Spatial adventures in energy studies: an introduction to the special issue

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Abstract

This paper has two purposes: first, it makes a case for the development of energy studies perspectives that consider 'relational space' as a key concept organising the provision and use of energy. Second, it presents an overview of this field of research with consideration to the papers included in this special issue. The argument is developed in three parts: first, there is an analysis of the growth of relational perspectives on space and energy looking at current debates within the literature; second, there is an analysis of visual representation of different energy-related aspects to demonstrate the empirical importance of a grounded understanding of relational space; third, there is an overview of the papers in this special issue as a means to put forward a diverse research agenda in this area. We conclude that relational perspectives have the potential to inform future energy studies and provide new insights for policy and practice.

1. Introduction

The visual lights display over Victoria Bay is one of the highlights of any visit to Hong Kong. Laser, LED lights, and other forms of lighting are displayed at different rhythms in more than 40 buildings over the harbour. The Hong Kong Tourist Board calls it "A Symphony of Light". Light-based spectacles are common attractions for tourists, from singing fountains to light shows. Active since 2004, the Hong Kong display is extraordinary, because it combines the fascination of the experience of light and sound with the features of the skyline over its emblematic harbour.

This example demonstrates the complex entanglements between space and energy services. The display is a means to reaffirm the world class city status of Hong Kong. It is presented as a tourist attraction, and it undoubtedly is one, but it is also a symbolic exercise to project the vision of an ultramodern city. Hong Kong is characterised by its liberal economic policies and focus on economic growth connecting flows of international capital. The display draws attention to the centres of those flows, the buildings where transactions are performed. Light is central to the Hong Kong experience, to its commercial history, and the display makes that explicit (Figure 1).

The power impression made by the display results from the confluence of spatial factors: the history of spatial development around the harbour; the focus on high-rise buildings motivated by the constraints of urban development and land scarcity; the development of a supply of electricity based on cheap provision from fossil fuels; and the symbolic role that light has traditionally played in Hong Kong's commercial areas. These are only some examples of the entanglement of energy and urban form in urban energy landscapes. Such a relationship was already wonderfully described by Susan Owens [1] in her seminal study of 'Energy, planning, and urban form'. However, despite this pioneering work, there has only been limited attention to this relationship, and especially how it influences trajectories of urban sustainability [2]. In Hong Kong, the relationship between energy development, energy supply, and energy services is shaped by spatial factors.

[Insert Figure 1 near here]

Over the last decade there has been an increasing interest in the study of energy as a spatial problem. Work in this area emerged first out of a concern with the sustainability of energy, and linked research results to policy recommendations [3-6]. Two new edited collections [7, 8] show the vibrancy of the field, the growing engagement with critical theory, and its potential to deliver new theoretical and practical insights to achieve sustainable energy goals. This special issue departs from the assumption that spatially-engaged energy research can make step-change contributions to understand the global energy challenge. The inclusion of a specific goal for energy in the United Nations' Sustainable Development Goals (SDGs) is a reminder of the contemporary relevance of a global policy agenda on energy. SDG7 ("Affordable and Clean Energy") underscores the global challenge of energy access (with 1.3 billion people still lacking access to electricity and over 3 billion people lacking access to modern fuels) alongside the increasingly pressing challenge to deliver a transition to clean energy and away from fossil fuels. Questions of distribution and differentiation are central to energy access. Concerns over 'space' are also at the heart of discussions of low carbon transitions [9].

However, space is a contested term subject to theoretical debates with implications for energy policy. The point of departure in this introduction is the work of Doreen Massey, who, in seeking to challenge the common definition of space as a container of social life, defined space as 'constituted through the social' [10, 11]. Massey developed her argument in dialogue with scholars concerned with the political implications of thinking space as relational [for example: 12, 13-17]. It follows that space is actively produced through processes of connectivity, proximity and differentiation. Thinking

of space as relational helps recognising multiple coexisting configurations and future possibilities. It is a means to contest hegemonic ways of thinking about collective social projects, such as the future of energy, with alternatives. For example, a commitment to relational space challenges the definition of spatial characteristics in terms of geographic positioning systems [18, 19]. This is crucial in the field of energy studies where certain spatial models of territorial control are central to the exploitation and differential provision of energy resources [20].

In a special issue edited by Zimmerer [21], for example, Harrison and Popke [22] developed a persuasive account of the relational aspects of energy poverty, drawing on an example from North Carolina. Thinking relationally has also revealed the politics embedded in practices of energy at home [23]. Two seminal reviews of the spatial aspects of energy-related problems have highlighted the importance of relational approaches [24, 25]. These perspectives both challenge traditional conceptions of spatiality in energy problems and invite us to rethink how the dynamics of energy provision can modify and transform spaces.

