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Author

Froestad, Jan, Shearing, Clifford

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Energy and the Anthropocene: security challenges and solutions

Jan Froestad[*] & Clifford Shearing[**]

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Abstract

This paper explores the role that energy regimes, and the search for energy security, has had in shaping humans and their societies, and the effects thereof. Energy enrolments through the domestication of plants and animals and the extraction and burning of increasingly energy-rich fuels enabled humans to build ever more productive and formidable societies, but also more complex and divided ones. Social stratification, combined with the new risks caused by the more intense interactions and entanglements that emerged between humans and nature, has culminated in the global environmental crises that humans are now facing. We conclude by arguing that an escape route from the destructive consequences that fossil fuel energy regimes have had for humans and their ecological security is provided by the emergence of electrical civilizations and the potential this provides for integrating energy and ecological securities.

Keywords

Energy, Security, Anthropocene

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[*] Associate Professor of Administration and Organizational Theory at the University of Bergen, Norway. Jan.Froestad@uib.no.

[**] Clifford Shearing holds professorships at the Universities of Cape Town, Griffith and Montreal and positions at the Universities of New South Wales and the Durban University of Technology. Clifford.shearing1@gmail.com. Both authors acknowledge funding support from the South Africa-Norway Research Cooperation (SANCOOP) Fund, the National Research Foundation of South Africa. Any opinion, findings and conclusions or recommendations expressed herein are ours alone and the agencies do not accept any liability in regard thereto.

Introduction

As outlined in the editors' introductory remarks, we are at the beginning of a new geological era, a new Earth, the Anthropocene. Humans through their collective actions have become geological agents who have disturbed, and are disturbing, the Earth systems that characterized our previous geological epoch, the Holocene -- a brief, and remarkably stable period in the Earth's geological history, of some 12, 000 years, which followed the last Ice Age. These developments have had damaging consequences for the ecological systems that flourished during this temperate and climatically stable period. These ecological services (Costanza et al., 1997) that flourished during the Holocene not only enabled the flourishing of humans as a species, along with many other species, they also have provided the bedrock upon which we humans have built our societies and civilizations – what sociologists think of as "social worlds" (for a recent review, see Harrington & Shearing, 2017; see also Zedner, 2009). In this paper we explore the crucial role that energy production - that has been so important in enabling the development of human civilization and particularly today's industrial societies - has played in reshaping Earth systems in ways that have undermined the ecological services upon which humans, along with many other biophysical beings, have depended for their survival as Earthlings.

For humans, the pursuit of well-being, and indeed the realization of human well-being, have been inextricably linked to forms of energy that have enabled us to move beyond the energy outputs of our biophysical bodies. These energy enrolments have changed significantly over time and across space. With each significant shift in enrolments there has been a shift in human ways of being, and in the social worlds that these ways of being have enabled.

A central feature of energy enrolments, through most of human existence, has been the release of stored energy through burning. This release -- for example the energy of organic materials (recently stored sunlight) by fire -- has been enormously consequential for human lives and for the planet (Clark & Yusoff, 2014). We humans have built our societies on successive fire regimes. Our societies have been built on fire. Understanding this linkage between fire and human societies provides a key to understanding a deep history that underlies the

Anthropocene and, at the same time, provides guidance to how humans might cope with the unintended consequences of our pyrogenic proclivities.

The discovery and use of fossil fuels – stored "ancient sunlight" (Hartmann, 1999) – to drive machinery gave birth both to the industrial revolution and to the associated belief that fossil fuels provided humans with unlimited access to vast, and endless, reserves of stored energy that could be enrolled to fuel ever-expanding energy demands. This belief was briefly tempered by the oil crisis of the 1970s. Escalating oil prices sent shockwaves across the world, elevating the issue of energy security into a new geo-political concern.

