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From 'energy geography' to 'energy geographies': Perspectives on a fertile academic borderland

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Abstract

This paper takes stock of geographical contributions to the study of energy and energy futures. The paper is written in two parts. First, I trace the methodological and philosophical traditions that underpin geographical approaches to energy studies. I argue that while 'energy geography' is arguably a pragmatic shorthand with which to communicate to the broader energy studies community, geographical studies of energy have expanded in scope and theoretical plurality so that 'energy geographies' is a more appropriate label. Energy geographers are well positioned to contribute to scientific and policy debates surrounding energy due to their privileged position at the borderland between various philosophical and methodological traditions. Second, I identify some of the problems, opportunities and uncertainties that contemporary energy geographers are helping to identify, understand, and resolve. Past contributions and critical issues for future scholarship are highlighted in four themes: (1) using advanced socio-spatial theory to better understand the energy-society relationship; (2) geo-political and geo-economic assessments of (changing) global energy trade networks; (3) geographical perspectives on socio-technical (energy) transitions; and (4) advanced spatial decision-support for energy planning and technology implementation. While this discussion is by no means exhaustive, it aims to bring some clarity and specificity to the policy and academic relevance of geographical thought and practice as it relates to energy issues.

Keywords

energy GIS, interdisciplinary, production of space, renewable energy, transition

I Introduction

Energy, or the ability to do work, is integral to socio-spatial relations. Social systems have been shown to increase in size and complexity in proportion to overall energy consumption (Haberl, 2002). The relationship between energy and society is co-productive; on one hand energy availability and consumption establishes the parameters around the types of lifestyles that are possible, while on the other hand cultural and political-economic value systems guide the resources from which, and end-uses toward which, energy is expended (Nye, 2001; Shove and Walker, 2010; Huber, 2013). More to the point, physical energy flows and social energy demands are co-productive of socio-spatial relations. Built environments,

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geo-political relationships, and flows of social and financial capital are organized in relation to the quality and location of the energy resources that are available and valued by a society (Luten, 1971; Chapman, 1989). Furthermore, energy is the primary mediator in the human-environment relationship and travels through coupled socio-ecological systems (Cook, 1976; Smil, 2008). The act of recovering energy, whether for food or fuel, necessarily requires some intervention in or re-orientation of natural energy flows and at the same time influences the scale and location of human modifications to non-human systems.

As these basic principles of the energy-society-environment relationship hold, patterns of energy production and use are currently undergoing fundamental change. The combination of geological and geopolitical constraints in conventional energy markets, social concerns over climate change and national energy security, and technological advances in energy recovery systems are driving two contradictory shifts in energy supply: toward 'unconventional' fossil fuels on one hand (i.e. shale oil and gas, oil sands; Farrell and Brandt, 2006; Greene et al., 2006) and toward renewable energy resources on the other (The Electricity Journal, 2013; REN21, 2014). At the same time, new end-use technologies (e.g. mobile telecommunications), investments into advanced energy distribution technologies (e.g. natural gas liquefaction, smart grids), and changing social expectations are having profound impacts on consumer choices (Spinney et al., 2012; van der Kroon et al., 2013), especially in so-called 'emerging economies' such as China and India where a growing industrial base and middle class are now driving the global demand curve for energy (Leach, 1992; IEA, 2012). When considered in the light of the 'first principles' discussed above, it is intuitive that these changing patterns of energy production and use are co-constitutive of much broader social and geographical change (Juisto, 2009; Bridge et al., 2013).

With all of this in mind, it is not surprising that the study of energy is increasingly recognized as being at the heart of the geographic tradition. Although the explicit study of energy was uncommon among geographers in the mid-20th century (Hoare, 1979; Pryde, 1985), a (re)surge(nce) is evident in recent special issues of geography-centric journals dedicated to energy issues (Walker, 1995; Bridge, 2010; Nadaï and van der Horst, 2010; Zimmerer, 2011; Rutherford and Coutard, 2014; Frantál et al., 2014); the contribution of geographers to the seminal publication of the new high-profile academic journal *Energy Research and Social Science* (see Sovacool, 2014); a spate of new books on energy written or edited by geographers (Pasqualetti et al., 2002; Sovacool and Brown, 2007; Smil, 2008, 2010; Yafimava, 2011; Bridge and Le Billion, 2013; Mitchell et al., 2013; Huber, 2013; Bradshaw, 2014; Desbiens, 2014; see also Pasqualetti, 2011); the strong and increasing presence of energy research at the Royal Geographical Society and, more recently, the annual meeting of the Association of American Geographers (see Petrova, 2014); and the emergence of energy-centric multidisciplinary research networks initiated by and including geographers (e.g. the Energy Geographies Limited Life Working Group; Energy Security in a Multipolar World; Incluesev; the Centre for Urban Resilience and Energy).[1] What's more, current and prospective students of geography are increasingly (seeking to be) trained specifically in energy issues while educators and administrators are thinking of ways to integrate energy studies into geographical education in order to keep pace with this growing demand (Bridge, 2012).

On the other hand, however, comprehensive and coordinated energy-centric curricula within or including geography departments are sparse (Pryde, 1985; Bridge, 2012). To paraphrase a question put forward to a group of panelists at a recent meeting on the topic of teaching energy geography, geographers are still unsure about the 'specificity' of geographical perspectives in energy studies and are finding it difficult to articulate the intellectual, scientific and social relevance of geographical perspectives relative to the wide range of disciplines already engaged in energy issues. To be sure, this is an understandably difficult task. As Pasqualetti (2011) reminds us, the ties between energy and geography are so common that they 'escape casual notice' and we take for granted the fact that, when it comes to energy, geography always matters. Although this is a valid ontological argument, the community of geographers studying energy must be careful not to suggest that *everything* related to energy is the intellectual domain of geographers, because this would be the same as suggesting that our domain *is nothing in particular*. The risk here is irrelevance by ambiguity and redundancy (see also Bridge, 2012) and an obfuscation of the validity and value of academic contributions and policy recommendations from geographers who are working to identify essential problems and solutions surrounding energy and energy futures.

