver will coordinate with regions on pollution and waste, as well as on regional growth strategy plans, but has not indicated relationships within the region to generate energy. Oslo indicates plans to collaborate with the county of Viken for the procurement of energy. Tokyo is planning hydrogen from renewable energy produced in the surrounding region. Islington is partnering with neighbouring London in a civic bulk purchase scheme of solar panels, and regionally through the London Environment Directors Network. The Hague is participating in a Regional Energy Strategy. In contrast, energy plans of Copenhagen, Fort Collins, Reykajavik, San Francisco, Seattle and Turku describe local and regional actors and locations of generation, as well as the existing energy system, because the existing energy systems are regional. For example, Platte River Power Authority sources some of its portfolio of renewables from communities in the region for Fort Collins. Regional utility Reykjavik Energy is owned by the City of Reykjavik, and two neighbouring cities of Akranes and Borgarbyggð and is planning a wind farm within city limits. Regional, community-owned utility Seattle City Light provides electric power to the city of Seattle, as well as areas North and South of Seattle. In Copenhagen, the district heating grid is linked to the grid in the neighbouring regional municipalities. This illustrates how plans are influenced by existing institutional arrangements.

Table 6: Comparing Actor Material scales and Location of Energy Generation

Decentralization Scale	Local energy generation	Local and regional energy generation	Local energy generation and existing energy system	Local, regional energy generation and existing energy system
Local actors	4	2	1	0
Local and regional actors	0	2	0	5
Local and centralized actors	1	0	11	1
Local, regional and centralized actors	1	2	4	13

5. 3 Analysis

From the descriptive results outlined above we can identify four distinct emerging actor material strategies. For each distinct strategy, specific interscalar relationships between the actors emerged from the coding of the plans as texts. Information about which specific actors are influencing different types of decisions are provided in rich detail (see Supplementary). These qualitative details illustrate the narratives and solution framing embedded in these plans.

5.3.1 Local and Centralized

Thirteen cities identify mainly local and centralized actors and focus on two main types of stakeholders: the city itself (community as actor), and the traditional centralized energy utilities governed at the provincial, state or national scale. For the most part, these plans are thin on description of activities and associated actors, making it difficult to distil emerging interscalar relationships. All of these plans identified the dependence on the traditional utility for energy supply. All thirteen focus on city operations and jurisdiction of the city, and with regards to external actors are largely limited to encouraging local residents and businesses. Most plans explicitly aim to influence the sources of energy used by utilities as a key strategy to obtain 100% renewable energy or carbon neutrality, as well as lobbying with state or central higher levels of government (state or national) to pursue these goals. Some plans outline important benefits for citizens, including training and skills development, and reducing energy bills of lower income groups. These plans also tend to associate with local ownership of renewable energy either in the form of self-consumption or, where there is control by centralised utilities, developing special arrangements to enable consumers to sell excell power onto the municipal grid. For example, Durban (South Africa) has established a city level feed-in-tariff to facilitate small-scale embedded generation. Within this category, just three cities adopt the most ambitious goal of 100% renewable energy. These were Saanich, Vancouver, and Victoria, cities in the Canadian province of British Columbia, that all have provincially mandated and regulated energy utilities (BC Hydro, Fortis BC). In the UK, London's plan specifically cites urban density as a key reason for why energy must be imported. The population densities and populations of the cities adopting this actor material strategy vary greatly. Further analysis could unpack the spatial material-economic, institutional and discursive factors that explain why these cities are pursuing a centralized strategy.

5.3.2 Local

Seven cities rely mainly on local actors to implement a renewable energy transition. In some cases (such as Barcelona, Malmo) the plans do not convey much detail on the specific activities, locations and actors involved. In these cases, the plans tended to focus on the actions that the municipality could take to promote local action by residents and businesses. All plans intend to deploy solar PV within the city. In Barcelona and Malmo, this includes citizen ownership of renewable energy installations, for example through household prosumership or community projects. Local energy development in Stockholm, Los Angeles and Austin is facilitated by municipally owned utilities (Stockholm's is a partnership), and Harrow is investigating the impact of a municipally owned utility on fuel poverty. Los Angeles' plan addresses the capacity benefits of local job creation, particularly for underserved or marginalized communities. Several of the municipally owned utilities are planning how to source renewable energy locally and from markets. For example, the municipally owned utility of Los Angeles will procure 100% renewable energy by 2045. In summary, purely local energy plans tend to either be at early stages of development, or be enabled by direct control and expertise over energy infrastructure in the municipality in question.

5.3.3 Local and Regional

Seven city plans are relying on local and regional actors for implementation of energy generation. These plans demonstrated both engagement of local residents and firms, but also had clear strategies to engage the broader region and to coordinate with the region and neighbouring communities to obtain renewable energy. Five of these seven cities, Copenhagen, Fort Collins, Reykajavik, San Francisco, and Seattle have pre-existing regional energy systems. These plans demonstrate cooperation and coordination among regional partners and stakeholders across the local and regional scales, with municipalities playing an important role in sourcing renewable energy from regional partners and neighbouring communities. Some of the energy suppliers are owned by one or multiple neighbouring communities. For example, Yokohama is planning to engage surrounding communities for the production of renewable energy. Hannover's renewable energy transition is coordinated at the regional scale through climate action plans, and binding agreements exist with several neighbouring communities for the production of renewable energy for Hannover.