With growing concerns for global warming and a looming global environmental crisis, this framing has been increasingly contested. This contest—between our reliance on fossil fuels and the need to live within our planetary boundaries --has become a defining conundrum of our time, a conundrum of competing securities. The conundrum can be expressed as a question: how to make the necessary transition away from fossil fuels a win-win scenario? This question has emerged as perhaps *the* 21st century concern – namely, how to meet escalating energy demands, particularly the demand for electrical energy required by our increasingly electrical civilizations, while at the same time establishing these civilizations, to borrow a term from China, as "ecological civilizations". This will require a recognition of ourselves as entwined Earthlings whose entanglements with Earth systems have defined who we are and will defined who we will be. In this paper we explore the deep entanglements of humans and their energy sources -- changing energy regimes requires changing cultures and associated institutions. In what follows we begin with a brief review of how we humans have used fire to enable our wellbeing. We explore how our energy regimes have been cumulative and how this tendency is shaping how we humans are responding to our emerging realization that what we have done to produce energy has been steadily undermining our ecological security. We then consider how electricity provides a pathway that has the potential to enable a win-win solution.

Energy regimes

Sieferle (2001) has sought to identify modes of human social organization, not simply from socio-economic perspectives, as Marx (1909) and other political economists have done for example, but rather though a socio-ecological lens. Energy and how it has been produced and used, and its implications for social relations, are at the center of the regimes he identifies. His analysis is of sources of energy and the conversion technologies used to relate this energy to human needs. Sieferle distinguished between hunter-gather societies characterized by "passive solar energy utilization", agrarian societies distinguished by "active solar energy utilization", and industrial societies based on burning fossil fuels that fundamentally transformed access to energy (see also Fischer-Kowalski, Krausmann & Pallua, 2014). We follow Sieferle's scheme to briefly consider the human-to-nature and human-to-human relations that became embedded in these different modes of energy use; each mode can be considered a fire regime.

Hunter-gatherers – the first human fire regime

Hunter-gatherers were among the first humans to learn to turn the destructive force of fire to productive uses. Fire gave protection, allowed land to be opened for travelling and hunting, extended the range of food humans could eat, increased adaptation to different environments, and facilitated territorial expansion out of Africa to all the remaining continents on Earth. With cooking humans could, through the dynamics of evolution, "exchange" big guts for big brains. Hunter-gatherers, with the control of fire, became much more formidable and productive societies and rapidly moved to the top of the food chain (Harari, 2014).

Humans' control of fire was by necessity a social project. Domesticating fire required collecting wood, keeping it dry and adding to the fire at appropriate intervals. Learning to control and nurture fire was the first civilizing process of human history (Goudsblom, 1992a, 1992b); it required discipline, order and self-constraint. Cooking, which implied a delay in food consumption, had a socializing effect through gatherings around campfires and stimulated the development of human language. Burning became a technology at the heart of hunter-gatherer's societies, with groups of humans defining themselves through the sharing of fire. Fire became the focus of group life, enhancing communication and solidarity (Harari, 2014). But domestication of fire also prompted new divisions to appear between humans and between humans and nonhumans. Humans started to segregate themselves from nature. This is illustrated by the first rock paintings appearing some 20- to 30,000 years ago. Rock paintings signified a species able to look at nature and other species from a distance, from an external view point, though typically they did not picture humans as dominating nature or other animals (Bird-David, 2006).

Fire also increased complexity within human society, with gender-based division of labor becoming more significant. With the fire regime, dyads of men and women became productive and reproductive units within the larger social group. All hunter-gatherer societies required women to cook for men, unrelated to how much the sexes, through their designated tasks, contributed to the capture of proteins for the family unit. A first critical step on a long journey towards more complex and divided human societies was taken (Harari, 2014).

Farmers - the agricultural fire regime

The Neolithic revolution, initiated some 10,000 years ago at the beginning of the Holocene, can be seen as a first step in a progressive movement towards human enlightenment, comfort and affluence. Agriculture altered the natural vegetation from perennial-dominated to annual-dominated landscapes. Humans typically settled in fire-prone places as this gave advantages for hunting, foraging, civilization and livestock herding (Pausas & Keeley, 2009). The emergence of agriculture illustrates the geological co-evolution of humans and nature; the Neolithic occurred simultaneously with and depended upon Holocene warming. It also illustrates how a focus on energy and combustion leads to a view of human collective life in terms of its deep imbrication with geological processes (Clarke & Yusoff, 2014).

