

Energy, space, and society: a reassessment of the changing landscape of energy production, distribution, and use

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ABSTRACT. While geography has always mattered for the energy sector, the relative effects of location and distance on the economics of energy regimes are increasing as we begin to deploy more renewable energy technologies. This re-introduction of the friction of distance is leading to an energy landscape that is far different from fossil-based regimes. The new energy paradigm, based as it is upon the physics and the economics of renewable energy, is being reflected in the landscape as distributed, decentralized, and diversified patterns of energy generation. Because the increased use of renewable energy technologies is beginning to change the spatial patterns of political and socio-economic activities, a thorough understanding of these patterns is crucial to increasing the socio-political acceptability of new technologies and to avoiding the socially costly unintended consequences of policy and investment decisions. This paper proposes a theoretical foundation upon which economists and economic geographers could scaffold their analyses of the spatial characteristics of the economics of energy use. To this end, we bring together two complementary conceptualizations of economic geography: firstly, as the study of the effects of location and distance on energy economics, and secondly, as the study of the ways in which political, economic, and technological energy-related practices give rise to particular spatial patterns of socio-economic welfare. We end the paper by developing the concept of energy rationality and showing how it relates to discussions of metarationality, common sense, and wisdom.

Key Words: renewable energy technologies; energy rationality; location; social change; economic geography; resource economics

“As change accelerates, so does the speed at which still more [obsolete knowledge] accumulates. All of us carry with us a far bigger burden of obsolete knowledge than our ancestors did in the slower-moving societies of yesterday.” (Toffler & Toffler, 2006: 114)

1. Introduction

There are (albeit few) global truths about the economics of energy, and our discussion must begin by elucidating some of them. Most important is the economic manifestation of the laws of thermodynamics, particularly as they apply to exhaustible energy reserves: as we exploit the highest grade and most accessible reserves we proceed to a state of higher entropy – i.e., marginal energy gradients and thus less ‘useful’ energy – in which capital and energy expenditures increase and future returns on investments decrease. It is thus inevitable that we will eventually become ‘priced out’ of fossil energy (Banks, 2000). As a consequence fuel mixes invariably become more heterogeneous

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with time as alternative sources of energy become competitive. Such transitions are slow and arduous, however, as a function of the ‘lock-in’ effect whereby significant investment and thus sunken costs in energy infrastructure encourage preferential political-economic treatment for incumbent energy sources. This is currently the case with respect to fossil energy sources – a situation that observers have called ‘carbon lock-in’ (Unruh, 2000). Such ‘lock-in’ effects³ cannot be overcome by market forces alone but require deliberate and delicate public management schemes (Unruh, 2002; Weiss and Bonvillian, 2009); and indeed all major historical energy shifts were driven by some form of public investment (Podobnik, 2006). Public investment is justified not only by the fact that access to reliable energy is a prerequisite to socio-economic development, but also by the fact that immature energy technologies become more efficient and cheaper when privy to collective investment and to guaranteed market opportunities (Söderholm and Sundqvist, 2007). The final truth worth mentioning is that the distribution of energy is uneven over the surface of the Earth, and its existence does not presuppose exploitation (Manners, 1971; Chapman, 1989). It is in this latter point that questions of the economic geographies of energy find relevance. We use the term ‘geographies’ deliberately to embrace the variegated nature of economic geographical practices (see Barnes & Sheppard, 2010; cf. Simandan, 2011a).

In what follows we shed light on some energy and energy-related issues surrounding renewable energy – taken here to mean hydro, biomass, solar, wind, and some geothermal and hydrogen applications (see Cassedy, 2000) – that would benefit from the sustained application of geographical thought and analysis. We engage this topic through two lenses of economic geography. The first lens rests on a conceptualization of economic geography as the study of the effects of location and distance on energy economics. The second lens rests on a conceptualization of economic geography as the study of spatial patterns of socio-economic welfare as a function of energy exploitation. This discussion aims to provide a broad initial foundation upon which economic geographers could build on to analyze energy and energy-related futures.

“When the environment is rapidly changing, so too are the problems”.
(Watts, 2004: 273)

2. Economic geography as spatial and regional analysis

In this section, we conceptualize economic geography as the study of location and (geo)metric relationships in economic processes, and apply this framework to the (changing) geography of energy production. Three topics are addressed in the respective sub-sections that follow: the changing energy landscape as a function of greater reliance on renewable energy sources, the geography of renewable energy market opportunities, and the use of the spatial domain to answer important technical questions surrounding renewable energy utilization.

2.1. Renewable energy sources and technologies: physics, economics, and geography

³ For a recent sustained critique of the concept of “lock-in” by an economic geographer, see Martin (2010).