5.3.4. Local, Regional and Centralized Actors

The 20 plans that outline roles for local, regional and centralized actors have the richest descriptions of activities and interscalar relationships. These city plans include centralized actors, such as state or national energy utilities and systems, alongside new decentralized energy actors, such as citizens and neighbouring communities. These plans offer many details of emerging interscalar relationships with decentralized actors taking advantage of opportunities offered by centralized and incumbent stakeholders and systems. For example, Paris, a city with one of the highest urban densities and highest populations, is coordinating renewable energy generation within the city, the region with neighbouring communities, and also relying on the national and European energy systems. Houston has power purchase agreements in place with neighbouring communities engaged in bulk purchase or "solar co-ops" in the region. Melbourne developed a power purchase agreement in cooperation with businesses, universities, local governments, public institutions, enabling construction of a 39 wind farm outside the city in regional Victoria. The Hague, Netherlands will develop new local markets by matching-making waste heat supply and demand, work with the national government to make changes, and is working on a regional energy strategy with a regional utility. Ghent, Belgium's plan stands out with the focus on regional specialization of developing a bioeconomy cluster. Amsterdam, the Netherlands, plans to develop a municipal energy hub at the harbour. This includes being the only city to plan to import a global supply of renewable energy in the form of hydrogen made in sunny international locations and supplying this hydrogen regionally. Amsterdam will also support citizen ownership of energy, and work with regional partners and with the national climate targets. Islington, Tokyo, Freiburg, and Paris are lobbying, supporting or relying on regional, provincial/state or national governments to decarbonize electricity. Finally, Guelph is relying on changes to provincial regulations to encourage net-metering and other prosumership and flexibility measures. This shows the wide variety of ways cities leverage, depend on and benefit actors beyond the city, both in regions and beyond, to implement energy transition plans.

6. Analysis & Discussion

Although these plans are stated commitments that have to a large extent not yet been achieved, the findings shed light on the strategies, narratives, associated scales of action and key actors presumed to be involved in energy transitions. These will frame subsequent efforts and underpin developments on the ground to shape the spatial reconfiguration of energy to supply and sustain large densely populated cities. The empirical findings confirm the importance of moving beyond local, urban or nationally bounded studies to include regions and the interscalar relationships between centralized and decentralized actors that are involved in renewable energy transitions.

6.1 Regional Land use and Regional Infrastructure

Despite the small number of plans that describe energy generation coming from the region to the city (Figure 1), the majority of plans identify that actors from the region are involved in the strategy to procure renewable energy for the city (Figure 4). From a material perspective, the inclusion of the regional scale for analysis is well-founded. Most cities are anticipating the need for renewable energy and infrastructure based in the surrounding region, necessitating the engagement of regional actors. Future analyses should consider the extent to which cities can supply their own demand, as well as their impact on the region and existing energy systems in renewable energy transitions. More research and practice needs to focus on the land-uses in regions associated with renewable energy (Ramirez Camargo and Stoeglehner, 2018) for cities.

6.2 Spatial agglomeration and smart specialisation of firms

The analysis provides empirical evidence of the need for cities to develop new interscalar relationships in order to "borrow size" and "borrow functions" from surrounding communities and rural areas to produce energy in practice. While the nature and extent of the required agglomeration economies and smart specializations to export energy to cities from regions is not fully described in most plans, there were exceptions. These were Amsterdam's hydrogen hub at the harbour, and Ghent's bio-economy cluster. A number of cities are supporting citizens to invest in renewable energy in the surrounding region, that will be imported into the city; these particular examples can be assessed for whether they are creating "borrowed size" and "borrowed function" and how they are changing economic and social relationships in regional urban systems. Borrowed size and function can also be explored in the many cases of utilities that are sourcing renewable energy from the surrounding region to import into the city.

6.3 Actor involvement

Cities are working with a range of local, regional and centralized actors to source renewable energy. Included are new civic and decentralized energy actors, alongside centralized and private actors. Some plans were more detailed than others and provided rich details of emerging interscalar relationships. About half of the plans outline details for decentralized decision making that substantially involves the surrounding region and neighbouring communities to achieve the city's renewable energy goals. Many of these plans outline the cities' role in regional communities of interest, pledging to work directly with other local authorities to procure resources, as well as to develop networks for citizens local to the city to invest in renewable energy projects located in other communities that provide supply for the city. Many plans provide evidence of the large influence of established interscalar relationships, such as contractual arrangements, institutional structures and processes in place, in shaping emerging energy plans. For example, Bonn, Germany collaborates with five energy suppliers in the Rhein-Sieg district through long-term agreements.

Although decentralized and civic actors are found in most of the plans, thirteen plans appear to rely on centralized energy companies and actors to supply renewable energy. What is notable about these plans is that most are outside of the European Union, with a few exceptions (Aarhus and Helsinki) that mention national targets in their plans. The European Union has arguably laid out the most explicit policy goals for providing opportunities for citizen participation in renewable energy and partnerships between citizens, businesses, local authorities and traditional centralized energy companies (Berka and Dreyfus, 2021; Hoicka et al., 2021).

6.4 Socio-economic outcomes

The majority of plans support implementation of many types of solar energy, considered compatible with urban areas and also a more equitable options for power production. Many plans focus on the participation of and benefits to citizens, local firms and workers. Some plans will use renewable energy to integrate former prisoners (Los Angeles), or focus on implementation in cooperative buildings (New York). However, for the most part, plans did not address all of the dimensions necessary to understand the broader socio-economic outcomes. There need to be more specific strategies in place to develop regional specializations for renewable energy and governance structures that benefit communities and improve socio-economic outcomes. These strategies may be present, although not outlined in the plans that were analysed.

The conceptual framework outlined in section three and these initial empirical findings lay the groundwork for understanding what influences equitable socio-economic outcomes. Further research could explore the established and emerging networks and interscalar relationships and how they are affecting socio-economic outcomes in detail on a case by case basis. This will help us understand the interactions between the civic, public and private actors in the city, surrounding regions and centralized actors; how the involvement of regional actors shapes equitable outcomes as the share of renewable energy increases; and finally, how these interactions are shaping whether cities and neighbouring communities in the regional urban system are gaining the benefits of "borrowed size" and "borrowed function". Complementary analysis can simulate or document land-uses and infrastructure change, to understand how these factors develop as the share of renewable energy provided to a city and in the region increases.