The notion of relational space extends beyond geography. It emerges in dialogue with long-standing debates in philosophy about the nature of space [for example: 26]. Notions of relational space may be commonly deployed to study energy in disciplines such as anthropology or sociology [for example: 27]. They have long influenced thinking within planning and architecture [28]. This special issue emphasises the importance of interdisciplinary work to critically examine the concept of space in energy studies.[i] Space emerges as a negotiating ground not just in relation to securing energy access or moving towards sustainable energy systems, but also in relation to how we know and understand these problems.

In this introductory paper we draw the contours of this research agenda in relation to the contents of the special issue. The following section outlines relational perspectives on energy and space, explaining the growth of relational perspectives on energy and the development of the notion of relational space as a means to articulate energy debates. Section three provides an empirical survey of conceptions of energy and space by focusing on the assumptions about space made in different types of energy maps. If maps can be understood as propositions [29], energy maps represent proposals for energy-related actions in relation to different conceptualisations of space. Thus, the systematic analysis of energy maps is a means to examine the different assumptions about space mobilised in energy studies. The analysis suggests that scalar understandings of space are dominant in visual representations of energy and they limit the possibilities to interpret possible energy futures. The paper concludes with a review of the papers included in this special issue, evaluating the contribution of each one to the development of a spatial and relational perspective, and demonstrating the variety of ongoing interdisciplinary work. In doing so, we seek to inspire further work to develop relational perspectives on energy within and beyond energy geographies.

2. Understanding the relationship between energy and space

In an old seminal paper on energy geography, Hoare [30; p. 507] lamented the limited engagement of geographers with energy issues because "…energy developments are characterized by large-scale enterprise, … few decisions are taken with an overtly spatial dimension, … the spatial element is frequently subordinated to compelling economic and political issues, and … obvious spatial impacts are few". Hoare was concerned with the limited presence of energy issues in a deliberately spatial academic field. Since then, there has been a reversing of the trend that Hoare described, with geographers and other spatially-concerned social scientists increasingly engaged in energy studies [24, 31]. In 2011, a special issue in the *Annals of the Association of American Geographers* demonstrated how far the new geographies of energy had developed since Hoare's lamentation [21,

32]. Energy geographers have opened up an interdisciplinary field which is generating new thinking and proposals to tackle global energy dilemmas [33].

The last three decades have also seen a shift in spatial thought, with an increasing interest in space as constitutive of social interaction and the radical questioning of space as a container [12, 34]. The notion of space as relational has been further developed via perspectives which emphasize the co-construction of space and social life, moving away from thinking of space as a pre-existing, fixed, category [19]. The notion of relational space recognizes that space is actively constituted through social and material relations, and thus, it is an unfinished project, characterized by its multiplicity [18]. In her book-length treatment of the notion of space, Massey stated three propositions: first, space is constituted through interactions; second, space is 'the sphere of possibility' that facilitates multiplicity, distinct historical trajectories and coexisting heterogeneity; third, space is performed and actively constructed, always in the making, unfinished [14]. While there are unsettled debates around the notion of relational space, Massey's reflections constitute a starting point to move away from notions of absolute space that support hegemonic forms of knowledge provision. In this conception, relational thinking questions spatial hegemony, recognises the production of space as a political project, and engages with geographies of differentiation and responsibility [35].

Such ideas about change have influenced energy studies. The scholarship that inspired and followed Hoare's paper sought to build some consistency across the field [for a comprehensive overview see: 36], but the plurality of the field we see today is such that the term 'energy geographies' is more appropriate [25]. Conceptions of relational space may also be more appropriate to reflect on a field of energy studies shaped by a plurality of forms of thinking around mixed flows and processes of differentiation and connection from the impacts of the extraction of energy resources, the public perception of energy projects, the political consequences of resource availability, and the entanglement of energy services with other issues such as housing, land transformations, urban design, property rights, and access to infrastructure.

Spatial issues manifest in multiple ways in energy-fuelled social lives [21, 23, 32, 37, 38]. A relational approach further interrogates how energy relates to and interacts with the political, social, cultural, economic, ecological and technological spheres in specific locales. Cupples, for example, uses a relational approach to analyse the case of electricity privatization in Nicaragua, showing how neoliberal ideas of energy provision materialize in the spaces of everyday life [38]. A relational perspective further challenges discourses and perceptions common in the geopolitics literature on energy 'scarcity' and 'security' [39]. This prompts the need to ask systemic questions that cut across energy, geography and society [40] including the patterns and scales of energy supply, distribution and consumption [24] and the energy-dependence of everyday social practices [41].