The physical nature of the energy source upon which a given conversion technology or an entire energy regime relies shapes the spatial pattern of its techno-economic viability. In other words, the extent to which location and distance matter in the economics of energy systems – which includes resource extraction and transport, and energy conversion and transmission – is intimately tied to the physical nature of the energy source. This is not only a matter of pecuniary economics expressed as, for example, monetary returns on investments, but also of physical economics expressed as net energy balances or energy valuations. In this sub-section we explore this relationship as it applies to the various energy sources that have been made available for societal consumption through time, and highlight some of the crucial variables that help explain existing and emerging energy landscapes.

While it is true that biomass, wind, and solar energy were being used in various ways by early civilizations, humanity's ability to harness the power of falling water arguably had the most profound impact on the course of economic and social transformation. Hydropower drove early mechanical developments, laid the foundations for the Industrial Revolution (Cook, 1976; Simandan, 2009), and was the first supplier of electricity. Prior to the development of high voltage electrical transmission, national balances of hydropower production and consumption were very near to equal (Guyol, 1971) because radial supply areas were limited. As a consequence, industrial developments radiated from these energy sources. Enhanced conductive qualities of transport mediums and knowledge of electro-physics have extended the distance at which hydropower can be used, but the fact remains that the capture and conversion of the energy source occurs on-site, and thus the techno-economic viability of energy generation is site-specific.

Fossil energy sources including uranium, coal, oil, and natural gas exhibit characteristics that are much different from hydropower. While they are also spatially fixed sources of energy, they are chemical energy *carriers* with power densities that are unmatched by any other Earthly resource. This high energetic and thus economic value has reduced the friction of distance that characterized early energy regimes. Of course, transportation networks need to be constructed and some are more confined than others (e.g., pipelines vs. oil tankers), but the fundamental point is that in a fossil-based energy regime there is little correlation between the location of energy supplies and the location of energy conversion and consumption since locating near natural energy sources (e.g., falling water) is no longer necessary to procure electricity and heat.⁴ Energy conversion facilities are able to locate based on patterns of demand rather than on supply, while at the same time operating in relatively remote sites at a 'safe' distance from urban areas. Fossil-based energy generation can also be mobile, as with steam and internal combustion engines. These favourable characteristics led to a steady decrease of the proportion of hydropower in the fuel mixes of high energy societies (Luten, 1971) that continues to this day, and have constructed an energy regime which can, unlike hydropower, 'transcend' geography.

⁴ Exceptions to this rule include low grade coal which crumbles in transit making it difficult to manage at the plant. Natural gas liquefaction technology is improving such that its geography is no longer limited to the regional scale.

As spatially-fixed stocks of potential energy that can be used on demand, hydro-dams, oil pools, coal seams, gas fields, and uranium ores are utilized and exhausted at a relatively predictable rate. Under these conditions, the efficiency and the installed capacity of an energy facility – e.g., a refinery or an electrical plant – become strong predictors of the energy and the revenue delivered from said facility, since loading conditions are for the most part optimized by a spatio-temporally stable and reliable energy source. In other words, a coal electrical plant with an installed capacity of 3000 MW will deliver approximately 95 per cent of that power at any given time (a 100 per cent loading factor would strain the plant), with the exception of annual downtime which usually approximates 10 per cent.

In contrast to fossil and large-scale hydro energy sources, the relatively low energy density of renewable energy, including micro-hydro applications, re-introduces the friction of distance in an energy regime (Elliot, 2000). For immobile renewable energy technologies (RETs) that passively convert energy flows – e.g., wind, solar, hydro, and some geothermal applications – energy must be captured on-site similar to pre-fossil fuel-based energy regimes (Cassedy, 2000). There is thus considerable spatial correlation between energy production and energy consumption. For mobile RETs which actively capture energy sources such as bio-energy applications, the relatively low density of the stored energy – which is a consequence of its partial oxidation as a carbohydrate versus oxygen-poor and carbon-rich hydrocarbons – prohibits long distance travel, and thus fuel supply-sheds are localized (Vasco and Costa, 2009). Furthermore, the viability of a bio-energy operation is easily compromised by transportation congestion (Bai et al, in press) and variations to biomass supply within a span of only a few hundred meters (Panichelli and Gnansounou, 2008).

Existing and emerging energy densification technologies can extend renewable energy fuel- and supply-sheds. This is presently the case for the bio-energy sector, which employs technologies that increase energy density per unit volume such as pelletization, gasification or pyrolysis. The addition of this pre-processing step to the energy system has enabled biomass to enter the global energy market. Other renewable energy sources as yet have no viable densification and transportation options, although wind-hydrogen or solar-hydrogen regimes, where the electricity generated by wind or solar technologies is deployed in the electrolysis process by which hydrogen is isolated and used as an energy carrier, may alter this state of affairs. In addition to this, solar refining systems used in conjunction with fibre optic cables are touted as a potential way to transmit solar radiation internationally – e.g., from Arabian deserts to European markets (Şen, 2004). It is important to note, however, that many of these systems are in the experimental stage, and in all cases their production chain begins with spatio-temporally variable and low-density energy fluxes.