Some important specific hypotheses and outcomes to be explored is who is involved in shaping more equitable outcomes across communities in the region and how; under what scenario cities and regions can each benefit from borrowed size and borrowed function and the extent to which this is affecting urban, local, and regional specializations, productivity, labour, identity, infrastructure and quality of life, and how this influences the dynamics and speed of city energy transitions. For example, studies could examine how the distinct actor material strategies taken by cities evolve and affect the success of cities in transitioning to greater shares of renewable energy. For instance, are there differences in the share, or speed, of renewable energy implementation or socio-economic outcomes between the cities that rely heavily on centralized actors or those partnering with regional actors?

6.5 **Limitations**

By virtue of having little precedent, this analysis is exploratory and comes with a number of limitations. The first limitation of the study is that although a wide variety of international organisations and published resources were consulted to identify the sample of city plans, the search was conducted in English, which potentially limits the results to countries with English plans or identified only by lists in English, resulting in omissions from countries where English is not commonly used to publish government documents and/or academic research, such as China. Therefore, we expect our sample may omit emerging or existing plans in Asia and South America. Furthermore, this is a fast changing field of practice. Any cities that had no plan published prior to July 2020 are not included in the study. Between July 2020 and July 2021, 13 cities[1] moved from in process or drafted to an approved plan that could have been included in this study. While we acknowledge that the dataset may be partial and not reflect the entire global sample of high ambition city plans, this does not detract from our analysis, which is aimed purely at conceptualising and identifying emerging spatial reconfigurations likely to be embodied in these strategies. A second limitation relates to the ambiguous relationship between the content of city level plans and their actual implementation on the ground. There was wide variability in the format of the plans, and in what information was provided, in particular since the plans are "living documents" and subject to change and evolve. In some cases, it's unclear if all details were provided, although this was mitigated to the extent possible by searching for all documents that related to the plans to include as much up to date information that was publicly available. The incorporation of surveys or interviews will yield additional information, however, given the size of the sample (47) there still is sufficient detail to reveal important findings and to generate new directions of research.

7. Conclusions and Policy Implications

This study draws on available literature to provide a conceptual framework with which to analyse emerging city energy transition plans for their material-actor scalar strategies and socio-economic outcomes. It analysed 47 ambitious renewable energy transition plans in densely populated urban cities around the world. The plans were analysed for the spatial organization of the proposed transition in terms of where renewable energy is produced, and place-based interscalar relationships between established and emerging actors.

This study makes several contributions. First, the conceptual framework provides clear linkages between the material, spatial, scalar, actor-decentralization, and socio-economic dimensions of a renewable energy transition. It offers clarity where gaps have been left by local, urban, or nationally bounded studies, by demonstrating the importance of the regional scale, and interscalar and place-based analysis both from a material and a socio-economic perspective. Taking a regional urban systems approach, this study outlines how the increase in renewable energy provided to cities may result in new locations of productivity, networks, and socio-economic outcomes. Empirically, this study confirms that, for the most part, regions are important emerging actors in the decentralization of energy systems in a renewable energy transition; that, as the community energy literature emphasises, the involvement of a wide range of civic and local actors is important in shaping

[1] These 13 cities are: Accra, Ghana; Barnsley, UK; Bath & North East Somerset, UK; Berlin, Germany; Cambridge, Massachusetts, USA; Camden, UK; Cape Town, South Africa; Exeter, UK; Haringey, UK; Indianapolis, USA; Manchester City, UK; Nottingham, UK; and Stroud, UK.

renewable energy transitions for cities; that renewable energy transitions require the forging of new economic relationships between cities and neighbouring communities and regions and neighbouring communities.

Studies that take regional approaches are engaging in the decentralization literature and incorporating regional scale actors (Balta-Ozkan et al., 2015; Müller et al., 2011; Naumann and Rudolph, 2020; Poggi et al., 2018; Ramirez Camargo and Stoeglehner, 2018). However, few studies in the decentralization literature are incorporating regional actors (one notable exception is Bauknecht et al. 2020), with a tendency to prioritize locally based civic actors and centralized incumbent actors. Some gaps and blindspots encountered in the literature review include the lack of modeling studies of how much cities would need to rely on surrounding regions and land-uses in a renewable energy transition, the potential specific land-use trade-offs of these impacts, the impacts of electrification (particularly of transportation) and infrastructure changes needed to address inevitable network constraints, coupled with the assumption that regions and rural areas will necessarily benefit from a city's renewable energy transition. Addressing the socio-economic outcomes, public acceptance, and speed of a renewable energy transition requires interdisciplinary analyses across subfields and disciplines, with specific focus on place-based interscalar relationships and infrastructures. Specifically, future analyses should address, both conceptually and empirically, how to support firms and citizens for the complementary economic specializations and networked locations to operationalize such a transition.

The most important policy implication is that with few exceptions, dense urban cities will rely on renewable energy imported into their boundaries in order to achieve 100% renewable energy or carbon neutrality. These cities need to develop more concrete and actionable plans to achieve this in a manner that leverages existing resources and capacity, that involves affected communities in transparent and open processes, and that delivers benefits both within the city and the wider region. Actors at a variety of scales will need to work together to enable networked citizen investments as communities of interest, working with communities of place; the distribution of benefits and capacity therein (locally) will be important to generating the public acceptance needed to accelerate such a transition. Taking one step back further in the chain of cause and effect, the institutional context has an important impact on the emergence of citizen led action, municipal and regional authorities, and the specific outcomes (Berka et al., 2020; Hoicka and MacArthur, 2018). Further attention should be paid to how the institutional context is shaping these distinct actor material strategies and emerging interscalar relationships across regions. This could be explored using comparative policy mix analyses and institutional analysis.