Such relational approach also challenges the concept of energy as a neutral, technical and physical entity. Relational perspectives reveal the multidimensional and multi-faceted nature of energy issues. Energy has come to mean many things, including: a natural resource; a technology and related processes of innovation; a measure of production and consumption; a networked infrastructure; a basic service; and a financial commodity. Energy access has become a matter for human rights [42]. Broadly speaking, a relational approach casts energy as a social relation, as opposed to an economic asset, ecological phenomenon or a resource [31].

A relational approach has further informed understandings of how energy is and could be governed, owned, regulated, produced, distributed and consumed. This thinking also highlights that there are significant interdependencies involved in systems of energy production and consumption that span administratively-conceived borders that follow scalar notions of space [43]. Energy is a site of

'struggle' [e.g. 44, 45, 46]. Such struggles may include cases of displacement, landscape destruction and the role of violence, conflict in the extraction of resources or the development of infrastructures. Furthermore, a spatial and relational approach focuses on how energy is bound up with the reproduction of uneven patterns of development and access to flows of capital. Examples include the constitution of electricity infrastructure alongside state projects [47] or transboundary conflicts around energy [e.g. 48]. The way in which energy is consumed also reflects social and political patterns of inequality [39].

In this way, a relational approach brings forward dimensions of justice, access and distribution [49, 50] and what this might mean for the requirements of space and territory for the extraction and use of energy resources, be that fossil fuels or renewable energy [40, 51] . For instance, uneven power relations over land and territory are reflected in both renewable energy developments and fossil fuel extractive industries [52]. Differential access to energy, and especially fuel poverty, can also be understood as manifestation of social injustice [53]. Energy poverty also emerges as a 'relational assemblage', embedded in socio-economic relations that also manifest in a relational space [22].

There is a particular case for applying a relational perspective to the energy transition, a key theme in energy studies [e.g. 54, 55]. On this point, Bridge et al [24] argue that there has been too much of a temporal, as opposed to a geographical, focus in studies of the energy transition, a literature which has overlooked changes in the spatial organisation of the energy system and how energy is embedded in economic activities more broadly, both within and between countries. Consequently, they call for thinking on energy systems and any low-carbon 'transition' to adopt a more spatial and relational perspective. This includes: how an energy system is embedded within a particular setting and the networked nature of energy systems which produce "geographies of connection, dependency and control" [24; p. 333]. A relational approach allows us to understand energy related activities within a particular space and the 'geographical connections and interactions' between that space and other spaces [24].

Relational perspectives are situated within alternative modes of representing energy and space. This is a proposal for analyses of energy and space that foreground social relations, spaces for political action, and justice. Relational thinking is inherent to energy studies. However, as the following section shows, making explicit the assumptions about the nature of space reveals the politics of territorial control embedded in energy projects and the choreographies of everyday life in practices of energy use.

3. Spatial assumptions in energy maps

Ideas about what maps represent have transformed ideas about the purpose of maps, and the extent to which they can be linked to a putative reality external to the map. In cartography, the map has been thought of 'as a proposition' [56-58]. This assertion means that maps play an active role not just in representing ontic worlds, but also in establishing the spatial relations between what is represented in the map and the broader connections with the world [58]. In doing so the map becomes a political tool which serves specific strategic purposes including actively producing space. The deployment of solar maps, for example, reveals the inherent politics of land grabbing and land transformation associated with energy projects [20]. An analysis of energy visualisations reveals the assumptions about the nature of space embedded in energy studies.

Critical analyses of practices of map-making seek to understand how visual representations constitute different worlds and advance political agendas [29, 57]. This reveals a heterogeneous set of practices of map-making, which enact different understandings of the relationship between

society and space [59]. When used in debates about resource access and service provision, maps have a definitive influence in drawing agendas based upon specific framings of inequality, possibilities, and needs [60].

Such perspective on maps and their analysis constitutes a means to reveal the contours of the relationship between society and energy. The focus is on the common tools that are used to map energy. Howell and Baylis [61; p. 209] have argued that maps are commonly used to demonstrate that the "display and contextualization of spatial information can help to clarify complex energy issues". They focus on the extent to which maps fit the communication purposes they purportedly serve. They also recognise how the production of maps is embedded in political processes of world-making. Looking at a set of maps in academic papers since the early 20th Century, they conclude that energy production issues and national-scale maps dominate energy representations and imaginaries, obscuring other aspects of the energy system. While Howell and Baylis's focus on representation leads them to overlook the performative character of maps, their analysis constitutes an initial approach to an understudied area that is concerned with the visual representation of energy processes and the production of energy spaces which we seek to understand. This performative character, however, is evident in the entanglement of energy maps with contemporary politics of development [20].