The purpose of this paper is to engage a number of questions which underpin these tensions and concerns: what does it mean to bring a 'geographic' perspective to energy studies? Where does this research agenda fit within the geographical tradition and within the broader field of energy studies? How can energy geographers make an impact in existing and emerging scientific, policy, and political/cultural questions surrounding energy futures? What role can geographers play in the large multidisciplinary research networks through which energy studies are increasingly undertaken? Although the answers that follow are by no means exhaustive or definitive, the purpose of this discussion is to provide energy geographers with a sensibility toward the history of their field, and to highlight growing areas and critical issues for future scholarship in this fertile field of inquiry.[2]

II Toward energy geographies

Retrospection will help to identify the shoulders upon which future energy geographers might stand. A useful starting point is provided by Solomon et al. (2004: 831), who describe the field of 'energy geography' as 'the study of energy development, transportation, markets, or use patterns and their determinants from a spatial, regional, or resource management perspective'. During the formative years of the subject, this mandate was addressed primarily through the lens of resource and economic geography with a managerial and positivist bent (e.g. Chapman, 1961; Luten, 1971; van Zyl, 1968; Manners, 1971; Hauser, 1971; Spooner, 1981; Wilbanks, 1982; Calzonetti and Solomon, 1985). Principal tasks included: monitoring energy supply-chain developments; identifying place-based factors which explained observed spatial patterns of energy-sector investment; assessing environmental and economic risk in facility siting, especially in the context of large scale nuclear energy development; understanding how energy technology diffuses within and between nations; and mapping regional variations in energy production, distribution, and use (see also Solomon et al., 2004). Cook (1976) describes 'energy geography' in very similar terms, but takes care throughout his book to document the ways in which energy mediates the human-environment relationship. Here, the study of energy is presented as an obvious link between human and physical geography (Hoare, 1979), thereby situating energy studies firmly within geography's human-environment or nature-society tradition (see also Smil, 2008). In this vein, major threads of research include formulating spatio-temporal models of energy budgets for socio-ecological systems; learning how processes of energy capture, storage, distribution, and use are manifest spatially within socio-ecological systems and how they are related to the physical properties of the resource base; understanding and forecasting spatial patterns of environmental impacts related to human energy production and consumption; and tracing links between energy development, livelihoods, and environmental injustice.

Common among these early works is the use of the descriptor 'geography' – as in 'a geography of energy' (Chapman, 1961) or 'the geography of energy' (Manners, 1971). This language persists in contemporary descriptions of the field as 'energy geography' (e.g. Solomon et al., 2004; Pasqualetti, 2011), while 'the geography of energy' remains a common title for courses in geography that teach energy issues. Deliberately or not, this language implies a coherent set of practices and a common philosophical (i.e. ontological; epistemological; methodological) foundation. While some perception of coherence is arguably practical when speaking to the energy studies community outside of the discipline, it does not reflect the state of the field. In fact, geographical studies of energy have incorporated theories, concepts, and techniques borne out of a range of (sub)disciplines from very different philosophical positions. An illustrative though not exhaustive list includes: evolutionary economics (Kedron and Bagchi-Sen, 2011); cultural studies (Spinney et al., 2012; Nadaï and Labussière, 2013); political science (Neville and Dauvergne, 2012); political economy (Huber, 2008); political ecology and legal studies (Andrews and McCarthy, 2013); history (Harrison, 2013) or historiography (Pooley, 2010); sociology (Dorow and O'Shaughnessy, 2013); environmental psychology (Devine-Wright, 2007); science and technology studies (Furlong, 2011; Bickerstaff, 2012; Birch and Calvert, forthcoming); urban planning (Owens, 1986); regional science (Feder, 2004; Mabee and Mirck, 2011; Court et al., 2013); climatology (Li et al., 2011); GIScience (Horner et al., 2011; Calvert et al., 2013; Resch et al., 2014); remote sensing (Sabins, 2004; Wang et al., 2009); and civil engineering/engineering economics (Zvoleff et al., 2009; Nguyen and Pearce, 2010).[3] Perhaps more importantly, there is no discernable desire within the community of geographers studying energy to produce a coherent approach that might be considered 'energy geography'. Indeed, many contemporary geographers studying energy have embraced theoretical and conceptual pluralism in an explicit way, opting to describe their work as fitting within the field of 'energy *geographies*' (Spooner, 2000; Zimmerer, 2011).

In this context, geographical approaches to energy are best conceived as an academic borderland (see Figure 1), i.e. a topical field of study where sometimes disparate or disjointed systems of geographical thought and practice, borne out of work rooted in the core sub-fields of geography (see Pattison, 1964; Robinson, 1974; Livingstone, 1992; Sui, 2004; Martin, 2005), converge on the study of past, current, and future patterns of energy production, distribution, and use at various geographical scales. In other words, the strength of energy geographers is their lack of ties to some common doctrine or particular mode of inquiry, which brings the flexibility required to contribute to multidisciplinary research projects (see also Sheppard and Plummer, 2007; Barnes and Sheppard, 2010).[4] This flexibility is a professional asset given the new research funding landscape that values transdisciplinary research (Spreng, 2014). Perhaps more importantly it is an intellectual asset. Energy is simultaneously (a) a physical entity that is derived from natural processes and transformed through physical systems, and therefore partly the domain of the 'physical geographer'; (b) a social relation to the extent that physical entities are socially constructed as energy resources through political-economic and cultural processes but also a primary agent in the spatialization of social activities, and therefore partly the domain of the 'human geographer'; (c) the primary mediator of our relationship with the environment and therefore partly the domain of the 'nature-society' or 'human-environment' geographer; and (d) non-uniform over space and made