Acknowledgements

This research was funded by a Critical Perspectives in Global Health Seed Grant from the Dahdaleh Institute for Global Health Research and the Faculty of Environmental Studies at York University.

References

Alazraque-Cherni, J., 2008. Renewable Energy for Rural Sustainability in Developing Countries. Bull. Sci. Technol. Soc. 28, 105–114. https://doi.org/10.1177/0270467607313956

Allan, G., McGregor, P., Swales, K., 2016. Greening regional development: employment in low-carbon and renewable energy activities. Reg. Stud. 51, 1270–1280. https://doi.org/10.1080/00343404.2016.1205184

Angel, S., Blei, A.M., Parent, J., Lamson-Hall, P., Galarza Sánchez, N., Civco, D.L., Lei, R.Q., Thom, K., 2016. The Atlas of Urban Expansion. MA: Lincoln Institute of Land Policy, New York; Cambridge; and Nairobi.

Arabzadeh, V., Mikkola, J., Jasiūnas, J., Lund, P.D., 2020. Deep decarbonization of urban energy systems through renewable energy and sector-coupling flexibility strategies. J. Environ. Manage. 260, 110090. https://doi.org/10.1016/j.jenvman.2020.110090

Avelino, F., Wittmayer, J.M., 2016. Shifting Power Relations in Sustainability Transitions: A Multi-actor Perspective. J. Environ. Policy Plan. 18, 628–649. https://doi.org/10.1080/1523908X.2015.1112259

Babbie, E., 2008. The Basics of Social Research, Fourth Edition. ed. Thomson Wadsworth, USA.

Baigorrotegui, G., Lowitzsch, J., 2019. Institutional Aspects of Consumer (Co-) Ownership in RE Energy Communities, in: Lowitzsch, J. (Ed.), Energy Transition. Palgrave Macmillan US, Cham, SWITZERLAND, pp. 663–701.

Balta-Ozkan, N., Watson, T., Mocca, E., 2015. Spatially uneven development and low carbon transitions: Insights from urban and regional planning. Energy Policy 85, 500–510. https://doi.org/10.1016/j.enpol.2015.05.013

Barca, F., McCann, P., Rodríguez-Pose, A., 2012. The case for regional development intervention: place-based versus place-neutral approaches. J. Reg. Sci. 52, 134–152. https://doi.org/10.1111/j.1467-9787.2011.00756.x

Bauknecht, D., Funcke, S., Vogel, M., 2020. Is small beautiful? A framework for assessing decentralised electricity systems. Renew. Sustain. Energy Rev. 118, 109543. https://doi.org/10.1016/j.rser.2019.109543

Bauwens, T., Devine-Wright, P., 2018. Positive energies? An empirical study of community energy participation and attitudes to renewable energy. Energy Policy 118, 612–625. https://doi.org/10.1016/j.enpol.2018.03.062

Bauwens, T., Gotchev, B., Holstenkamp, L., 2016. What drives the development of community energy in Europe? The case of wind power cooperatives. Energy Res. Soc. Sci. 13, 136–147. https://doi.org/10.1016/j.erss.2015.12.016

Bauwens, T., Hekkert, M., Kirchherr, J., 2020. Circular futures: What Will They Look Like? Ecol. Econ. 175, 106703. https://doi.org/10.1016/j.ecolecon.2020.106703

Becker, S., Kunze, C., 2014. Transcending community energy: collective and politically motivated projects in renewable energy (CPE) across Europe. https://doi.org/10.3351/PPP.0008.0003.0004

Berka, A., Dreyfus, M., 2021. Decentralisation and inclusivity in the energy sector: Preconditions, impacts and avenues for further research. Renew. Sustain. Energy Rev. 138, 110663. https://doi.org/10.1016/j.rser.2020.110663

Berka, A.L., 2018. Communitarian approaches to sustainable development: The governance, local impacts and costs of community energy. University of Helsinki.

Berka, A.L., Creamer, E., 2018. Taking stock of the local impacts of community owned renewable energy: A review and research agenda. Renew. Sustain. Energy Rev. 82, 3400–3419. https://doi.org/10.1016/j.rser.2017.10.050

Berka, A.L., MacArthur, J.L., Gonnelli, C., 2020. Explaining inclusivity in energy transitions: Local and community energy in Aotearoa New Zealand. Environ. Innov. Soc. Transit. 34, 165–182. https://doi.org/10.1016/j.eist.2020.01.006

Bickerstaff, K., 2017. Geographies of energy justice: concepts, challenges and an emerging agenda, in: Handbook on the Geographies of Energy. Edward Elgar Publishing, Cheltenham, UK.

Bomberg, E., McEwen, N., 2012. Mobilizing community energy. Energy Policy 51, 435–444.