Following this, we sought to make an analysis of the propositions embedded in different energy maps. We examined grey literature on the theme of energy, including textbooks, international policy documents such as the 2014 IPCC report and International Energy Agency annual reports, planning documents, utility company websites, marketing materials, and reports from activists and NGOs. We analysed maps that claim to represent any part of an energy system, including natural resources from which energy is generated, the technological infrastructures used to transmit it, and the numerous practices involved in the extraction of primary energy and its subsequent conversion and distribution. The idea was to find out different types of maps that are part of the structures of hegemonic knowledge on energy processes, to examine common assumptions about space. The analysis focuses on two questions: what claims are made in different maps? What purpose do they serve?

3.1 What claims are made in energy-related maps and how?

Maps have long assisted with the identification of primary energy resources, given that the location of those resources is central to the ability of any company, investor or individual to extract profit from them. For instance wherever possible, oil fields and coal reserves are mapped prior to their extraction in order to maximise gains to be made. The more recent development of maps of renewable energy resources play a similar role (Figure 2) [see also: 20]. Maps of solar resources have proliferated, from the more basic ones that rely on meteorological information to the more sophisticated which incorporate information on the build environment. Maps that illustrate wind speed data and ocean currents are usually a prior requirement for the construction of any renewable energy project. In another example, bioenergy, which is frequently tied to land, either to agricultural crops or forest production is also routinely mapped in thematic cartographies.

[Insert Figure 2 about here]

There is a wide range of thematic maps that represent different features of the energy system. Dasymetric maps[ii] on a georeferenced base map are commonly used to depict the distribution of primary energy resources, from maps of the oil and gas reserves, distribution of coal deposits and potential for renewables, such as for example, wind speeds. Dasymetric maps are also a common tool to depict impacts of the production and distribution of energy, for example, the concentration

of airborne pollutants resulting from coal and gas combustion. A common type of dasymetric map, with numerous applications in planning and design, are heat maps. Choropleth maps are also common and they are the favoured map to depict energy use, in relation to pre-given administrative units, such as for example, maps of energy use in different provinces or boroughs. Impacts calculated in relation to use data, such as carbon emissions, may also be represented in choropleth maps. Statistical maps may substitute the choropleth map by depicting the administrative units and the statistical information next to them, although this is mostly in relation to general maps with less level of detail. More recently, cartograms, where areas are given in relation to the size of associated data to that unit [63], have irrupted as a means to present statistical data more persuasively. For example, the carbonmap.org includes cartograms of resource extraction and carbon emissions in different nations [64].

Infrastructures for generation, transmission, storage and transformation may also be recorded with the use of reference maps, from the location of hydraulic power plants to the positions of storage facilities. Reference maps emerge from a scalar conception of space, as a direct representation of physical features on the Earth. Reference maps are used to represent the geographical location of energy infrastructures, most often electricity networks. Dots are used to represent sites of energy production, conversion or reception, while lines represent the cable connections between such dots. Administrative units (e.g. the area of coverage of a given utility) are represented with area features. Such reference maps can be georeferenced or, depending on use the reference information is presented in relation to a general and not necessarily georeferenced map, particularly when the scale is very large. These maps, georeferenced or not, can be characterised by a high degree of generalisation which is involved in their elaboration. As explained by Monmonier [65; p. 25], “map symbols usually occupy proportionately more space on the map than the features they represent occupy on the ground”. In reference maps of electricity facilities large dots represent buildings and lines are straightened. Complexities in administrative boundaries are streamlined. Representing the importance of infrastructure takes precedence over representing its assumed relative size or position.

Maps of fuel transport flows (e.g. by road or sea) or maps of fuel markets are most often presented at larger scales and providing very general information. Unlike thematic or reference maps, flow maps represent dynamic aspects of the energy system, such as for example, the trade of oil between different countries, the capacity of electricity transmission between different regions within a country, or the emissions trading between different regions. They may track the movement of finance, primary resources, electricity, or pollutants but in any case, whatever moves across.

Network diagrams can be thought of as a subcategory within flow maps. Block diagrams and bond graphs, have developed as an attempt to develop a unified language of networks. Circuit diagrams have existed since the inception of electricity networks. Figure 3, for example, shows a ‘single-line diagram’ of connections between generation stations and district loads in 1939 [66]. Network diagrams refer to the different topological arrangements for infrastructure provision, in the sense that they show the different connections between generation and conversion facilities and load centres. They conserve the topology of elements in space and explain their relationships. They are a means of representation that does not presume a point-by-point correspondence between the points in the diagram and their referent in the surface of the Earth. However, they are far from incorporating notions of relational space and they obscure the social relations that permeate those networks.