With the Neolithic revolution, humans initiated a technological development that allowed us to rummage even deeper into the forces of nature. Agriculture had geological significance in the way it radically reorganized the conditions for terrestrial combustion. New pyro-technological advances were made, as with the burning of plants to enrich and energize soils. Humans learned that periodic torching of accumulated phytomass reduced the likelihood of more intense and damaging wildfires. Combustion likewise played a critical role in the development of new tools. We first learned to use fire to harden wood, crack rocks and bake clay. The pivotal stage in combusting other materials was to raise and control the intensity of heat, leading to advances in pottery and the melting of copper and other metallic ores (Clarke & Yusoff, 2014). With new agricultural technologies using more advanced iron tools, the productivity of per unit of land used by humans increased dramatically, leading to higher fertility rates and a considerable growth in human numbers. In this regard the Neolithic revolution was indeed a huge step forward for *sapiens* in dominating the Earth through a new fire regime.

But as with the fire regime of hunter-gatherers, the agricultural regime that emerged created new divisions between humans, and between humans and nonhumans. As humans domesticated selective plants and animals they were also forced to cultivate and protect their domesticates. Humans were trapped into caring and had to be constantly involved in the lives of non-humans, since things, as well as domesticated animals, were not equipped with or rapidly lost the ability to maintain or reproduce themselves. Compared to hunter-gatherers, the non-human stuff in the lives of farmers increased dramatically. More work became required to keep things going; much longer hours of increasingly specialized and standardized work (Harari, 2014).

Domestication of animals in the context of rising temperatures also exposed humans to new risks, as "micro-predators" in the form of bacteria and viruses emerged and sometimes preferred to jump from their animal habitat on to the human. Settled and populous human societies became plagued with recurring pests and had few preventive measures to rely upon (Diamond, 1997).

During the Neolithic period, differences between and within agricultural societies increased. Societies became increasingly complex and stratified. Powerful centralized agricultural societies emerged, swallowing or marginalizing communities of hunter-gatherers. The first centralized agrarian regimes were often priest-led, but tended later to be conquered by agrarian societies led by warrior classes, monopolizing the use of violence. The rein of professionalized warriors was often built on a symbiotic relationship with peasants who provided free work in exchange for protection (Goudsblom, 1992b). Conquest of new territory, more than economic and technological advancements, became the major means for agrarian elites to enrich themselves. Centralized agrarian states and empires increased their capacity for destruction and rendered humans in the Neolithic much more vulnerable to catastrophes caused by inter-human violence.

New risks caused by the more intense interactions and entanglements that emerged between humans and nature, prompted by the rise of agriculture, combined with the new risks arising from more divided and stratified human societies. New divisions within human society tended to shield the elites from the consequences of their actions and reduced the collective capacity to respond to environmental or climatic changes (Diamond, 2005). The average heights of men and women seem to have been reduced by 15 to 20 cm with the transition from hunter-gathering to agricultural societies (Sieferle, 2001), which is a clear indication of a reduction in affluence and welfare.

Humans as industrialists – the capitalist fossil-fuel fire regime

Historians continue to dispute the cause or causes of the Industrial Revolution, emphasizing different blends of incentive, culture, ideology and value-change, or more material and demographic forces (Clarke, 2012). Wrigley (2010) may be right, however, that the more interesting question may not be why the Industrial Revolution happened in England, but why it did not fizzle out. His own answer is that without a supply of abundant and cheap coal the economic revolution would not have been possible. A secure and affordable supply of fossil fuels, predominantly coal, up to the Second World War and coal in combination with oil thereafter, drove the transition from organic to energy-rich societies. Contrary to the thoughts of the classical economists, it became possible to escape the Malthusian constraint of the agricultural fire-regime and embark on a trajectory of cyclic, but long-lasting, economic growth, lifting whole populations out of poverty (Wrigley, 2010). It was the transition of the energetic system from biomass to fossil fuel-based that removed the constraints (Weisz, 2011).