https://doi.org/10.1016/j.enpol.2012.08.045
Bouzarovski, S., Haarstad, H., 2019. Rescaling low-carbon transformations: Towards a relational ontology. Trans. Inst. Br. Geogr. 44, 256–269. https://doi.org/10.1111/tran.12275
Bridge, G., Bouzarovski, S., Bradshaw, M., Eyre, N., 2013. Geographies of energy transition: Space, place and the low-carbon economy. Energy Policy 53, 331–340. https://doi.org/10.1016/j.enpol.2012.10.066
Brisbois, M.C., 2020a. Shifting political power in an era of electricity decentralization: Rescaling, reorganization and battles for influence. Environ. Innov. Soc. Transit. 36, 49–69. https://doi.org/10.1016/j.eist.2020.04.007
Brisbois, M.C., 2020b. Decentralised energy, decentralised accountability? Lessons on how to govern decentralised electricity transitions from multi-level natural resource governance. Glob. Transit. 2, 16–25. https://doi.org/10.1016/j.glt.2020.01.001
Bulkeley, H., Castán Broto, V., Maassen, A., 2014. Low-carbon Transitions and the Reconfiguration of Urban Infrastructure. Urban Stud. 51, 1471–1486. https://doi.org/10.1177/0042098013500089
Burger, C., Froggatt, A., Mitchell, C., Weinmann, J., 2020. Decentralised Energy: A Global Game Changer. Ubiquity Press. https://doi.org/10.5334/bcf
Burger, M.J., Meijers, E.J., van Oort, F.G., 2014. Editorial: The Development and Functioning of Regional Urban Systems. Reg. Stud. 48, 1921–1925. https://doi.org/10.1080/00343404.2014.979782
Burke, M.J., Stephens, J.C., 2017. Energy democracy: Goals and policy instruments for sociotechnical transitions. Energy Res. Soc. Sci., Policy mixes for energy transitions 33, 35–48. https://doi.org/10.1016/j.erss.2017.09.024
C40 Cities, 2019. Why cities? [WWW Document]. C40 Cities. URL https://www.c40.org/why_cities (accessed 12.9.19).
Camagni, R., Capello, R., Caragliu, A., 2016. Static vs. dynamic agglomeration economies. Spatial context and structural evolution behind urban growth: Static vs. dynamic agglomeration economies. Pap. Reg. Sci. 95, 133–158. https://doi.org/10.1111/pirs.12182
Chick, M., 1995. The political economy of nationalisation: the electricity industry, in: The Political Economy of Nationalisation in Britain. Cambridge University Press.
Chilvers, J., Longhurst, N., 2016. Participation in Transition(s): Reconceiving Public Engagements in Energy Transitions as Co-Produced, Emergent and Diverse. J. Environ. Policy Plan. 18, 585–607. https://doi.org/10.1080/1523908X.2015.1110483
Clack, C.T.M., Choukulkar, A., Coté, B., McKee, S.A., 2020. Why Local Solar For All Costs Less: A New Roadmap for the Lowest Cost Grid. Vibrant Clean Energy.
Coenen, L., Campbell, S., Wiseman, J., 2018. Regional Innovation Systems and Transformative Dynamics: Transitions in Coal Regions in Australia and Germany, in: Isaksen, A., Martin, R., Trippl, M. (Eds.), New Avenues for Regional Innovation Systems - Theoretical Advances, Empirical Cases and Policy Lessons. Springer International Publishing, Cham, pp. 199–217. https://doi.org/10.1007/978-3-319-71661-9_10
Coenen, L., Hansen, T., Glasmeier, A., Hassink, R., 2021. Regional foundations of energy transitions. Camb. J. Reg. Econ. Soc. rsab010. https://doi.org/10.1093/cjres/rsab010
Creamer, E., Eadson, W., van Veelen, B., Pinker, A., Tingey, M., Braunholtz-Speight, T., Markantoni, M., Foden, M., Lacey-Barnacle, M., 2018. Community energy: Entanglements of community, state, and private sector. Geogr. Compass 12, e12378. https://doi.org/10.1111/gec3.12378
de Moor, T., 2013. Homo cooperans: instituties voor collectieve actie en de solidaire samenleving. Universiteit Utrecht, Utrecht.
Devine-Wright, P., 2019. Community versus local energy in a context of climate emergency. Nat. Energy 4, 894–896. https://doi.org/10.1038/s41560-019-0459-2
European Parliament, 2019. What is carbon neutrality and how can it be achieved by 2050? [WWW Document]. Eur. Parliam. URL https://www.europarl.europa.eu/news/en/headlines/society/20190926STO62270/what-is-carbon-neutrality-and-how-can-it-be-achieved-by-2050 (accessed 12.7.19).
Foray, D., 2014. From smart specialisation to smart specialisation policy. Eur. J. Innov. Manag. 17, 492–507.