The seasonal and diurnal fluctuation of renewable energy sources at any given site means that the rated capacity of a renewable energy system is a poor predictor of delivered energy, as it is rarely satisfied (Leijon et al, 2010). There are three explanations for this fact. First, technological configurations are standardized to make the manufacturing process of RETs economical while the physics of natural energy fluxes are spatio-temporally variable (ibid). Second, project designers lack the data necessary to make optimal site-selection choices or to match the physics of the design with the physics of the local energy source (Carriona et al, 2008). Third, the naive belief that we can

optimize project designs assumes that we can fully predict natural energy fluxes, and this simply is not the case. As a consequence of these factors, many RET installations have been prone to unnecessarily high capital costs and poor overall process economics ensuing from sub-optimal loading (Leijon et al, 2010; Skoglund et al, 2010).

In describing the relationship between the physics, the economics, and the geography of renewable energy, a number of themes emerge. Three are most important: 1) the physics of renewable energy sources are more spatio-temporally variable and less energy dense than fossil energy sources, 2) the fitness of a given RET is site specific, and 3) a number of different renewable energy sources exist at any given location and thus decision-makers are burdened by having to choose among a wide variety of source and conversion options. In the subsections that follow we wish to extend the logic suggested by these physical principles of renewable energy and identify how geographical thought and analysis lends itself well to the organization, management, and analysis of future energy regimes.

2.2. The geography of RET market opportunities

Given the site-specific fitness of renewable energy options and the scope of technologies that might be employed at any one location, having an understanding of spatial patterns of demand is crucial. Identifying market opportunities from a spatial perspective will help to rationalize an energy regime. As an example, the identification of urban heat and electricity ratios are crucial in determining the feasibility and the configuration of municipal combined heat and power (CHP) applications, as explored by Beaumont and Keys (1982). This section elaborates on some other key relationships between location and market opportunities, thus identifying some immediate research opportunities for economic geographers.

Isolated communities relying on low grades of energy are favourable market opportunities for RET investors and developers (Thompson and Durrigala, 2009). This is not a matter of *absolute* location, but rather of the relative lack of a) market clout by which to achieve scale economies and thereby reduce the price per unit of fossil fuel delivered and b) existing infrastructure with which to deliver said energy. In addition to this, isolated communities are most likely to rely on inefficient diesel generators or on heavy oil for home heating. As climate change policy begins to impact energy policy such that incentive structures encourage the consumption of cleaner energy, these consumers will be low-hanging fruit for RET investors.

That being said, supply-side renewable energy policies including quota systems, certificate trading, and feed-in-tariff programs are beginning to expand and modify the geography of market opportunities (for a more detailed discussion of these mechanisms see Palmer and Burtraw, 2005). Through obligatory mandates or by paying a premium for renewable energy delivered, such policies level the economic playing field and thus enable RETs to compete in otherwise inaccessible markets. In fact, such policies have a tendency to swing the pendulum too far. Ontario, Canada boasts North America's first feed-in-tariff program, and a generous subsidy for solar photovoltaic farms has encouraged sub-optimal location decisions (Nguyen and Pearce, 2010). This suggests that renewable energy policies need to consider geography more seriously to reduce the short-run marginal costs of carbon mitigation and fossil fuel avoidance.

Another potential mechanism by which to expand the market opportunities of RETs is to base electricity pricing systems on locational marginal prices (LMPs), or at least to consider these prices before making a determination about the location of resource investments. Brown and Richards (2009) demonstrate that solar photovoltaic technologies become economically competitive at locations where heavy burdens or bottlenecks in the system are present and thus localized electricity rates are high. This is especially the case when long distance transmission and thus sunk capital can be avoided by distributed technologies. The same effect has been demonstrated by Lewis (2008) in relation to wind energy utilization. Economic geographers should work to uncover the spatial patterns of these high value investments, especially since aggregate pricing systems obscure these market opportunities by subduing these price signals.

2.3. Taking geography seriously in renewable energy analysis

The fitness of RETs is localized and in many cases site-specific. Indeed, small scale geographical nuances are consequential to RET techno-economic viability. Spatio-analytical technologies, generally referred to as geomatics, are adept at synthesizing the data necessary to flesh out these nuances, and indeed attempts are being made to link spatially explicit resource inventories with systems analyses tools by which to capture the effects of geography on renewable energy process economics (Dominguez and Amador, 2007). One publicly available tool in this regard is RETScreen 4.0, a software package designed by a consortium of agencies including NASA and Natural Resources Canada. This software has been downloaded more than 265 000 times, and has been used to derive results that are published in peer-reviewed literature (e.g., Thompson and Duggirala, 2009; see also Connolly et al, in press).