With the Industrial Revolution humans came to perceive of energy in new ways. Previously "energy" was something multiple and incommensurable tied to different concrete practices or survival purposes; biomass was burned to produce heat for cooking, washing or keeping bodies warm; crops were diversified to capture the sunlight that made them grow; animal muscle was used to plough the Earth, for transport and a range of other practices. Such practices were typically localized, with the energy generated being used close to where it was produced. The use of fossil fuels, and the mechanical devices they empowered, allowed energy to be dis-embedded from particular socio-ecological activities. Heat and mechanical energy could now be expressed and calculated on the basis of a singular and abstracted energy concept and the density and efficiency of different energy fuels could be compared along a single scale (Hildyard, Lohmann & Sexton, 2012). Coal-powered railways and oil-powered vehicles mobilized the circulation of people, objects, energy and information, restructuring physical and social worlds.

At the center of these developments was the turn to electricity, which, although a component of the universe from the outset, was until recently a little understood form of energy that had contributed little to energy enrolments. This all changed in the late 1800 with the discoveries of Edison and Tesla. The development of electricity generated by spinning coils reshaped human lives. Human societies became electrical civilizations. Indeed, with the computer and the internet, we have become electrical cyber-space beings.

A variety of forms of energy were used to generate electricity. One of the most significant of these was through the gravity-enabled energy of falling water – a well-establish technology (as with the water wheel) used to drive turbines to produce electricity. This was a hugely effective technology, enabling some nations, like Norway, with the right condition (related to the cycles that shift water vertically, from *terra firma* to clouds and then back to the land) to produce electricity via turbines abundantly and cheaply. There were ecological effects but relatively few. The situation has been, and is, quite different for most of the world where these water-cycle conditions have not been as favorable. In most parts of the world electricity production, on scales necessary to sustain our electrical civilizations, depended on the burning of fossil fuels. Even with electricity, with a few notable exceptions, fossil fuels became *the* defining pathway of our contemporary industrial civilization. In Harari's term, the use of fossil fuels became a defining human "project" (Harari, 2014).

On average, the metabolic rate -- the material and energy input used by human societies -- as we transitioned from one fire-regime to the next increased three- to five-fold. At the turn of the millennium the metabolic profile of the industrial fossil fuel fire-regime has been calculated to be about 40 times larger in scale, per human, than that of hunter-gatherers (Fischer-Kowalski & Haberl, 1998), made possible by the shift in energy source from agrarian biomass to fossil fuels. Hunter-gatherers probably counted less than 10 million, by 1800 we reached the first billion and by 1950 approximately 2.5 billion. By far the largest and fastest increase in the human population, however, came after the Second World War, the human population reaching its current seven billion people within just a few decades. This occurred simultaneously with what has been called The Great Acceleration, a dramatic intensification of the amount of energy and materials that humans extracted from nature (Fischer-Kowalski, Krausmann & Pallua, 2014).

The fossil fuel industrial fire-regime led to immense human progress in material living conditions, gains in life span and health, increase in knowledge and education, and new opportunities for freedom and choice in many parts of the world, if not in all. Fossil fuel-based energy also became a new “great divider”. As energy, based on fossil fuels, became organized on larger and larger scales, new divisions within, and between, human societies emerged. Coal-based power enabled the West to develop a different trajectory from the East. China and India, the largest economies in the world until the 18th century, went into relative decline (Urry, 2014). The invention of the carbon-based industrial economies, initially nurtured by unequal exchange with peripheral or colonized regions (Pomeranz, 2000), enabled the West to dominate the world for the next two-to-three-hundred years (Marks, 2002; Bonneuil, 2015).

In the West, a dependence on fossil fuels enabled new political opportunities for the weak. Coal workers were able to utilize their strategic position in the industry to successfully fight for political rights and welfare reforms. In contrast, with the emergence of oil as a crucial fossil fuel after the Second World War the tide changed; oil undermined the organizing power of coal miners and their unions and paved the way for neo-liberal reforms, which once more produced human inequalities across the globe (Mitchell, 2011; Urry, 2014). The inequalities between countries and regions in the world grew exponentially until the middle of the previous century (Kocka, 2016). Since the turn of the millennium the centre of gravity of global capitalism has tended to move from the West toward China and South-East Asia -- with the BRICS alliance beginning to challenge western dominance.