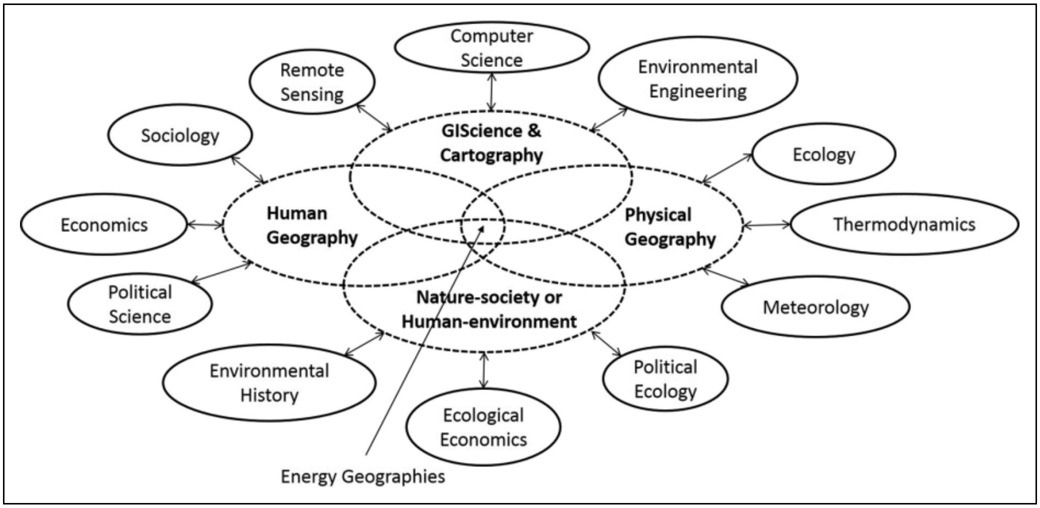

Figure 1. Core subfields and borderlands (overlapping subfields) in geography. Geographical subfields exchange concepts and techniques with other academic and applied research domains, some of which are identified above, in order to study energy and energy futures. Figure adapted from Zimmerer (2010).

accessible or not by site-level conditions and therefore partly the domain of the 'GIScientist' and 'cartographer'. Working at the borderland is therefore necessary to fully engage with the essential energy policy problems and key scholarly questions surrounding energy.

The challenge here, however, is to ensure that a 'rich diversity of approaches' does not digress into a 'confusing hodgepodge of approaches' (cf. Simandan, 2011). Building on all of geography's 'turns' (quantitative, cultural, discursive, and so forth) might have energy geographers walking in circles. In this light, the recent work of Bridge et al. (2013) to establish a vocabulary or conceptual roadmap with which energy geographers might 'map the geographies of a low-carbon energy system and so guide choices among different potential energy futures' (p. 531) is vital in clarifying the specificity of, and productive tensions created by, a geographical perspective relative to perspectives from other disciplines. My objective in the next section is to build on this and other work (e.g., Chapman, 1961; Solomon et al., 2004) in order to identify some of the critical issues/questions surrounding energy and energy futures that are particularly suited to the skills and expertise of (energy) geographers, and which might serve as focal points for future geographical studies of energy.

III Energy geographies: Recent trends and critical issues for future scholarship

Similar to the discipline of geography in general, energy geographies have 'changed to reflect the world as inhabited – but also the world as desired' (Frantál et al., 2014: 5). Energy geographers are adapting to a new research funding landscape which emphasizes multidisciplinary research teams focused on timely energy policy issues. At the same time, energy geographers are working to ensure that their research is not wrapped too tightly into meets the intellectual expectations of the geography community. Emerging from these rhythms are a number of ongoing contributions and critical issues for future scholarship: (1) using advanced socio-spatial theory to better understand the energy-society relationship; (2) geo-political and geo-economic assessments of (changing) global energy trade networks; (3) geographical perspectives on socio-technical (energy) transitions; and (4) advanced spatial decision-support for energy planning and technology implementation. These themes are not mutually exclusive and are separated below into sections only for the sake of bringing clarity and organization to the discussion.

1. Energy, space, society

The role of energy systems in shaping the spatialization of social activities and in mediating the human-environment relationship is a long-standing focal point for energy geographers (e.g. Luten, 1971; Cook, 1976; Manners, 1971; Chapman, 1989; Smil, 2008). Recently, this work has been advanced by a shift from conceptualizing energy as an economic asset or ecological phenomenon to conceptualizing energy as a social relation. The 'energy landscape' concept has been most prevalent here, helping us to understand how different modes of energy production, distribution and use underpin material relations (i.e. landscape form and livelihood arrangements) as well as immaterial relations (i.e. perception and representation) (Pasqualetti et al., 2002; Nadaï and van der Horst, 2010; Blaschke et al., 2013; Frantál et al., 2014). Here, we can use the term 'energy geographies' to signify that various geographical imaginaries, spatial identities, and connections to place are co-productive with particular systems of energy provision.

Indeed, systems of energy provision underpin the way societies perceive and behave toward their surroundings. The introduction of electricity, for example, brought to us 'big city lights' and the notion of the 'city as spectacle' (Nasaw, 1992). Once dark and fearful spaces, such as canal-side walkways or downtown areas, were transformed into quaint and romantic settings suitable for 'respectable' forms of leisure (Nasaw, 1992). Those of us with access to internal combustion engines and powerful liquid fossil fuels see the world 'naturally' at 60 miles per hour and have very different ideas about distance and proximity than societies that are not based around the personal automobile or rapid transit (Nye, 2001). Advanced climate control systems such as electric air-conditioning or natural gas furnaces have changed perceptions of thermal comfort (Nicholls and Strengers, 2014) so that, for example, a winter storm, once dreadful or inconvenient, can be perceived as delightful and oddly comforting. A pipeline system that carries gas to the home eliminates the daily necessity of fuel-wood gathering and therefore changes the roles of women and children within the household as well as their relation to the local environment (van der Kroon et al., 2013).