https://doi.org/10.1108/EJIM-09-2014-0096
Goldthau, A., 2012. The uniqueness of the energy security, justice, and governance problem. Energy Policy 41, 232–240.
Golubchikov, O., O'Sullivan, K., 2020. Energy periphery: Uneven development and the precarious geographies of low-carbon transition. Energy Build. 211, 109818. https://doi.org/10.1016/j.enbuild.2020.109818
Gorroño-Albizu, L., Sperling, K., Djørup, S., 2019. The past, present and uncertain future of community energy in Denmark: Critically reviewing and conceptualising citizen ownership. Energy Res. Soc. Sci. 57, 101231. https://doi.org/10.1016/j.erss.2019.101231
Haf, S., Parkhill, K., McDonald, M., Griffiths, G., 2019. Distributing power? Community energy projects' experiences of planning, policy and incumbents in the devolved nations of Scotland and Wales. J. Environ. Plan. Manag. 62, 921–938. https://doi.org/10.1080/09640568.2018.1453490
Hannah, L., 1979. Electricity before Nationalisation: A Study of the Development of the Electricity Supply Industry in Britain to 1948. The Macmil- lan Press Ltd, London & Basingstoke:
Helm, D., 2004. First steps towards the market philosophy, in: Energy, the State, and the Market: British Energy Policy since 1979. Oxford University Press.
Heras-Saizarbitoria, I., Sáez, L., Allur, E., Morandeira, J., 2018. The emergence of renewable energy cooperatives in Spain: A review. Renew. Sustain. Energy Rev. 94, 1036–1043. https://doi.org/10.1016/j.rser.2018.06.049
Hewitt, R.J., Bradley, N., Baggio Compagnucci, A., Barlagne, C., Ceglarz, A., Cremades, R., McKeen, M., Otto, I.M., Slee, B., 2019. Social Innovation in Community Energy in Europe: A Review of the Evidence. Front. Energy Res. 7, 31. https://doi.org/10.3389/fenrg.2019.00031
Hicks, J., Ison, N., 2018. An exploration of the boundaries of 'community' in community renewable energy projects: Navigating between motivations and context. Energy Policy 113, 523–534. https://doi.org/10.1016/j.enpol.2017.10.031
Hoicka, C.E., Lowitzsch, J., Brisbois, M.C., Kumar, A., Ramirez Camargo, L., 2021. Implementing a just renewable energy transition: Policy advice for transposing the new European rules for renewable energy communities. Energy Policy 156, 112435. https://doi.org/10.1016/j.enpol.2021.112435
Hoicka, C.E., MacArthur, J.L., 2018. From tip to toes: Mapping community energy models in Canada and New Zealand. Energy Policy 121, 162–174. https://doi.org/10.1016/j.enpol.2018.06.002
Horlings, L.G., 2015. Values in place; A value-oriented approach toward sustainable place-shaping. Reg. Stud. Reg. Sci. 2, 257–274. https://doi.org/10.1080/21681376.2015.1014062
Horst, D. van der, 2017. Energy landscapes of less than two degrees global warming, in: Handbook on the Geographies of Energy. Edward Elgar Publishing, Cheltenham, UK.
IEA, 2019. Global CO2 emissions by sector, 2017. IEA, Paris.
IEA, 2017. World Energy Outlook 2017. International Energy Agency (IEA), Paris, France.
IRENA, 2020. Renewable energy finance: Institutional capital, Renewable Energy Finance Brief.
IRENA, 2016. Renewable Energy in Cities. International Renewable Energy Agency, Abu Dhabi.
Jacobson, M.Z., Delucchi, M.A., Bauer, Z.A.F., Goodman, S.C., Chapman, W.E., Cameron, M.A., Bozonnat, C., Chobadi, L., Clonts, H.A., Enevoldsen, P., Erwin, J.R., Fobi, S.N., Goldstrom, O.K., Hennessy, E.M., Liu, J., Lo, J., Meyer, C.B., Morris, S.B., Moy, K.R., O'Neill, P.L., Petkov, I., Redfern, S., Schucker, R., Sontag, M.A., Wang, J., Weiner, E., Yachanin, A.S., 2017. 100% Clean and Renewable Wind, Water, and Sunlight All-Sector Energy Roadmaps for 139 Countries of the World. Joule 1, 108–121. https://doi.org/10.1016/j.joule.2017.07.005
Jaegersberg, G., Ure, J., 2017. Renewable Energy Clusters, Innovation, Technology, and Knowledge Management. Springer International Publishing, Cham. https://doi.org/10.1007/978-3-319-50365-3
Judson, E., Fitch-Roy, O., Pownall, T., Bray, R., Poulter, H., Soutar, I., Lowes, R., Connor, P.M., Britton, J., Woodman, B., Mitchell, C., 2020. The centre cannot (always) hold: Examining pathways towards energy system de-centralisation. Renew. Sustain. Energy Rev. 118, 109499. https://doi.org/10.1016/j.rser.2019.109499
Kelsey, N., Meckling, J., 2018. Who wins in renewable energy? Evidence from Europe and the United States.