Energy security in the Anthropocene

The industrial and electrical fire-regime enabled an escape from the Malthusian constraints and associated risks of the organic economy. This was reflected in contemporary academic thought. A range of energetic theories emerged in the early 20th century that perceived the level of energy consumption as the most significant variable underlying progression in human civilizations and energy as the ultimate basis for economic growth and prosperity (Rosa &

Machlis, 1983). The anthropologist Leslie White (1943) formalized this idea as an equation, being $C = E \times T$, where C represented the level of cultural evolution, E the amount of energy harnessed and T the level of technological efficiency available for a given civilization.

For some time, scientists have been warning about the implications of the tendency to perceive energy as an unlimited resource. For example, Frederick Soddy, a Nobel Prize winner in chemistry, who as early as 1912 argued that energy was a critical limiting factor to economic growth, since, unlike materials, it could not be recycled. However, notwithstanding recognition of Soddy by notable scholars (for example, Cottrell, 1955; Georgescu-Roegen, 1971; Meadows et al., 1972; Daly, 1977) his work became an intellectual dead end among energy theorists for decades to come (Rosa & Machlis, 1983). Mainstream thinking embraced the idea that humans had unlimited stockpiles of materials and energy at their disposal. The underlying assumption of this thinking was that if an energy resource became depleted technological developments would always locate a suitable substitute. Accordingly, reliable and affordable energy supplies for unlimited economic growth became an implicit assumption as well as a formula for wealth and successful industrialization.

But the combination of intensifying metabolic rates and humans multiplying into the billions was only made possible by what can be thought of as a massive fossil fuel energy project, which entailed huge ecological costs as a consequence of carbon waste. This has shifted the planetary boundaries that have enabled us to thrive as biological beings. This project of "enslaving" or colonizing nature (Fischer-Kowalski & Haberl, 1998) while it enabled much human thriving entangled us ever more closely with nature in ways that have fundamentally shifted Earth systems. Thus, while this enabled us to postpone for some decades the questions of what a sustainable energy regime for industrial societies may look like, this has now become the central question of the 21st century. As we move forward in a time of rapidly diminishing ecological security, the risks of failing to integrate energy systems that will enable continuing human flourishing with ecological security becomes ever larger (de Vries & Goudsblom, 2003). A collapse of human industrial society within the foreseeable future has become a theme of report after report on climate change and its implications for human civilizations.

Feeding fossil fuel fire has produced one of the largest economic sectors of the world (Patterson, 2015), with extensive path dependencies, huge investments and strong vested interests that prefer, and work hard to maintain, the status quo (Hughes, 1983). Yet another energy transition is clearly on its way, but it has been slow in coming and has taken place alongside existing fossil-fuel regimes. The global tendency has been for renewable energy sources, like wind and solar, to add capacity to electricity grids, while doing little to reduce the use of fossil fuels. Given this, while the inclusion of renewably-generated electricity into electricity grids has done much to meet new demands for energy it has done little to lessen reliance on the use of fossil fuels.

This pattern of adding to rather than replacing existing energy sources has a long history. New energy sources have been put into use without old ones disappearing. The historical challenges have always been about increasing energy outputs rather than shifting energy sources. The challenge the Anthropocene poses is fundamentally different. The dangers of global warming do not require simply the adding of sustainable sources to the total energy output; they require the near disappearance of what are now the dominant fossil fuel-based industries in the world. It requires a radical transformation of our energy mix as well as reshaping human societies (Mitchell 2011). Sustaining human well-being, as well as many, and perhaps most, other life forms, requires us to stop the burning! How we can do this is the critical challenge of our time.

Decentralized energy and the electricity escape route

A crucial vehicle for a move towards a more sustainable human civilization, towards what China has termed an "ecological civilization", is electricity – a hugely versatile and flexible form of energy. Electricity, in contrast to fire, is not a chemical process that increases entropy on Earth, and it can be produced via a variety of energy sources (Patterson, 2015). It is in principle a clean technology that enables easy transference of electric power from a generation source to consumers. Electricity provides an escape route, a pathway that might enable new safe operating spaces for humanity (Rockström et al., 2009). It is also a form of energy that human societies, with few exceptions, have, over a remarkably short period, become utterly dependent upon. Within less than a century electricity has gone from being a novelty, to a convenience, to an advantage, to an absolute necessity and has come to define the human existence. Today, without access to reliable and affordable electricity, one is effectively excluded from participation in our new cyber-space-based forms of life, which include computerized economies. Electricity has, as predicted (Hirsh, 1989), fundamentally changed everything from the factory floor to how domestic tasks are done (Jewell, 2013). And, the electric economy is far from being at its peak. Humans are still finding more and more ways of using electricity, with electrification of the transport sector fast becoming the next technological breakthrough. Further, the developing world is rapidly catching up to the electricity-hungry lifestyle of the industrialized world and in many arenas is taking the lead (Berst, 2008).