At the same time, energy production and consumption represents a re-ordering of the non-human world in the context of some culturally significant imaginary or vision. In other words, geographers have helped to connect modes of energy production and distribution to acts of 'place-making'. In general, more capital intensive energy systems which reduce strain on human muscles ultimately increase leisure time and contribute to periods of energy surplus so that energy can be expended through relatively unproductive but culturally significant services that are reflected in the landscape – e.g. maintaining a manicured lawn. Building on social practice theory geographers have shown that energy consumption is involved in an interdependent web of socio-material relations through and in which personal identities and social norms are re-affirmed or resisted (Walker, 2014). Spinney et al. (2012), for example, show how the combination of relatively cheap electricity and design improvements to the laptop computer are co-constitutive of idealized images of domesticity and spaces of comfort. Shove and Walker (2010) demonstrate how ideas about 'freshness' as it relates to social acceptability or social status, combined with the interaction of material elements such as shampoo and indoor plumbing at spaces dedicated for bathing, perpetuate energy intensive hygiene. The concept of 'livelihood' is also helpful here. Energy is after all the basic necessity of any livelihood strategy and, as geographers have shown, 'the production and reproduction of livelihoods are interlinked with the processes producing and reproducing space' (King, 2011: 298). Through spatially explicit, contextual analyses which conceive of energy as one of many basic ingredients in the geographies and practices of everyday life, we learn that fuel choices and the diffusion of particular energy resources or technologies is not a pre-ordained progression along some 'energy ladder' toward more 'advanced' energy systems, but represents a complex diffusion of 'multiple, multi-sited' social practices which are co-constitutive of normative geographical imaginaries and spatial identities (Nicholls and Strengers, 2014). From a policy perspective, these place-based dynamics require commensurate place-based solutions (see Parker et al., 2003).

These acts of place-making and the energy landscapes which emerge from them, are of course not neutral. On the contrary, energy is inherently a 'political resource' – a fact which has been substantiated by energy geographers in three ways. First, recognized prospects for new flows of energy bring together (disparate) social groups into conversations about allocation, costs and benefits, and acceptable end-uses (Bridge and Le Billon, 2012; Kennedy, 2014). Bulkeley et al. (2014) conceptualizes energy infrastructure as sites of contestation and as spatial expressions or material articulations of dominant political-economic ideologies and geographic imaginaries (see also Vogel, 2008). Second, deliberately or not, the development of energy infrastructure has ethical implications which are not experienced evenly across space. Decisions about which resources to prioritize and where to build new infrastructure (re)produce uneven economic development at regional scales (Bouzarovski et al., 2012; Harrison, 2013) as well as situations of energy poverty at more localized and household scales (Buzar, 2007a, 2007b). As Mulvaney (2014: 178) notes, efforts to achieve a 'green' and 'sustainable' economy in one part of the world introduces a 'tension between innovation and environmental justice as efforts to drive down the cost of solar energy introduce new environmental, health and safety risks' that can be traced to, for instance, large-scale nickel extraction in nations with poor labor and environmental standards. When these social and environmental costs are known, decisions about energy production and consumption are shaped by socio-cultural perceptions of and ethical positions toward one's surroundings. As Nye (2001: 249) explains, the desire among early European settlers to make a landscape more productive for human uses through intensive management was not shared by indigenous populations, and this cultural difference rather than inherent technological ingenuity or access to coal underpinned European status as a 'high energy society' and the dominance of the new world (see also Lizot, 1977). Third, and related to the previous point, energy production and use translates directly into control over space so that energy is an important physical medium through which to tilt the balance of power and exert social control. Indeed, political maps are (re)drawn by those groups or nations that manage energy resources in ways that enable the control of large populations over great distances, even in relatively small numbers, e.g. in the construction of naval infrastructure and weaponry (Adams, 1975; Lizot, 1977; Nye, 2001).

Given that energy is integral to socio-spatial relations, it is intuitive that spatial representations are used as rhetorical ploys in order to advance particular agendas related to energy production and use. Energy is discursively wrapped up into socio-spatial identities such as 'community' (Bailey et al., 2010; Dorow and O'Shaughnessy, 2013), 'nation' (Perreault and Valdivia, 2010; Bouzarovski and Bassin, 2011); 'home' (Spinney et al., 2012), 'local' (Devine-Wright and Wiersma, 2013), and 'region' (Vogel, 2008). Political and cultural geographers have shown the way in which these spatial identities do work in the process of energy transformations. In some cases spatial representations are formal acts of boundary-ma(r)king, as in claims to sovereignty for the purpose of establishing authority over resource access (Kennedy, 2014) or in negotiating the definition and delineation of 'community' and criteria for belonging (citizenship) when determining how to allocate financial benefits related to particular projects (Bristow et al., 2013). Desbiens (2014) documents how a national identity in Quebec, Canada, converges with legal claims to territory (territoriality) in order to foster consent for large energy infrastructure projects, in this case at the expense of indigenous land claims and livelihoods. Similar strategies underpin shale energy production in the USA, where land-owner and public approval is won by framing the industry as an expression of patriotism and a means of achieving national security (Hudgins and Poole, 2014). Cowell (2010) examines the political-economic power imbalances that underpin the identification of 'acceptable' sites for renewable energy infrastructure development and finds that spatial plans are often based on the objective to preserve sites of national heritage while neglecting local heritage or the value systems of local (and often marginalized) populations. In these examples we learn how 'site preparation' activities for energy production involve the politicization of space and a politics of place long before any physical preparations (see also Hunold and Leitner, 2011; Andrews and McCarthy, 2013). Moreover, framing energy production and consumption activities through spatial identities is a powerful way to organize individuals toward a common goal, e.g. helping to ensure that the full weight of the nation (symbolic power) supplements the full weight of the state (legislative authority) (see Figure 2). Huber (2013) shows how the political geographies of oil are not always state-centric and in fact operate to produce an oil-consuming individual or subject,

Figure 2. A t-shirt exemplifying the way in which spatial identities are entangled with (particular types of) energy resources. Source: http://www.buycoal-region.com/shop/cart.php? m=product_detail&p=25

primarily through appeals to the way in which oil consumption can (re)produce idealized images of individuality, home, freedom, and life (see also Kennedy, 2014).