It is important to note that RETScreen 4.0 is a *pre-feasibility* modeling tool, and thus its intent is not to be entirely accurate but to provide quick and easy ‘go’ or ‘no-go’ decisions that dictate if, when, and where further research is warranted. RETScreen communicates results as net present values, returns on investment, and internal rates of return. It is thus sensitive to the scope of different investment criteria. Perhaps most importantly, it provides these indicators for both a proposed and a ‘base case’ scenario. Figure 1 displays the user-interface of the geo-referenced resource data from which these criteria are derived, and includes variables related to renewable energy stocks and flows at a given location. These data represent the physical basis of RETScreen: the model requires inputs in terms of capital costs, operation and maintenance costs, debt / equity ratios, and other key financial variables. It also has a bank of existing technology performance data from which efficiency and net energy delivery are estimated depending on the chosen technology. Given the emergence of this software program and others of the sort it is important to critically analyze underlying assumptions and data structures and discuss ways in which it might be improved.

The premise of RETScreen is promising: it recognizes that the first vital step in feasibility analyses is the geographical potential of energy availability. There are, however, three key shortcomings with this software package. First, it does not model a ‘degradation factor’ – i.e., the rate at which the performance of a technology in terms of energy efficiency begins to deteriorate. Second, it lacks a comprehensive bio-energy module. Comparative analysis of all possible options is crucial in energy planning,

especially at the pre-feasibility stage. Without a resource or a technology database to draw on for bio-energy, public and private investment decisions can be biased by a limited solution space. Finally, in cases where the data source is ‘NASA’, the value represents aggregation over a 1 degree x 1 degree area of Earth which approximates an area of 110 km². From a geographical perspective, this is perhaps the most important limitation.

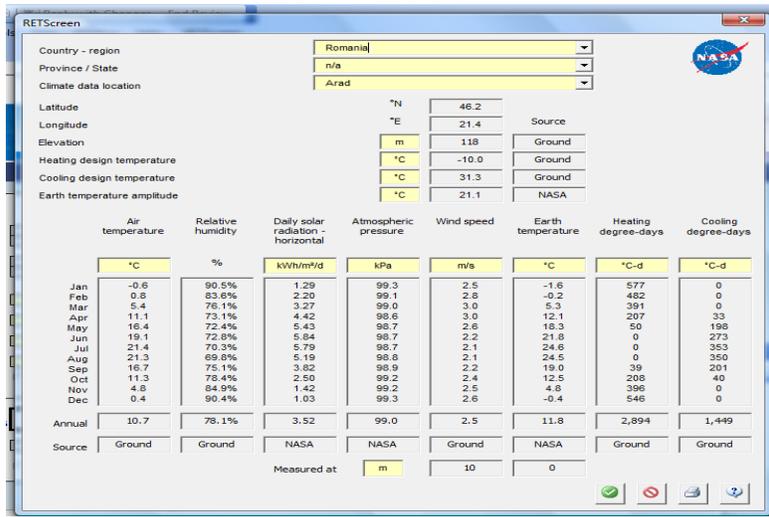


Figure 1: A screenshot of RETScreen 4.0 resource data

Given the localized nature of RET viability a key consideration to RET techno-economic analyses is the spatio-temporal resolution at which resource information has been assessed (Van Hoesen and Letendre, 2010). Indeed, scale-aware logic must be embedded in renewable energy analyses. This will privilege distributions instead of averages⁵ while at the same time reflecting the scale at which renewable energy systems operate. Solar energy systems simply do not operate at a scale of 110km², and in fact spatial units of 1km² are suggested as optimal for solar photovoltaic farms (Nguyen and Pearce, 2010). Rooftop-mounted solar energy systems and combined heat and power systems both require resource analyses at the community level (see Wikington et al, 2010 and Beaumont and Keys, 1982, respectively). The scale at which RETs are best assessed requires further attention, and in this context multi-level analyses are welcomed (see Ayoub et al, 2007). The subject of scale will be re-visited in section 3.1.

The spatial domain offers a useful framework within which to synthesize data necessary to distinguish actual from potential energy sources prior to deriving any financial information. RETScreen assumes that a site has been chosen, and that this site is economical in terms of transmission hook-up, transportation infrastructure, land-use and land-values, and other key spatial variables. Using overlay analysis in a GIS, datasets associated with these variables can help to distinguish actual from theoretical energy availability. This will help to reduce the assumptions of RETScreen, and models of the sort, and thereby communicate more meaningful results. These spatially-explicit

⁵ For an excellent discussion of the disastrous implications for risk management of excessive preoccupation with averages at the expense of distributions, see Savage, 2009.

results are crucial because obtaining the finances necessary to move forward with a RET project is dependent on available information, the paucity of which hinders RET investments.