Electricity produced through renewable energies constitutes the most likely pathway towards ecologically sustainable industrialized societies. An increasing reliance on electricity as our preeminent source of energy, developed with due consideration to the second law of thermodynamics, is our most significant, and perhaps our only, opportunity to build energy-rich and sustainable human civilizations. Achieving this has been and will be challenging, as it requires, in March's (1991) term, "off-the-path" solutions that do not simply exploit existing pathways but explore new ones, requiring inventions that differ significantly from existing pathways that have paid scant regard to the second law of thermodynamic. We have to ask, as Commoner (1976) did decades ago: "What is electricity good for?"

The answer, in today's context, is that electricity, generated through renewable energy sources, produced locally, offers a possibility of developing ecologically sound industrial civilizations. This contrasts sharply with highly inefficient fossil fuel-based technologies for producing electricity and other energy outputs. For example, power plants that use fossil fuel to generate electricity only convert a portion of the energy produced into the mechanical motion needed for electricity generation. When this is coupled with losses that take place as electricity is generated via centralized grids, only about one-third of the energy used to generate electricity is converted into electricity delivered to the end-users (Commoner, 1976, p. 28). Sustainable electricity systems that are compatible with an ecologically sustainable future must be a lot smarter. For this to happen electrical power must not only be produced sustainably it must be produced in close proximity to its users. Currently, solar power is the technology that seems most suitable for this due to its suitability to generation at a variety of scales.

More sustainable energy systems also require us to re-think what electricity should not be used for. Installing pipes to distribute waste heat from heating systems to produce hot water is generally much more efficient than installing the equivalent electric distribution capacity

(Lovins, 1977) but is often met with institutional resistance. In Norway, for instance, the district heating industry is excluded from the green certificate subsidy that production of green electricity is offered, because it produces and distributes warm water directly (Midttun, 1988). A transition to sustainable electricity systems will require a massive shift from the centralized electricity systems of today to the decentered, modular and mixed energy resource systems of tomorrow, as well as combining electricity with a range of other renewable energy technologies. Such a shift will require both public and private sector action and regulation.

Energy security through decentralized generation of electric power would be a significant aspect of what Lovins (1977) called a "soft energy path" towards, what he perceived, as a more promising future for all humankind. This is highly relevant to energy security, perceived as a key to the political order we establish and upon which our policies are built. A shift towards decentralized energy infrastructures offers a hope of empowering consumers through the transfer of ownership rights to individuals and local communities, facilitating a broadening of participation in decision-making, as well as new job creation. Compared to today's centralized energy systems, a shift towards more decentralized and modular systems should also allow for more considerations of local contexts, adapting energy systems to local circumstances and accommodating energy security with any other kind of policy need (Lovins, 1977, p. 66). Such a shift would also be important to prevent technological lock-ins that might constrain future choices, which is critical in the current transformation process.

All of this depends on how we engage with renewable energy sources and how we build our electricity systems of the future. The future is open, but much depends on the choices we make in the next couple of decades. Many countries around the world have taken initiatives that point in the direction of a more sustainable energy future.

In South Africa for example, the major metropolitan regions and several smaller municipalities have put in place regulatory systems that allow for embedded electricity generation, reducing costs for private users to connect and contribute excess energy to the grid. A new electricity energy market, consisting of multiple generators, buyers and sellers is emerging (Raw, 2016, p. 4). Similarly, as a way of preventing electricity theft, several of the larger cities in Brazil are experimenting with decentralized generation and smart metering in the *favelas* as a way of seeking to include poor communities as customers. While paying for electricity is a cost, the advantage is that electricity bills can be used as proof of residence, which enables poor clients to establish bank accounts and become legitimate participants in the formal economy. Both Brazil and South Africa have taken steps to prevent the emergence of dual electricity systems, where rich customers exit from the grid and the public system is left to service the poor. Both countries have established "Independent Power Producer" systems to expand the use of renewable energy in the grid, designed as auction systems that combine competition on price with the ability to promote socio-economic development locally (done formally in South Africa and *de facto* in Brazil through the lending practise of its national development bank) (Baker & Wlokas, 2014; Eberhard, Kolker & Leigland, 2014).