Collectively, these geographical insights into the energy-society relationship provide examples of all three facets – as described in Karplus and Meir (2013) – of what Lefebvre has called the 'production of space' (Lefebvre, 1991). Social value systems related to the non-human world re-position physical entities as energy resources and at the same time establish the legal and extra-legal institutions through which resource access and spatial planning are enforced (conceived space). Different systems of energy provision have very specific landscape expressions (perceived space) and underpin the construction of 'acceptable' or 'normal' spaces of everyday experience (lived space). Surely there is room to apply and explore these facets of the 'production of space' concept further in relation to energy. Through creative combinations of energetics and science and technology studies, energy geographers have begun to chart a new path by documenting the ways in which the material properties of energy resources and energy systems are active in and co-constituted by the (social) (re)production of space (Huber, 2011; Birch and Calvert, forthcoming; Bulkeley et al., 2014b; see also Bakker and Bridge, 2006; Bridge, 2009).

2. Geographies of carbon lock-in

The production and use of fossil energy resources are so engrained in our political-economic and cultural systems that terms such as 'fossil capitalism' (Huber, 2008) and 'hydro-carbon man' (Shaffer, 2009) are as accurate as they are provocative. Despite, or perhaps because of, the ubiquity and taken-for-grantedness of fossil fuels, they remain a compelling focal point for geographers interested in energy and extractive industries – particularly in this era of more frequent price shocks and environmental catastrophes such as the Deepwater Horizon oil spill (Kennedy, 2014).

Fossil fuels, particularly oil, are the dominant commodity within global trade networks. As such, tracing their stocks and flows offers a critical entry point into understanding the dynamics of international geo-political relations and political-economic globalization more generally. Indeed, trade in fossil energy resources 'knits' states together through 'productive connection and shared vulnerabilities' (Montgomery, 2010: 58) so that new geo-political alliances and power imbalances are forged through the discovery and exploitation of new reserves (Bouzarovski, 2009; Bouzarovski and Bassin, 2011; Misiagiewicz, 2012). Those 'shared vulnerabilities' are beset with real and perceived risks of politically motivated disruptions to energy supply. Bridge and Wood (2010) find that 'Big Oil' are more worried about these 'above-ground' sources of scarcity than about resource scarcity in a geological sense (peak oil). In response to these above-ground concerns, supply lines are made more secure through various spatial fixes which, in turn, reconfigure geo-political relations and the distribution of costs and benefits. The Suez Canal crisis of the 1950s which closed a crucial choke-point in oil transport between supply in the Middle East and demand in Western Europe, for example, provided the impetus to invest in super-tankers that could carry large volumes of oil around the African continent (Cook, 1976). These shipping networks are now the focal point of piracy which, according to Kennedy (2014: 267), can be understood as an act of defiance toward the 'exclusionary violence of geographies of oil development which (re)produce glaring economic disparities between those who live atop oil deposits and those involved in its extraction, distribution, and consumption' (see also Pasqualetti, 2011). Another spatial fix involves building redundancy into pipeline infrastructure to avoid political instability within 'transit states' that lie between producer and consumer nations in order to reduce the strategic value of any single host of energy distribution infrastructure. Recent research has studied how these spatial fixes are not only productive of but also responsive to or embedded in (uneven) regional and global economic transformation. In Eastern and Central Europe, for example, (territorial differences in) post-socialist reforms aimed at attracting foreign capital to increase domestic capital accumulation, at least as much as geographical position relative to prevailing energy flows and markets, have shaped patterns of foreign investment into oil and gas extraction and distribution infrastructure (Bouzarovski, 2009; see also Buzar, 2007a).

The most profound changes to the geographies of carbon lock-in involve the surge of oil and gas production from unconventional resources, and especially in countries where production was once thought to have peaked. Contrary to conventional wisdom of just a few years ago, for example (see Solomon et al., 2004), by 2040 the USA is expected to become an overall net energy exporter, if only for a few decades, due to expanded production of oil and gas held in domestic tight shale formations (IEA, 2012). Andrews and McCarthy (2013) have studied how legalities over space (e.g. sub-surface rights, air and water regulations) at multiple levels of government, combined with politics of space and ecology at multiple geographic scales, have intersected to enable this boom in a way that could not be immediately replicated in other nations. Pasqualetti (2009) describes how views on the development of unconventional resources are relational to the way in which costs and benefits will be distributed. Speaking about oil sands deposits in Canada, he notes that unconventional fossil energy resources are framed as virtuous by location, i.e. they reside in areas that are described as 'secure' or without conflict and therefore able to contribute to energy independence and national security goals. On the other hand, these resources are shrouded in conflicted geographies such as land-claim disputes along proposed pipeline routes, distributional conflicts related to the real and perceived ecological threats of these new extraction methods, and the extent to which local citizens will need to bear these costs only to see the resources sent to overseas markets to command a higher price (see Figure 3).

A number of fruitful areas for geographical inquiry continue to present themselves in these seemingly familiar geographies of carbon lock-in. Much can be learned from documenting how energy space-economies and broader geopolitical relations co-evolve with the shift toward unconventional fossil energy resources. Of course, the pace, scale, and longevity of unconventional resource extraction, and especially shale energy production, are as yet uncertain. In this context, research focused on the social construction of scarcity (Bridge and Wood, 2010; Zalik, 2010; Kennedy, 2014) should turn its lens on North American fossil energy production to capture opportunities for comparative analysis, since many of the sources of scarcity are either removed or are qualitatively different than those in other regions of the world. Indeed, it will be important to study the process and implications of the social construction of 'plenty'; e.g. framing the USA as the 'Saudi Arabia of natural gas' (Koebler, 2012). What is the role of sustainable energy systems in this new 'fossil energy landscape of plenty'? How are social and environmental injustices being (re)produced and (re)distributed? How will (should) the role of the USA in militarizing and securing global oil supply-lines change given their position as an energy producer? How can social and environmental objectives be balanced in development and connectivity of supply with demand? Will local support for domestic unconventional energy extraction change if supply lines are opened to global markets in order to widen profit margins rather than contributing to low regional consumer prices and, if so, how?