[Insert Figure 3 about here]

Energy resources, environmental impacts and infrastructures for energy production and distribution are thought to be amenable to existing forms of visualisation (thematic, reference, flows), but there are other- those which relate with the representation of space as relational- which are not so easily rendered visible, especially cultures of energy use and lifestyles, conflicts, professional practices, energy governance, differences in energy access, and the dynamic interactions between energy uses, infrastructures and the built environment. In accepting the notion of absolute space, energy maps become tools for the naturalisations of specific propositions [67] about the availability of resources, the most appropriate provision systems, or the distribution of demands. As these propositions become familiar, they also become incontestable foreclosing alternative energy futures that emerge from experiences around energy.

3.3 What purpose do they serve?

If maps are propositions, they play a key role in the creation and fixation of models of territorial appropriation. In relation to energy, maps that represent different aspects of energy provision and use are a means to establish different types of actions. In doing so, maps also reveal common assumptions about the spatial aspects of energy systems. For example, some maps present georeferenced information about energy resources and infrastructures. They are thought to reflect the truth about the location and position of those elements over the surface of the Earth. Even in cases where any putative truth is disputed- such as the precise location and size of energy resources- maps are effective tools to put forward particular programmes of action about what is to be done.

Table 1 depicts some of the most common performative roles of energy maps, observed in our sample. Utilities have an important role in the production of energy maps because maps of energy are an intrinsic part of their management procedures [68]. They use a variety of maps for planning, management and communicating with customers. Georeferenced information may not be so important for the day-to-day management of facilities, which may be operated more simply with flow diagrams. One important application of flow diagrams is ensuring infrastructure reliability and identifying vulnerabilities, from a perspective that examines the infrastructure ‘under threat’ from sabotages, weather, operational errors or terrorist attacks. For example, in an electricity grid, diagrams will depict different elements of the transmission system, including transformers, switches, transmission towers and lines, control centres and computer controls are represented in flow diagrams. Such diagrams are also part of ‘Supervisory control and data acquisition’ (SCADA) systems to regulate transmission operations [69]. Planning operations, such as, for example, tending new networks, however, may require representing facilities and infrastructure on a georeferenced base map, but often this is done at a more general level with less detail. Communicating with customers may require general thematic maps indicating, for example the areas provided or the quality of service. When the impacts have a spatial distribution (e.g. waste facilities, pollutant plume) maps also represent impacts of energy production and consumption

Planning authorities may share cartographic information with utilities. They will need a range of maps that enable, for example, consultation of plans for new facilities with multiple stakeholders and maps of predicted impacts [70]. Construction companies also use georeferenced maps, for example, to gather information from utilities and to avoid construction accidents when digging holes. They may use both reference and thematic maps. Also, thematic maps may be used to estimate demand. There is a variety of maps that are used to present information on energy use, energy access and carbon emissions in maps at diverse scales, from the local to the global. General maps may also be used to demonstrate the impacts of regulations or facilitate connection projects. Rather than being an exhaustive list, the types outlined in Table 1 reflect the dominance of certain

narratives of energy and the operation of systems of provision and use, of an industry directed towards the extraction of resources to meet an ever-expanding demand.

The question of how to map the social aspects of energy processes has seldom be asked. Energy maps thus follow the demands of specific functions: exploration and investment, business management, consultation and planning, policy and education. However, energy maps can also emerge as means of political action and protest. Visual representations of energy have been appropriated to imagine and propose alternative visions of the present and the future. Activists have produced energy maps as a performative tool to enable change. Many are finding 'new' things to map and 'new' methods of mapping [57, 71]. Sometimes, this involves reimagining the propositions embedded in existing maps. For example, the Energy Justice Network, an activist network based in Philadelphia, US, has developed a mapping facility to "share information about power plants, and facilitate networking between people and groups that oppose them" [72].

[Insert Table 1 near here]

Ideas of democratising spatial data production, for example, with participatory GIS is an attempt to reflect a 'multiplicity of geographical realities' [73]. An example is the 'Global Atlas of Environmental Justice' (EJAtlas, Figure 5), "an online database and interactive map that documents socio-environmental conflicts, defined as mobilizations by local communities against particular economic activities whereby environmental impacts are a key element of their grievances" [74]. Many such conflicts relate to resource extraction and the development of energy infrastructures. The EJAtlas is also a proposition, in this case, about the knowledge base of environmental activism and the need for a global perspective on locally-based environmental conflicts. According to its authors, the EJAtlast has been compiled through a collaborative, iterative process in participatory GIS, as a living process. The underlying assumption is that the EJAtlast makes visible an alternative vision of environmental processes.