Securing finances, however, is not only a matter of reducing uncertainty through robust baseline geographical information. Preliminary discussions with a select group of energy consultants by one of the authors suggests that trust is more important than the way in which information is derived when soliciting finances for project development. As such, and although the objective of RETScreen is to develop a cheap way to provide the information by which finances can be secured and projects mobilized, it is necessary but not by itself sufficient. More important is social capital and risk management, and in this regard having municipalities involved in renewable energy procurement may help considerably. The capacity of municipalities to provide such leverage should be explored (see as a starting point Woodward et al, 1994), and as suggested above, spatially explicit analyses should be conducted with these audiences in mind. This latter point is explored further in the following section.

“The starting point...is to determine what changes slowly or not at all...once we construct this framework, we want to incorporate the elements that seem easier to control or predict. It is usually easier to predict technological change than social change”. (Holland, 2002: 172-173)

3. Economic geography as the study of the nature-society relationship

Forms of socio-spatial organization are at least in part a consequence of the manner in which a society exploits available natural energy. Indeed, the use of different forms of energy changes physical and socio-economic landscapes in profound ways (Foley, 1976; Solomon and Pasqualette, 2004), in part because different forms of energy require specific forms of socio-physical organization for optimum performance (Chapman, 1961; Beaumont and Keys, 1982; Zvoleff et al, 2009). It stands to reason, then, that as we begin to deploy RETs we will witness, with some delays, changes in how our society is organized and managed. This section speculates on the shape that society will (should?) take as we begin to rely more heavily on the rhythms of renewable energy.

In order to avoid grossly inaccurate predictions of technological and regulatory changes in energy systems, we emphasize from the very beginning that it is important to pay close attention to delays. The energy infrastructure is best conceived of as a collection of material stocks and flows with a degree of inertia that is higher than that of most other economic sectors. The stocks of the energy sector – ranging from the stocks of fossil fuels to the stocks of built plant capacity and the stocks of electricity grids – are particularly worthy of note for our purposes because all delays presuppose stocks. If we define delays as processes whose output lags behind their input (Sterman, 2000), it becomes apparent that the only way in which they could happen is by having a stock in-between the input and the output of the system. This intercalated stock effectively decouples its output from its input and thus generates disequilibrium dynamics with massive economic and geographical implications (as the slow reactions of the energy sector to energy crises have shown). Stocks are a concept from system dynamics that is

equivalent to what Simandan (2001, 2006) calls ‘legacies’ (which are one of the three ontological categories in his logic of recursive cartographies, the other two being rhythms and events). Stocks are the explanation for the inertia of the energy systems because the weight of the past is embodied in stocks. The current stocks of the energy sector constitute the memory of past deeds (inflows, outflows) in that sector. The energy sector we have today is the accumulation of decades of past practices and beliefs, fact which begins to explain why change will not happen overnight and why the enthusiastic predictions of the 1970s about the dominance of renewables by the year 2000 turned out so wrong.

3.1. Renewable energy and socio-spatial change

Recent paradigm shifts in energy planning from large-scale, centralized and relatively homogenous to a decentralized and diversified energy regime (see Helm, 2005; Sebitosi and Okuo, 2010) are underpinned by the physical characteristics of renewable energy and by technological achievements. Advancements in technologies related to harnessing two thermodynamic cycles (e.g., combined cycle turbines) or two energy vectors (e.g., combined heat and power) have diluted the notion that ‘bigger’ energy facilities are inherently more economical (Sebitosi and Okuo, 2010; Li, 2005). As such, smaller and distributed forms of energy generation are more prevalent. Furthermore, the physics and the economics of renewable energy necessitate greater spatial correlation between energy availability, energy conversion, and energy consumption (see Elliot, 2000). This makes it possible – and in some cases necessary – to establish short energy procurement, production, distribution and consumption chains (Pepermans et al. 2005). This suggests the increasing relevance of the ‘local’ scale, and thus of local actors (see also Fraser et al, 2004; Bagliani, 2010).

It is important to qualify the term ‘increasing’. Surely, given the decentralized nature of renewable energy, energy production will be visible to a greater proportion of the population. It stands to reason that a greater number of protests or public consultation will characterize future energy decisions. But this does not mean that local actors are acquiring more power *relative* to outside interests⁶. In fact, market evidence supports the opposite claim. Renewable energy ‘subsidy farming’, which might be conceptualized as a neo-colonial enterprise, is a common phenomenon. This is a situation in which multi-national corporations, increasingly of the foreign brand and not always traditional energy companies, are installing a significant proportion of renewable energy systems in jurisdictions that subsidize renewable energy. Opposition to deals struck between Samsung and the Government of Ontario for wind energy development exemplifies this phenomena. Indeed, local ownership is not a fundamental element to the nature of a decentralized energy regime (Pepermans et al, 2005). Further, there are considerable signs that RETs will simply be mass-produced in cheap labour countries, and we should

⁶ The transition from conventional to renewable energy must also be seen in the broader political context of the neoliberal regulatory frameworks that often dominate national energy systems. Neoliberalism is a regulatory regime that prides itself for emphasizing devolution. The extent to which neoliberal devolution actually empowers local constituencies is questionable, as Simandan’s (2002) discussion of Norway shows. That being said, and in contrast to typical neo-liberal reform, the devolution of energy-related decision making authority and energy market restructuring is in most countries accompanied by greater, and not less, government intervention and regulation (Hammons et al, 2000).

be careful to assume that this economic rhythm will be disturbed simply as a function of renewable energy research, subsidization and deployment in developed countries.