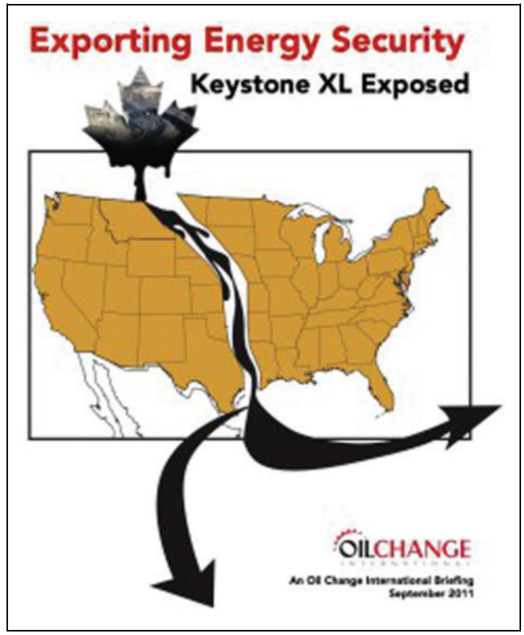

Figure 3. Dirty oil from Canada is shown to divide the United States for the purpose of being exported to overseas markets. Source: Oil Change International, 2011.

3. Geographies of energy transition

Armed with an interdisciplinary perspective on energy and in the light of concerted political efforts to achieve a low-carbon economy, geographers have renewed their interest in the geographical implications of the transition toward renewable energy (RE) (Juisto, 2009; Calvert and Simandan, 2010; Bridge et al., 2013). I qualify this research priority as *re*newed because this vein of research can be traced back to the work of Cook (1976) and Hoare (1979), who began to explore how societal reliance on alternative energies might lead to, or demand, an active construction of, alternative geographies (see also Spooner, 2000).[5] Here, the energy landscape perspective discussed above has helped us to better understand debates around energy planning and siting. The symbolic meaning vested in prevailing energy landscapes, whether in terms of form (aesthetics) or function (livelihoods), are often inconsistent with the forms and functions of landscapes shaped by, for example, wind turbines and solar panels. Social resistance tends to be most pronounced where these unfamiliar landscape impacts and images are not counterbalanced through 'acceptable' levels of local consultation and/or 'fair' distribution of costs and benefits (Fast, 2013). Although these challenges can be partly met through the design of place-based systems of energy governance that embrace multiple voices and value systems (Nadaï and Labussière, 2013), equally important is a fundamental cultural shift in acceptable livelihood strategies and landscape expressions given the new demands on land that come with renewable energy implementation (Späth and Rohracher, 2010). Van der Horst (2014) suggests that we meet this challenge head-on by 'assessing, envisaging, and communicating counterfactual geographies' – i.e. producing and communicating an imaginary of the functions, forms and social relations of a given place if decisions had been made earlier to invest in more 'best practices' related to sustainable energy infrastructure. Pooley (2010) provides a working example of this by describing how Britain might have evolved in cultural and physical terms in the absence or curtailment of car ownership.

Energy transitions are inherently sociomaterial transitions because they involve users and institutions in addition to built infrastructure and natural resources. In other words, resource availability and technological efficiency are by themselves insufficient to explain the evolution of energy systems – a fact which explains failed efforts at rural electrification programs in areas where local populations could not afford the appliances necessary to utilize electricity, nor had they developed a set of cultural practices that necessitated or valued electricity consumption in the first place (Taylor, 2005). Building on socio-technical transitions theory, geographers are helping to unpack the ways in which local political, economic, cultural, and ecological trajectories shape technology diffusion and uptake in order to better understand the geographic conditions under which energy transitions specifically, but sustainability transitions more generally, are most likely to occur. Much of this work has drawn on the 'multi-level perspective' of socio-technical transitions, whereby transitions are conceived as an outcome of alignments at three levels: novel innovations and innovative actors (niche), established and dominant socio-technical configurations (regimes) and exogenous context (landscape) (Coenen et al., 2012; Coenen and Truffer, 2012). In the spirit of traditional regional economic geography, Coenen et al. (2010) explore the advantages and disadvantages of regional agglomerations (physical proximity) in terms of fostering a shared vision of niche-level market standards and business practices (institutional proximity). Shared spatial identities have also been shown to be important, as new understandings of livelihood and landscape help to create the social contexts in which new technologies are deemed appropriate and acceptable (Späth and Rohracher, 2010). Späth and Rohracher (2012) identify spatially differentiated and cross-scalar 'regime structures' which shape the trajectory of potential energy transitions at very localized scales, a finding which adds further reason to move away from, or at least complement, national-level studies that tend to dominate studies of energy transition (e.g. Smil, 2010).