[Insert Figure 4 here]

These last two examples demonstrate that maps are effective ways to identify and demonstrate the prevalence of conflicts around energy, thus, challenging managerial conceptions of energy provision and use. However, these examples do not escape a conceptualisation of space as a scalar, absolute truth- as a container for social relations that are expressed as conflicts in particular places. They are nevertheless examples of attempts to appropriate dominant technologies of spatial representation. Their potential lies in the extent to which they may mash relational conceptions of space with representations of absolute space already constructed [75].

Taken as a whole, this exploratory analysis demonstrates the limitations of scalar notions of space to apprehend the relational characteristics of contemporary energy challenges. A challenge remains about the possibility of make compelling visual representations of social relations around energy that move beyond notions of absolute space. If relational thinking follows on from interpretative, situated thinking about energy problems, we can follow Drucker's call to use interpretative principles to develop visualisations, rather than looking to develop new set of applications to display interpretative data [67]. In that sense turning to exploring alternative means of visualisation also points to a gap in terms of limited engagement of the visual arts in energy studies. Alternatively, this is also a call for a critical to continue engaging with a critical analysis of dominant knowledge narratives in energy studies, and to examine social life around energy beyond the map. This is a task which all the papers of this special issue engage with, whether this is by adopting a critical perspective on current regimes of energy provision and use, understanding the everyday

experiences of energy provision and use, or reflecting upon possibilities for alternative futures that emerge in energy transition narratives.

4. The papers in this special issue

The 18 papers in this special issue address global energy challenges from a deliberately spatial perspective, albeit from a variety of different locational, sectoral, and conceptual approaches. Some of them, especially Aitken, Bridge and Hui & Walker, adopt a relational perspective to understand both space and energy, examining how they are constitutive of and simultaneously constituted by social lives. Alongside these papers that engage directly with the theme of the special issue, we have also included papers that focus on the different ways in which spatiality shapes different aspects of energy provision and use.

The first two papers take up the challenge of interpreting the notion of relational space and its significance for energy studies. Bridge focuses on the 'spatial turn' in energy research, in an attempt to delineate a coherent core of central themes that the current field of spatially-sensitive energy research has developed. He argues, however, that the full potential of a spatial perspective on energy studies is yet to be realised, and proposes three generative themes as proposals for future research: the decolonisation of energy geographies through an understanding of geographies of knowledge production about energy; the differentiation processes at work in the making of energy territories; and the processes of destabilization that actually challenge incumbency. We have loosely taken these broad themes to structure this SI, to demonstrate the potential for current research to move forward the limits of the field.

In 'Concepts and methodologies for a new relational geography of energy demand: social practices, doing-places and settings', Hui & Walker articulate the concept of space as a set of relations "that are continually made rather than given", rather than space an objective surface or container. In doing so, they fully embrace the notion of relational space. They reconstruct a conceptual set of tools by taking the work of Theodor Schatzki on site ontology. In contrast with Bridge's paper, which delineates a research agenda, Hui & Walker make a methodological proposition about how the concept of relational space could be taken seriously within the geography of energy demand, introducing exciting concepts such as 'anchors' and 'settings' to understand energy practices.

The following section includes a number of papers that aim at moving beyond dominant structures of knowledge production in energy studies. Baptista makes a passionate case for a research perspective that emphasises a historical and spatial analysis of contemporary energy systems in sub-Saharan Africa beyond a focus on private investment, efficient markets and technological leapfrogging. Such a perspective includes an understanding of the diverse colonial experiences of different countries and how this has shaped energy trajectories to date. Some of the ideas of Baptista extend beyond sub-Saharan Africa in pointing to the need to find points of engagement with a diversity of understandings of what energy means in different contexts.

Ghanem, for example, offers a unique perspective in her examination of how energy provision and use has been shaped and influenced by urban Lebanon's post-conflict environment in light of the significant destruction of buildings and infrastructure. She uses a qualitative approach to reveal 'the multi-faceted experience of power outages in Lebanon'. In doing so she brings to life local understandings and experiences of energy, often overlooked in energy policy. Her analyses focuses on three main junctions in order to understand relationships produced by the 'new' and informal infrastructures that have since emerged: informal electricity providers, new routines and practices of households and the objects and artefacts that constitute the energy landscape in the city. Roberts

and Henwood adopt a similar strategy to explore 'the everyday energyscapes of rural dwellers in Wales', seeking to reveal the experiences of a population group whose views are frequently overlooked in energy policies. The paper provides a rich and in-depth account of the challenges facing two rural households in Wales to transition to a low-carbon economy and an understanding of how and why people use energy in the ways that they do. Such challenges include ageing and inefficient housing stock, reduced local services including public transport resulting in higher rates of car ownership, and the limited reach of the gas network