That being said, the idea that the local scale and local actors will be privileged as renewable energy is deployed has some merit when referring to political organization. At the municipal level in Canada, 'community energy plans' are becoming more common (St. Denis and Parker, 2009), and this socio-spatial strategy is being endorsed by the federal government (NRCan, 2007). Furthermore, a localized, bottom-up regulatory approach to renewable energy is accredited with the relative success of RET deployment and utilization in Germany (Doern and Eberlein, 2009). The seemingly contradictory effects of devolution discussed here are, to be sure, a matter of initial conditions and is itself a geographical issue, but researchers must begin from the premise that there is 'nothing inherent about scale' (Brown and Purcell, 2005) when addressing the political economy of renewable energy.

In addition to these political-economic (re)configurations, research has pointed to socio-economic changes as a consequence of RET deployment. This is mostly a function of direct and indirect employment creation. Investigations have shown that a significant share of the expenditures associated with bio-energy systems stays in the local economy, creating local jobs and increasing local income (Kammen et al, 2004; Thomassin and Baker, 2000). This is especially important for single-industry forestry towns that suffer from an ailing forestry industry: bio-energy applications can provide market opportunities for woody biomass of all qualities, thus opening otherwise inaccessible or uneconomical market opportunities. These economic benefits, however, are not exclusive to a more resource-oriented or labour intensive energy system such as bio-energy systems. Wind-farms, which might be misconstrued as 'dead labour' given that man-power is not needed to collect and transport energy feedstock, have also been shown to generate considerable job growth in the local area (Valentine, 2010). In a recent study out of the US, Wei et al (2010) discovered that solar photovoltaic technologies actually create the most jobs per electricity output. These effects are magnified in jurisdictions in which RET markets are created through government incentives, but it is important to note that government incentives might also be subsidizing foreign economies if a domestic manufacturing industry is non-existent (Branker and Pearce, 2010). Indeed, the tight coupling between energy investments and economic growth manifests itself not only in major energy producing regions (e.g., Dubai), but also at the very local scale. It is important that we understand the processes through which this coupling occurs, and ways to capture the full range of benefits that might accrue locally. This will help to place higher energy prices, taxes, and the visibility of energy generation within a favourable context, thus increasing the social acceptability of RETs.

These changes are contingent, not inevitable (Simandan, 2010). Indeed, the unqualified endorsement of some variant of energy determinism in terms of socio-spatial organization and patterns of welfare would be a mistake. Instead, the fruitful research vein we wish to highlight has to do with the geographical articulation of energy regimes with ways of living. More specifically, we want to ask what constitutes an energy efficient form of socio-spatial organization. This question is fundamental to economic geography because: (a) energy is an important variable for socio-spatial organization, (b) the economic manifestation of the second law of thermodynamics and the environmental effects of our dependence on fossil fuels have jointly led to our growing reliance on

renewable energy, and (c) renewable energy is localized and site-specific. Preliminary answers suggest a polynucleated urban form and / or are predicated on the principles of smart growth and urban densification (Beaumont and Keys, 1982; Behan et al, 2008). This suggests that, as we begin to deploy RETs and focus on their efficiency, the “energy problem can be conceptualized, in one sense, as related to the spatial organization of the urban environment” (Beaumont and Keys, 1982: 177; see also Cuddihy et al, 2005). Perhaps, then, urban (or, more generally, local) scales should take on greater emphasis as a unit for analysis in these economic geographies of renewable energy (see also Zvoleff et al, 2009). In addition to following the logic discussed above, this scalar orientation would also help to highlight other localized political-economic energy-related issues such as the causes and consequences of the hidden geographies of energy poverty (Buzar, 2007), or of the local agglomeration of innovative ideas, institutions, and technologies from which a renewable energy market might flourish.

3.2. Toward energy rationality

‘Hydro-carbon man’ (Shaffer, 2009) – a people whose basic provisions (e.g., comfortable living space, light, nutrition, mobility) and higher-level desires (e.g., entertainment) are fulfilled almost exclusively by hydro-carbon based energy resources – is becoming an increasingly accurate generalization. National energy policies remain chiefly concerned with maintaining a steady supply of fossil fuels by encouraging domestic production and / or developing international trade relations (Simon, 2005). While familiar to developed countries, this policy concern is increasingly relevant for the developing nations as well.