Cities and large urban regions have become important case studies for work on energy (socio-technical) transitions (see also Coutard and Rutherford, 2010; Rutherford and Coutard, 2014). Cities are critical nodes in energy systems, hosting the very upstream – e.g. corporate finance and decision-making related to exploration, capital investments, siting and site-preparation – as well as the very downstream – i.e. high concentrations of energy use. In addition, the deployment of distributed renewable energy systems is transforming urban areas from spaces of energy consumption into spaces of energy production. In other words, a city helps us to unpack the dynamic interplay of energy production, distribution, and use in spatial context. Coenen et al. (2010) discuss the role of cities in facilitating spatial as well as social proximity, as in agglomerations of industrial or financial activity, which helps to strengthen the social networks that ultimately shape the evolution of novel technologies. As our spaces of lived experience, cities (and regions) can become powerful focal points for discourse coalitions to articulate shared visions of an energy future, thereby providing context for deviations from established regime structures (Späth and Rohracher, 2012). Bulkeley et al. (2014a) use a case study of London to show that although energy futures can be predicated on alternative resources, technologies, and spatial identities, they are often spatialized by prevailing dominant logics and political-economic power imbalances in terms of who owns, who has access, and how costs and benefits are (re)distributed. Here, we are reminded that there are limits on the extent to which a 'sustainable' energy transition is also a 'just' energy transition and that there are marginalized voices in an allegedly 'shared' vision of energy futures (see also Newell and Mulvaney, 2013). In other words, and despite popular claims that might suggest otherwise, greater 'energy democracy' through hyper-distributed and less capital intensive energy production systems is not an inherent characteristic of a renewable energy socio-material assemblage, but is part of the tensions shaping the trajectory of these new assemblages.

Growing emphasis on urban energy transitions notwithstanding, geographical perspectives are unpacking the cross-scalar socio-technical networks which emerge through, and make possible, the alternative socio-material assemblages that constitute energy transitions and new energy landscapes. Technological innovations in energy distribution are of course important here because they can expand the geographic reach of supply chains (e.g. natural gas liquefaction systems which are poised to re-scale natural gas markets from regional to global; see Bridge, 2004). Leach (1992), albeit uncritically, describes how the global diffusion of new household appliances has enabled poor households to climb the 'energy ladder' toward high quality fuels such as liquefied petroleum gas (Leach, 1992). Taylor et al. (2011) consider some of the socio-spatial relations facilitating these shifts, showing how remittances to Guatemalan households from migrant workers in the United States might help to explain local shifts from traditional fuel-wood systems to liquefied petroleum gas systems. At a macro-level, networks of social and economic power clearly extend well beyond local and national borders in efforts to secure necessary expertise and financial capital for desired energy system change and/or to maintain political-economic power imbalances guiding energy system development (Huber, 2008; Bradshaw, 2014). With this in mind, Mulvaney (2014) applies a global commodity chain approach to map some of the unseen and perhaps unintended environmental injustices that are tied to the local implementation of allegedly sustainable energy technologies such as photovoltaics.

Recent work has also shown that engagement of actors across scales is a deliberate strategy to pursue interests in particular energy systems. Through case studies of emerging biomass energy systems, Seiwald (2014) and Raven et al. (2012) show how stakeholders use a combination of strategies in efforts to achieve continuity across scales. These strategies include aligning multi-level governance institutions along with spatial identities in order to produce a facilitative legal environment as well as a facilitative moral and political environment (Späth and Rohracher, 2012; Andrews and McCarthy, 2013; Calvert and Simandan, forthcoming).

These geographical insights on energy transitions have raised significant academic and policy questions including, but not limited to, the following: What social and physical factors are influencing how and why RE technologies are dispersing geographically? What new social networks and geographic connections are constructed throughout the process of energy transition, and with what consequence? In what ways are RE systems being made to adapt to regional/local settings? Do small regional or local differences matter in explaining the pace, scale, and outcome of energy transitions and, if so, which ones are most important? How do different ontologies of space and nature influence individual and public perception of (particular forms of) energy production and use? How and with what effect is space (or scale or nature) politicized in the construction and negotiation of energy futures? What will a sustainable energy landscape look like (e.g. how will solar and wind access laws change the morphological evolution of urban city-scapes) and how will it be perceived? In what ways are shifts in energy supply entangled within (broader changes to) socio-technical and socio-ecological systems? (How) can we proactively adjust the spatial organization of social, economic and institutional activities to expedite uptake of sustainable energy technologies? At what spatial (and temporal) scale are energy transitions best analyzed and managed? How are regional and national economies responding to the distortive effects (in, e.g., socio-spatial relations and global value chains) of emerging energy industries? What are the links between energy transitions and other socio-political spatial strategies and transformations (e.g. the post-staples economic transition, landscape/nature conservatism, neoliberalism, spatial planning, urbanization)? The complex geographies of energy production, distribution, and use suggest that energy transitions are more than just a simple shift in the technologies and resources through which energy services are met, and indeed 'political-economic and cultural factors co-evolve with changes in the quality, location, and environmental impact of energy resources' (Juisto, 2009: 533).

4. Geo-spatial decision support for alternative energy futures

The fourth major research trajectory I wish to highlight includes the application of concepts and techniques of resource and environmental geographies to the study of emerging energy resources. As in all matters of resource development (see Mitchell, 1989), 'where to develop' and sustainability questions are important for emerging RE industries. Where are reserves of high quality energy resources? Through which transportation or distribution networks are they best brought to market? Where can resource development occur with minimal impact on social and ecological systems? Which communities/stakeholders should be involved in development decisions, and through what mechanisms can their voices be heard? What mix of energy resources best serves the energy end-uses in a particular community/region/nation? Through these and other questions, energy geographers are working to establish roadmaps for the development of RE resources and implementation of emerging technologies.[6]

Increasingly, concepts and techniques from traditional regional geography or area studies are deployed in order to take seriously the role of unique regional geographies (infrastructure, land cover, bio-productivity, economic activities, spatial identities, land-use preferences) in structuring place-based technology solutions and in shaping spatial patterns of development (Feder, 2004; Mabee and Mirck, 2011; Calvert and Mabee, 2014; see also Court et al., 2013). The use of geographical information systems and remote sensing has figured prominently in these endeavours (Voivontas et al., 1998; Sabins, 2006; Horner et al., 2011; Calvert et al., 2013; Resch et al., 2014). Although energy mapping work mostly focuses on crisp geo-economic criteria for identifying and evaluating resource options, recent work has applied multi-criteria decision-making tools and fuzzy set theory to consider the non-monetary merits of multiple resource/technology options in an area (Aydin et al., 2013). Of increasing interest are the economic and ecological risks of RE implementation, and especially of achieving 100 per cent RE systems and local energy independence. These risks include land-use competition, land-use and land-cover changes, and the re-allocation of ecosystem services (Schmidt et al., 2012; Sliz-Szkliniarz, 2013; Stoms et al., 2013; Mellino et al., 2014). Map algebra techniques, which identify suitable and preferred areas for RE development based on developer interests and regulatory constraints, help to make projections about how these burdens will be spatially distributed in a given area as policy action moves from target setting to implementation (e.g. Mann et al., 2012).