The second section of the SI engages with a group of papers that focus loosely on multiple processes of differentiation and territorial structuring around energy. The first two engage with the political economy of energy. Baker takes on concepts of energy demand and consumption within the context of growing research on embodied emissions. She draws on the UK as an example to unpack the global socio-economic and ecological inequalities inherent in the measurement of greenhouse gas emissions on a territorial basis under the international climate change framework. Her paper problematises questions of distribution, allocation and responsibility with regards to the pressing need to reduce global GHG emissions and the consumption that generates them. Davies, Wlokas and Swilling actively challenge exiting renewable policies in South Africa, via a critical analysis of the Renewable Energy Independent Power Producers Procurement Programme (REIPPPP) launched in 2011. Their analysis focuses on the political economy of energy and highlight the entanglement of renewable energy policies with land use management and spatial policy.

Ideas of differentiation are central to studies that tackle issues of fuel poverty, energy demand and consumption, and household energy use. Working in the UK, Butler and Parkhill argue for the need to look far beyond energy policy to non-related energy governance such as health, work and the economy, in order to understand and tackle energy demand. Robinson, Bouzarovski and Lindley critic the Low Income High Cost (LIHC) fuel poverty indicator in England, introduced in 2012, which include for its failure to acknowledge the contextual and regional specificities of the nature of fuel poverty and energy vulnerability. They argue that the reduction in fuel poor households has happened in areas with lower housing costs but there is a higher prevalence of fuel poverty in urban areas. Alamel focusses on the commodification of all-inclusive packages in student housing of multiple occupancy (HMO) and their influence on students' residential decision making processes and housing experiences. She explores the relationship between low-quality housing and energy consumptions as HMO landlords frequently include energy, water, and internet bills in the rent cost. Such commodification has a detrimental impact on pro-environmental behaviour and lack of transparency of energy consumption.

Finally, there is also a strong material component to processes of differentiation. Pasqualetti and Stremke explore the evolving concept of landscape in relation to energy. Focussing on the US and Europe, their analysis includes what they describe as the "growing public awareness of the environmental consequences and associated human hardships of energy" as well as opposition to new, cleaner developments such as wind farms. De Laurentis and Pearson propose a novel way to research renewable deployment "by investigating the relationship between energy and materiality". In order to do this, they develop a heuristic framework that foregrounds the importance and role of natural resources and the issue of materiality in explaining the uneven processes of low carbon innovation. In doing so, they challenge much of the literature on innovation and systems innovation. Labussière also deals with concepts of materiality and natural resources building on the thinking of the French philosopher Gilbert Simondon, arguing for a consideration of specific practices of territorial intensification intrinsic to the exploitation of energy resources.

The last group of papers focuses on destabilizing incumbent energy regimes, in a search of processes to understand and accelerate the energy transition. One salient concept is 'community', because of the enthusiasm on community-led energy projects and other community-based initiatives. In 'One-way street? Spatiality of communities in low carbon transitions' Aitken draws from spatial theory to deliver an theoretical exploration of the concept of 'Transition', Aitken argues for "an explicitly geographical understanding of the role of community in energy production and use" in order to assess the uneven power dynamics that are inherent in any community working in pursuit of low carbon futures. Through this case study, which focuses on a government-funded community project which aims to adapt and retrofit houses in the street with low carbon technologies and reduce energy consumption, Aitken considers two notions of community that are at play in a low-carbon transition. The first refers to the street and its residents as "territorially delimited, location-bound, and static", while the second refers to those involved in the community project working to transform the street, "as networked, performative, and interpersonal: those involved in the community project". The paper concludes that a greater understanding of the co-constitutive relationship between space, community and energy is needed.

In 'Community energies: exploring the socio-political spatiality of energy transitions through the Clean Energy for Eternity campaign in NSW Australia', Hill & Connelly analyse the spatial and scalar dynamics of a community based campaign which has successfully promoted the use of localised renewable energy provision from solar and wind power on the far south coast of New South Wales. Not only has the campaign facilitated community energy generation projects, but also the development of a new social infrastructure and community engagement and participation which has had an impact on energy use and climate change mitigation at the regional level. In 'Rural labs and experiment at the fringes: a case study of Bruny Island, Australia', Lovell, Hann & Watson challenge dominant perspectives on energy experiments that focus on the urban and as an alternative consider possibilities for energy innovation in rural communities. They examine Bruny Island which is trialling residential battery storage and solar PV energy systems as an alternative to meeting peak demand with diesel generators during the tourist season. In this case, the specificities of the context were crucial to shape the politics of experimentation.