The discussions of resource, and thus energy, management typically juxtapose two variants of rationality: economic rationality and ecological rationality. The former signifies the pursuit of the maximization of fitness. Depending on the scale of reference, this may come to mean personal or collective (e.g., national) fitness. This pursuit is made in the light of alternative choices, alternative states of affairs, and the expected decisions of others. Ecological rationality, on the other hand, signifies the pursuit of human-environment interactions that do not extend beyond the limits of Earth’s ecological systems. This is rooted in notions of sustainability, and is less of an anthropocentric decision-making model.

As suggested above, energy is at the core of the society-nature relationship. The combustion of fossil fuels is the chief causal factor behind climate change and unprecedented rates of land-use and land-cover change (see Slaymaker, 2001). As such, we contend that *energy rationality* can help to resolve some of the conflicts between these two decision-making models discussed above. Examples of how energy rationality might be encouraged and practiced are beginning to take shape. Ontario, Canada has recently introduced time-of-use electricity pricing. At peak hours electricity prices are increased (see Figure 2). This structures the decision-making environment in which individuals operate such that the operation of inefficient and fossil-based ‘peak plants’ which must be run to satisfy peak demands might be avoided. Carbon taxes have been introduced for the same purpose in some jurisdictions including Sweden and Finland, making renewable energy economical and offering market opportunities to alternative forms of energy (Ericsson et al, 2004). Key to an effective energy-rational policy

environment, however, is to avoid regressive tendencies whereby the poor are disadvantaged even further given that energy consumes a greater overall proportion of their income. Two research avenues here are a) to examine the spatial patterns of renewable energy utilization using energy-rational incentive structures as the independent variable, and b) to analyze the socio-economic effects of these policies.

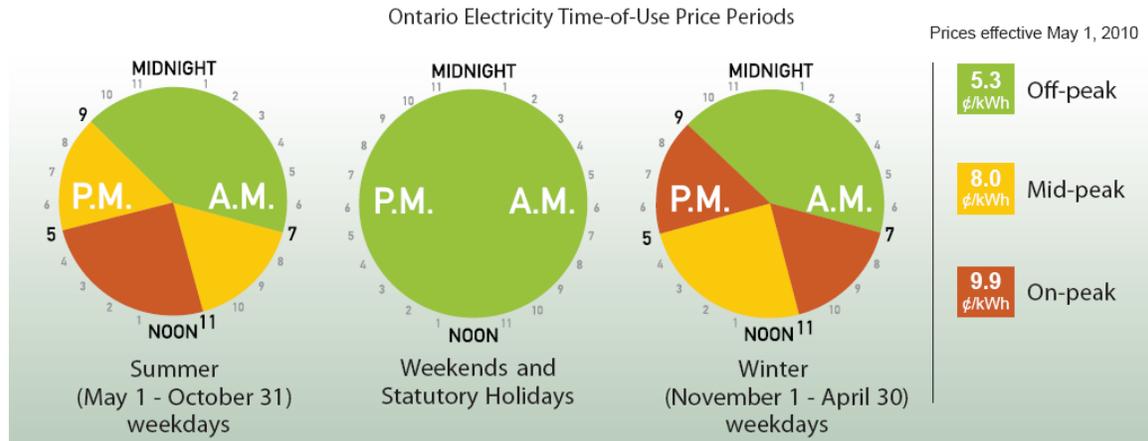


Figure 2: The logistics of Ontario's time-of-use pricing policy. Source: Ontario Energy Board

These said, we would like to move to a higher level of abstraction and develop more fully our concept of energy rationality by taking into account not so much the distinction between economic rationality and ecological rationality, as the more relevant distinctions between instrumental rationality and epistemic rationality, and between thin rationality and broad rationality. We begin by pointing out that an economic geography of renewable energy must make recourse in its explanatory endeavors to all the three important mechanisms of social change: constraints, choice, and selection. In geography, maybe because of too much reliance on social constructionist ideas, we tend to emphasize the role of constraints and to downplay the role of choice. We think this situation should be remedied, because as Elster notes (Elster, 2007: 298):

“Constraints operate before the fact, to make certain choices unfeasible. Selection operates after the fact, to eliminate those who have made certain choices. Although both mechanisms contribute to the explanation of behaviour, they cannot jointly or singly, account for all of it. Choice remains the core concept in the social sciences”.

Choices can be more or less rational. Therefore, to introduce a concept of energy rationality is to implicitly reassert the significance of the mechanism of choice in the explanation of the space-economy of renewable energy. As we have already suggested, many of the facts that govern this particular space-economy are counterintuitive (Sterman, 2000), and, therefore, relying on common sense when making investment decisions in this area means, in the long run, taking a road to perdition. It is difficult to improve on Gallie's beautiful description of the pitfalls of common sense (Gallie, 1978: 106-107):

“Common sense is characterized by a sane but lazy disregard of difficult, even if very important, questions which it leaves to those whom it considers tiresomely clever and rather silly people, until the day comes when men [sic] must either face their difficult questions or perish. The sane but lazy position may often carry with it real temporary advantage”.