Through the use of such extensive and intensive geo-information, fuel mix targets and land-use planning can be co-developed such that the transition toward sustainable energy stays within acceptable social and ecological limits (Calvert et al., 2013). Indeed, geospatial concepts and information technologies can be used to trace and forecast the new tensions that are emerging between energy production and land-use as a function of renewable energy development (see Walker, 1995) by demonstrating how spatial patterns of development might change based on different policy, technology, and regional geography combinations (e.g. Sliz-Szkliniarz, 2013). Cowell (2010) has pointed out, however, that while spatial planning for RE development is apparently driven by such objective research, the use of particular models and integration of particular sets of criteria by which resources and 'acceptable locations' for development are identified is an inherently political project, often caught up in prevailing political-economic power imbalances and environmental injustices. In other words, 'cartography and global information systems must be acknowledged as representing relations of power, rather than acting as objective tools of measurement and management' (Neville and Dauvergne, 2012: 287; Howell and Baylis, 2014). Being mindful of how power and politics are co-constitutive of map form and content is requisite to reflexivity in the energy mapping process and to providing politically as well as scientifically attuned research and recommendations. Moreover, energy resource mapping exercises should work to empower local decision-makers given the added burden they experience as a function of the distributed and localized nature of renewable energies. These efforts need to be based on a firm understanding of the needs of the user-base and audience to know how geographic information systems and cartographic outputs are best designed (e.g. in terms of symbolization and scale) for effective communication and decision-making.

IV Conclusion

In the context of growing concerns surrounding fossil energy production and use and the intensive development of RE resources, the geographical study of energy has grown as both an intellectual enterprise and a societal/policy imperative. Energy geographers are well positioned to contribute to scientific and policy debates surrounding energy. Their privileged position at the borderland between various philosophical and methodological traditions enables strong multidisciplinary research which can engage the complexities of energy realities.

As an academic borderland, the geographical study of energy has been practiced in various ways in relation to geography's core traditions while ebbing and flowing with the changing policy and research funding landscape. With this in mind, the field is best described as 'energy geographies'. The multiple dimensions of this fertile ground include, but are not limited to, the description and explanation of:

- The spatio-temporal distribution of energy stocks and flows as well as the geophysical processes which underlie that distribution;
- The relationship between the spatial form of socio-ecological systems and energy availability, production, distribution, and use at various geographic scales;
- National and regional differences in the above, as well as how they are intertwined with inter- and intra-regional distributions of political-economic power and social activities;
- The ways in which energy production and consumption mediates, and is mediated by, spatial politics and the human-environment relationship;
- The co-constitution of energy production and consumption with place-making activities, geographical imaginaries, spatial identities, and spatial representations;
- The geographical dimensions of the political tensions, social injustices, and scientific uncertainties that surround prevailing and future energy resource management decisions;
- The study of place-based solutions to the social, economic and environmental problems of energy system development including integrated regional supply-demand planning, integrated land-energy planning, and (critical) energy-GIS.

In general terms, however, energy geographies represent the convergence of concepts and techniques borne out of geography's core subfields to past, prevailing, and future patterns of energy production, distribution, and use at various geographical scales. This includes an emphasis on the material (e.g. biophysical, technological) as well as immaterial (discursive, cultural) spatial dimension of scientific (academic) and policy (applied) imperatives. Although many of the principal tasks of an earlier 'energy geography' can be found in contemporary works, a new cohort of geographers studying energy has expanded upon the physical conceptualization of energy as the 'ability to do work' to consider simultaneously the work (political, economic, technological, cultural) that is done to establish and maintain particular forms of energy production, distribution, and use (see also Mitchell, 1989; Bridge, 2009). This critical and cultural sensitivity should bleed into applied and technical/physical approaches to energy studies. Indeed, energy geographers must continue to lead efforts to develop concepts and tools with which to understand the connections between social systems and physical systems through which energy is transformed and how these systems are spatialized. Toward this end, energy geographers must continue to forge productive ties with a variety of existing and emerging interdisciplinary frameworks imbued with geographical reasoning such as political ecology, environmental economic geography, and critical physical geography.

A number of gaps in knowledge and policy imperatives to which geographical concepts and techniques are well suited were identified and briefly explored in this paper. Given the broad pluralism that characterizes energy geographies, and the uncertainties which surround energy futures, the discussion above is by no means exhaustive or definitive. In fact, it is intended as a contribution to an ongoing, lengthy discussion about energy studies and the geographical tradition.

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Notes

1. For more information, see http://energygeographies-workinggroup.wordpress.com; www.exeter.ac.uk/energsecurity; www.lancaster.ac.uk/lec/sites/incluesec/; and http://urban-energy.org/about/, respectively.
2. It is important to note that this paper reviews work by academics who would not necessarily self-identify as 'energy geographers', but who have contributed directly to bringing a geographic perspective to energy studies.
3. For other entry points into key works, see Solomon et al. (2004); Calvert and Simandan (2010); Zimmerer (2011); and Pasqualetti (2011).
4. On the distinction between inter- and multi-disciplinary research, see Mitchell (2008).
5. The work of Lovins (1977) and Haberl (2006) are also clearly situated within this research agenda, if not from a 'geographical' perspective strictly speaking.
6. Remote sensing techniques are also becoming more prevalent in the exploration for conventional and unconventional fossil energy resources, especially as easily accessible reserves are exhausted and increasingly difficult to locate through in situ exploration methods (Sabins, 2004).

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