The final two papers aim at developing new frameworks to incorporate relational conceptualisations of space into transitions theory. Huang & Castán Broto focus on urban energy transitions in their study of solar hot water heaters in China, introducing the Dimensions of Urban Energy Transitions (DUET) framework as a means to analyse different factors involved in such transitions systematically. The case of the popularization of solar water heaters in Rizhao reveals the dynamic interactions between urban processes and energy transitions, and demonstrate how the potential for transitions are continuously shaped by the conflicts and alignments between industry interests and territorial priorities. With a similar objective, Popke & Harrison have a different take on the spatial aspects of transitions. Using the concept of 'energy metabolism' from urban political ecology the authors explore how initiatives to introduce renewable energy in Jamaica and Eastern Caribbean countries have brought these territories 'into international circuits of technology, finance and expertise'. This process has influenced the region's regulatory environments and has contributed to the reconfiguration of its energy landscapes and infrastructures. In a poignant conclusion, the authors ask whether the renewable energy infrastructures under development can be considered a move towards energy sovereignty through the development of indigenous sources of energy, or rather "a local node in a wider network of global infrastructure space".

Overall, these collection of papers demonstrates the emergence of a field of study concerned with developing theoretically sophisticated studies of the spatial dimensions of energy challenges. This is

a rich and diverse field. Like the analysis of energy maps, the SI points towards significant gaps in studies that challenge hegemonic understandings of energy, and suggests that the notion of relational space can make a significant contribution to attempts to decolonise energy knowledges.

5. Conclusion

This SI demonstrates the multiple spatial dimensions of energy challenges: how global energy challenges manifest in different locations according to spatial categories and characteristics (e.g. global/local; urban/rural; community/ state level; global south/ global north); the development of systems of energy production and use; economic geographies of energy production and use and their links to the unequal distribution of resources; the political economy of energy provision and use as it manifests in different locations; and the linkages between energy governance and spatial transformations. These papers raise multiple questions about what does it mean to think of energy and space as relational.

However, to what extent do relational space perspectives offer an entry point for practical decisions about the global energy challenge? The global energy challenge, as specified in the SDG7, is a call to address the competing objectives of achieving universal energy access on the one hand, whilst reducing energy consumption and demand on the other. Both objectives depend on deeply entrenched spatial questions. Energy access is not merely a question of generating unlimited supplies of electricity and modern fuels. Rather, there is an increasing realization that energy access relates to how particular needs are defined within specific social and cultural contexts, and this is spatially determined. Spatial relations influence the way in which different people and institutions use energy, in both private and public spheres, and within specific infrastructure regimes. De-carbonisation will require broader societal changes and, in turn, the creation of new relations between systems of energy provision and energy uses. Such changes include attempts to control carbon in particular locales, and how place-based initiatives create alternative pathways for possible futures [76].

Moreover, there are profound geographical differences in terms of how global energy challenges are framed, for example, the inequalities of energy access found between and within high, middle and low income countries. Inequalities of service provision shape both the potential for energy access and the variegated practices whereby different actors cope with a perceived mismatch between needs and resource availability. The way space is conceptualized as, for example, being underdeveloped, shapes the policy imaginations about possible energy futures. Different forms of visualisation may reaffirm those imaginations, but they could also challenge them. A stronger engagement with visual arts may be a means to enrich the depiction of the spatial characteristics of energy. The papers in this special issue either challenge current imaginations or advance new perspectives on energy provision and use. In doing so, they map new research areas in the quest towards an energy transition for all.

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[i] This special issue emerged from a workshop that took place in Windsor, in May 2016 on "Spatial adventures in energy studies" funded by the Economic and Social Research Council. The motivation for the workshop was to bring an explicit consideration of philosophical and geographical debates of space to energy studies. The workshop proposed 'an adventure' because it asked participants to write speculative essays aiming to look into the future of their own scholarship. Adventure comes from the Latin word *adventūra*, 'what is about to happen', from the verb *advenīre* 'to arrive'. Here the word 'adventure' was not proposed as an exploration, implying an exercise of intellectual appropriation (cf. Bridge's paper in this issue) but quite the opposite: an invitation to take intellectual risks out of love for the subject matter and to express audacious views in the sense of 'venturing an opinion'.

[ii] Dasymetric maps determine areas that feature a characteristic of interest, and appear as zoned representations of that characteristic's density. Choropleth maps represent statistical variables by assigning a value to discrete political/administrative units. In cartograms administrative units are resized in proportion to a thematic variable. For critical analyses of different types of maps, with a focus on the choropleth map see [62] J. Crampton, GIS and geographic governance: reconstructing the choropleth map, Cartographica: The International Journal for Geographic Information and Geovisualization 39(1) (2004) 41-53.