The history of the energy sector bears testimony to the fact that all too often the concerned economic agents have taken “the sane but lazy position” of common sense, in blissful ignorance of the counterintuitive logic of dynamic complexity that governs the behaviour of real-world systems. Instead of relying on common sense, we need a wiser stance (Simandan, 2011b), that gives a fuller acknowledgment to the extent of our ignorance. As Nickerson observes (Nickerson, 2008: 330):

“What is most important for rationality is an awareness of the limits of one’s understanding – an accurate appreciation of what one understands well, what one understands less than well, and what one does not understand at all.”

But to fully grasp the meanings we want to associate with our concept of energy rationality, we need to situate it in the state-of-the-art rationality debates, so as to bring out its intimate bond with metarationality and with a broader definition of rationality itself. Keith Stanovich’s words (Stanovich, 2010: 5) help drive home our point:

“To think rationally means taking the appropriate action given one’s goals and beliefs, and holding beliefs that are commensurate with available evidence – but it also means adopting appropriate goals in the first place. Instrumental rationality covers the first of these (taking the appropriate action given one’s goals) and epistemic rationality covers the second (holding beliefs that are commensurate with available evidence), but the third factor (adopting appropriate goals in the first place) introduces a new issue. The issue is the distinction between a thin and broad conception of rationality.”

He goes on clarifying the meaning of metarationality and does so by means of examples from game theory that have a clear relevance for the economic and environmental tangles that complexify the current landscape of renewable energy policies (Stanovich, 2010: 159-160):

“The best tools of thought are self-correcting because they critique themselves. Metarationality consists of bringing rational tools to bear in a critique of rationality itself...[One] area where rationality critiques itself is in the Prisoner’s Dilemma or commons-dilemma situations. In these cases a response that is narrowly rational, in that it displays dominance over other alternatives, turns out to be dysfunctional for everyone if all the people involved in a collective action respond in a way that is narrowly rational for themselves. Many dilemmas of modern life have this structure – individuals, pursuing their narrowly rational interests ruin the environment for themselves when others also act on only the thinnest rational theory. What the Prisoner’s Dilemma and other commons-

dilemmas show is that rationality must police itself – that there are situations where people might want to bind themselves to an agreement not to pursue their own interests, so that we all might obtain a better outcome.”

To sum up, by energy rationality we mean not only having correct beliefs about the energy domain (epistemic rationality) and choosing the best means for achieving one’s goals in the energy domain (instrumental rationality), but also having the wisdom (Simandan, 2011b) to choose the right goals in this domain. To be wise enough to do so requires overcoming the five attributes of foolishness (omniscience, omnipotence, invulnerability, selfishness, and insouciance; cf. Sternberg, 2005), acknowledging one’s ignorance, balancing short-term concerns with long-term interests, and remembering that it is not greed alone that makes us human.

“The future will be as grand, and as particular, as we are. We cannot build a single bridge from here to there, for neither here nor there is a single point. And there is no abyss to cross”. (Postrel, 1999: 218)

4. Conclusion

While geography has always mattered for the energy sector (see Wilbanks, 1982), the relative effects of location and distance on the economics of energy regimes are increasing as we begin to deploy more RETs. This re-introduction of the friction of distance is leading to an energy landscape that is far different from fossil-based regimes, and which will only be overcome if advanced hydrogen-based regimes or solar fibre optics come to fruition. This is to say that the new energy paradigm, based as it is upon the physics and the economics of renewable energy, is being reflected in the landscape as distributed, decentralized, and diversified patterns of energy generation. But this transition will be slow so long as incumbent fossil energy sources remain privileged by political-economic power holders. Since economic geographers already study economy-environment interactions, we are well positioned to provide valuable conceptual and analytical tools with which to help structure a renewable energy revolution. Given the site-specificity of renewable energy fluxes and the localized nature of renewable energy, these tools are most effectively directed at local and regional scales.

The increased deployment of RETs is beginning to change patterns of political and socio-economic activities. Understanding these patterns is crucial to increasing the socio-political acceptability of new technologies and to avoiding the socially costly unintended consequences of policy and investment decisions. Indeed, we need to be sure that analyses are not privileging production at the expense of consumption (or vice versa). To this end, geographers should strive to unpack geographical patterns of energy related socio-spatial change and to examine the causes and consequences of alternative energy policies.

Surely there remain regulatory and technical concerns that are just as, if not more, important than the geographical and the spatial-analytical issues that we have highlighted in this paper. The point, however, was to demonstrate that all of these other variables being equal, geography is a hugely important limiting factor when it comes to renewable

energy utilization. These spatial characteristics of the economics of energy use have yet to be fully explored. We hope that our contribution has provided a theoretical starting point from which these issues might be addressed.

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