Energy Res. Soc. Sci. 37, 65–73. https://doi.org/10.1016/j.erss.2017.08.003
Kennedy, C., Stewart, I.D., Westphal, M.I., Facchini, A., Mele, R., 2018. Keeping global climate change within 1.5 °C through net negative electric cities. Curr. Opin. Environ. Sustain. 30, 18–25. https://doi.org/10.1016/j.cosust.2018.02.009
Kooij, H.-J., Oteman, M., Veenman, S., Sperling, K., Magnusson, D., Palm, J., Hvelplund, F., 2018. Between grassroots and treetops: Community power and institutional dependence in the renewable energy sector in Denmark, Sweden and the Netherlands. Energy Res. Soc. Sci. 37, 52–64. https://doi.org/10.1016/j.erss.2017.09.019
Krietemeyer, B., Dedrick, J., Sabaghian, E., Rakha, T., 2021. Managing the duck curve: Energy culture and participation in local energy management programs in the United States. Energy Res. Soc. Sci. 102055. https://doi.org/10.1016/j.erss.2021.102055
Lawrence, A., 2020. Energy decentralization in South Africa: Why past failure points to future success. Renew. Sustain. Energy Rev. 120, 109659. https://doi.org/10.1016/j.rser.2019.109659
Loorbach, D., Wittmayer, J., Avelino, F., von Wirth, T., Frantzeskaki, N., 2020. Transformative innovation and translocal diffusion. Environ. Innov. Soc. Transit. 35, 251–260. https://doi.org/10.1016/j.eist.2020.01.009
Lovins, A.B., 1977. Soft energy paths: toward a durable peace.
Lund, P.D., Mikkola, J., Ypyä, J., 2015. Smart energy system design for large clean power schemes in urban areas. J. Clean. Prod. 103, 437–445. https://doi.org/10.1016/j.jclepro.2014.06.005
MacArthur, J., Matthewman, S., 2018. Populist resistance and alternative transitions: Indigenous ownership of energy infrastructure in Aotearoa New Zealand. Energy Res. Soc. Sci., Sustainable energy transformations in an age of populism, post-truth politics, and local resistance 43, 16–24. https://doi.org/10.1016/j.erss.2018.05.009
MacArthur, J.L., Hoicka, C.E., Castleden, H., Das, R., Lieu, J., 2020. Canada's Green New Deal: Forging the socio-political foundations of climate resilient infrastructure? Energy Res. Soc. Sci. 65, 101442. https://doi.org/10.1016/j.erss.2020.101442
Martinot, E., 2016. Grid Integration of Renewable Energy: Flexibility, Innovation, and Experience. Annu. Rev. Environ. Resour. 41, 223–251. https://doi.org/10.1146/annurev-environ-110615-085725
Maruyama, Y., Nishikido, M., Iida, T., 2007. The rise of community wind power in Japan: Enhanced acceptance through social innovation. Energy Policy 35, 2761–2769. https://doi.org/10.1016/j.enpol.2006.12.010
Maya-Drysdale, D., Krog Jensen, L., Vad Mathiesen, B., 2020. Energy Vision Strategies for the EU Green New Deal: A Case Study of European Cities. Energies 13, 2194. https://doi.org/10.3390/en13092194
McCauley, S.M., Stephens, J.C., 2017. Changing human geographies of the electricity grid: shifts of power and control in the renewable energy transition, in: Handbook on the Geographies of Energy. Edward Elgar Publishing, Cheltenham, UK.
Mitchell, T., 2009. Carbon Democracy. Political Power in the Age of Oil. Verso Books.
Morton, C., Wilson, C., Anable, J., 2018. The diffusion of domestic energy efficiency policies: A spatial perspective. Energy Policy 114, 77–88. https://doi.org/10.1016/j.enpol.2017.11.057
Müller, M.O., Stämpfli, A., Dold, U., Hammer, T., 2011. Energy autarky: A conceptual framework for sustainable regional development. Energy Policy 39, 5800–5810. https://doi.org/10.1016/j.enpol.2011.04.019
Naumann, M., Rudolph, D., 2020. Conceptualizing rural energy transitions: Energizing rural studies, ruralizing energy research. J. Rural Stud. 73, 97–104. https://doi.org/10.1016/j.jrurstud.2019.12.011
Neumark, D., Simpson, H., 2015. Place-Based Policies. Elsevier, pp. 1197–1287.
Nijkamp, P., 1980. Energy Problems and Regional Development. Reg. Sci. Urban Econ. 10, 299–301.
Norton, B.G., Hannon, B., 1997. Environmental values: A place-based theory. Environ. Ethics 19, 227–244. https://doi.org/10.5840/enviroethics199719313
Ornetzeder, M., Rohracher, H., 2013. Of solar collectors, wind power, and car sharing: Comparing and understanding successful cases of grassroots innovations. Glob. Environ. Change 23, 856–867. https://doi.org/10.1016/j.gloenvcha.2012.12.007

Owens, S.E., 1986. Energy, Planning and Urban Form. Pion Limited.
Parr, J.B., 2014. The Regional Economy, Spatial Structure and Regional Urban Systems. Reg. Stud. 48, 1926–1938. https://doi.org/10.1080/00343404.2013.799759
Pasqualetti, M.J., 2012. Reading the Changing Energy Landscape, in: Stremke, S., Dobbelsteen, A.V.D. (Eds.), Sustainable Energy Landscapes: Designing, Planning, and Development. Chapman and Hall/CRC, Baton Rouge, UNITED STATES, pp. 11–44.
Phimister, E., Roberts, D., 2012. The Role of Ownership in Determining the Rural Economic Benefits of On-shore Wind Farms: The Rural Economic Benefits of Wind Farms. J. Agric. Econ. 63, 331–360. https://doi.org/10.1111/j.1477-9552.2012.00336.x
Plastrik, P., Cleveland, J., 2018. Carbon Neutral Cities Alliance Framework for Long-Term Deep Carbon Reduction Planning.
Poggi, F., Firmino, A., Amado, M., 2018. Planning renewable energy in rural areas: Impacts on occupation and land use. Energy 155, 630–640. https://doi.org/10.1016/j.energy.2018.05.009
Ramirez Camargo, L., Stoeglehner, G., 2018. Spatiotemporal modelling for integrated spatial and energy planning. Energy Sustain. Soc. 8, 32. https://doi.org/10.1186/s13705-018-0174-z
Rand, J., Hoen, B., 2017. Thirty years of North American wind energy acceptance research: What have we learned? Energy Res. Soc. Sci. 29, 135–148. https://doi.org/10.1016/j.erss.2017.05.019
Sasse, J.-P., Trutnevyte, E., 2019. Distributional trade-offs between regionally equitable and cost-efficient allocation of renewable electricity generation. Appl. Energy 254, 113724. https://doi.org/10.1016/j.apenergy.2019.113724
Schroth, O., Pond, E., Tooke, R., Flanders, D., Sheppard, S., 2012. Spatial Modeling for Community Renewable Energy Planning: Case Studies in British Columbia, Canada, in: Stremke, S., Dobbelsteen, A. van den (Eds.), Sustainable Energy Landscapes. CRC Press, pp. 330–353. https://doi.org/10.1201/b13037-20
Seyfang, G., Hielscher, S., Hargreaves, T., Martiskainen, M., Smith, A., 2014. A grassroots sustainable energy niche? Reflections on community energy in the UK. Environ. Innov. Soc. Transit. 13, 21–44. https://doi.org/10.1016/j.eist.2014.04.004
Seyfang, G., Park, J.J., Smith, A., 2013. A thousand flowers blooming? An examination of community energy in the UK. Energy Policy 61, 977–989. https://doi.org/10.1016/j.enpol.2013.06.030
Sierra Club, 2016. What does it mean for a city to commit to 100% clean energy? [WWW Document]. Sierra Club. URL https://www.sierraclub.org/ready-for-100/what-does-it-mean-for-city-commit-100-clean-energy (accessed 12.9.19).
Smil, V., 2015. Making Sense of Power Densities, in: Power Density: A Key to Understanding Energy Sources and Uses. MIT Press, pp. 190–220.
Smil, V., 2010. Power Density Primer: Understanding the Spatial Dimension of the Unfolding Transition to Renewable Electricity Generation.
Smith, A., 2005. The Alternative Technology Movement: An Analysis of its Framing and Negotiation of Technology Development. Hum. Ecol. Rev. 12, 14.
Späth, P., Rohracher, H., 2014. Beyond Localism: The Spatial Scale and Scaling in Energy Transitions, in: Padt, F., Opdam, P., Polman, N., Termeer, C. (Eds.), Scale-Sensitive Governance of the Environment. John Wiley & Sons, Ltd, Oxford, UK, pp. 106–121. https://doi.org/10.1002/9781118567135.ch7
Sperling, K., Arler, F., 2020. Local government innovation in the energy sector: A study of key actors' strategies and arguments. Renew. Sustain. Energy Rev. 126, 109837. https://doi.org/10.1016/j.rser.2020.109837
St. Denis, G., Parker, P., 2009. Community energy planning in Canada: The role of renewable energy. Renew. Sustain. Energy Rev. 13, 2088–2095. https://doi.org/10.1016/j.rser.2008.09.030
Stephens, J.C., 2019. Energy Democracy: Redistributing Power to the People Through Renewable Transformation. Environ. Sci. Policy Sustain. Dev. 61, 4–13. https://doi.org/10.1080/00139157.2019.1564212
Stremke, S., Van Den Dobbelsteen, A., Koh, J., 2011. Exergy landscapes: exploration of second-law thinking towards sustainable landscape design. Int. J. Exergy 8, 148–174.

https://doi.org/10.1504/IJEX.2011.038516
Tozer, L., 2013. Community energy plans in Canadian cities: success and barriers in implementation. Local Environ. 18, 20–35. https://doi.org/10.1080/13549839.2012.716406
Tozer, L., Klenk, N., 2019. Urban configurations of carbon neutrality: Insights from the Carbon Neutral Cities Alliance. Environ. Plan. C Polit. Space 37, 539–557. https://doi.org/10.1177/2399654418784949
Turnheim, B., Sovacool, B.K., 2020. Forever stuck in old ways? Pluralising incumbencies in sustainability transitions. Environ. Innov. Soc. Transit. 35, 180–184. https://doi.org/10.1016/j.eist.2019.10.012
UN DESA, 2019. United Nations Demographic Yearbook 2018, Sixty-ninth issue. ed. United Nations, New York.
United Nations, 2018. 68% of the world population projected to live in urban areas by 2050 [WWW Document]. UN DESA U. N. Dep. Econ. Soc. Aff. URL https://www.un.org/development/desa/en/news/population/2018-revision-of-world-urbanization-prospects.html (accessed 12.9.19).
van de Ven, D.-J., Capellan-Peréz, I., Arto, I., Cazcarro, I., de Castro, C., Patel, P., Gonzalez-Eguino, M., 2021. The potential land requirements and related land use change emissions of solar energy. Sci. Rep. 11, 2907. https://doi.org/10.1038/s41598-021-82042-5
Van Vliet, B., 2003. Differentiation and Ecological Modernization in Water and Electricity Provision and Consumption. Innov. Eur. J. Soc. Sci. Res. 16, 29–49. https://doi.org/10.1080/13511610304515
Walker, G., 2011. The role for 'community' in carbon governance: The role for 'community' in carbon governance. Wiley Interdiscip. Rev. Clim. Change 2, 777–782. https://doi.org/10.1002/wcc.137
Walker, G., Cass, N., 2007. Carbon reduction, 'the public' and renewable energy: engaging with socio-technical configurations. Area 39, 458–469. https://doi.org/10.1111/j.1475-4762.2007.00772.x
Walker, G., Devine-Wright, P., 2008. Community renewable energy: What should it mean? Energy Policy 36, 497–500. https://doi.org/10.1016/j.enpol.2007.10.019
Walker, G., Devine-Wright, P., Hunter, S., High, H., Evans, B., 2010. Trust and community: Exploring the meanings, contexts and dynamics of community renewable energy. Energy Policy 38, 2655–2663. https://doi.org/10.1016/j.enpol.2009.05.055
Wei, T., Wu, J., Chen, S., 2021. Keeping Track of Greenhouse Gas Emission Reduction Progress and Targets in 167 Cities Worldwide. Front. Sustain. Cities 3, 696381. https://doi.org/10.3389/frsc.2021.696381
Wierling, A., Schwanitz, V., Zeiß, J., Bout, C., Candelise, C., Gilcrease, W., Gregg, J., 2018. Statistical Evidence on the Role of Energy Cooperatives for the Energy Transition in European Countries. Sustainability 10, 3339. https://doi.org/10.3390/su10093339
Wyse, S.M., Hoicka, C.E., 2019. "By and for local people": assessing the connection between local energy plans and community energy. Local Environ. 24, 883–900. https://doi.org/10.1080/13549839.2019.1652802

For further information about the GEIST Working Paper series, see: www.geist-wp.com

Environmental Social Sciences
Eawag - Swiss Federal Institute of Aquatic Science and Technology
Contact person: Johan Miörner
Überlandstrasse 133, 8600 Dübendorf, Switzerland
Tel.: +41-587-656493
E-Mail: johan.miorner@eawag.ch
https://www.eawag.ch/en/department/ess/

Department of Geography and Regional Research
University of Vienna
Contact person: Michaela Trippl
Universitätsstraße 7/5/A0528, 1010 Vienna, Austria
Tel.: +43-1-4277-48720
E-Mail: Michaela.trippl@univie.ac.at
https://humangeo.univie.ac.at/