Germany's energy revolution has been built on a large coalition of interests, spanning the public and private domains. Much of this has been coming from the grass roots, with energy *genossenschaften* by local citizens, farmers and villages counting for half of the investments made in renewable energies. In Western Europe, only Denmark exhibits a similar pattern of development, which has elevated the country into one on the most energy secure nations in the world, and one of the most successful exporters of wind energy (Moe, 2015). In Denmark, wind turbines were legally required to be owned by electricity consumers and many wind projects are owned by hundreds of landowners and farmers in "wind partnerships". Currently 20 percent of Denmark's electric power comes from wind and 85 percent of this is owned by residents of Danish communities (Farrell, 2016). Germany, however, seems currently to be at an energy crossroad. Having established one of the most generous feed-in-tariffs for renewable energies in the world, the emphasis in recent years has been for a change to more market-oriented supply systems, centralization in energy generation and cost-efficiency, with conventional utilities spearheading the reforms (Moe, 2015). Recently, the energy cooperative movement has also lost some of its momentum.

What happens in the US and in China over the next couple of decades will be critical. The US has recently elected a "climate change denier" as president. Its federal institutional political system, with its many veto points, checks and balances, does not favor radical transitions, which the Anthropocene requires. Key challenges in the US are the lack of reliable renewable energy policy instruments, unstable and unpredictable support frameworks for renewables at the federal level, as well as the ease with which policy reforms can be blocked at various veto points. In spite of this, the US has in some areas been surprisingly effective in reducing its greenhouse gas emissions beyond the OECD average over the last decades (Nye, 2014).

Further, largely as a result of its decentralized political arrangements, the US has built one of the world's largest industries for wind and solar. The drivers behind this seem to be the general strength of the US economy, its industrial actors, and its influential science sector (Mazzucato, 2013). Another significant trend has been how the electricity market in the US has recently shifted towards more distributed forms of energy generation. For solar energy, in particular, there has been massive growth in distributed generation, albeit with limited opportunities for collective ownership as a consequence of many institutional barriers. This notwithstanding that half of the households and businesses in the US do not have access to appropriate roof space (Farrell et al., 2016). A critical barrier to community ownership in electricity generation is the fact that electricity generation utilities in many US states have establish monopoly rights to sell electricity to customers (Farrell et al., 2016).

The US has 900 rural electric cooperatives, established in the 1920s, serving 42 million Americans. The majority of these cooperatives, however, currently employ dirty and expensive coal assets as a consequence of long-term purchase contracts, preventing them from moving into solar and wind power. Many of these cooperatives are struggling with low membership and non-transparent leadership structures. More recently, however, several of the rural cooperatives have found ways of incorporating local renewable energy generation, some adding home-grown feed-in tariffs, as well as energy efficiency measures, to their energy portfolios (Farrell et al., 2016).

During the last couple of decades China has risen to become one of the world's largest markets for renewable energies and one of the world's top exporters of renewable technologies. A combination of factors has driven these developments. These include rapidly rising energy imports and concerns about energy security and energy dependency, as well as fear of inflation as a consequence of increasing energy prices and perceived threats of political instability due to the environmental impacts of fossil-fuel combustion (Hippel et al., 2012). The Chinese National Development and Reform Commission has responded to these challenges with plans to massively increase the use of energy from biofuels, hydropower, nuclear, solar, and wind, with the aim of making China a global leader in alternative energy developments. While considerable progress has been made in realizing this goal, recently significant obstacles have emerged. Expansion plans for biofuels have been scaled down, as it conflicts with food and land security. Hydropower development has increasingly been subject to scrutiny due to the environmental and social impacts of building large water reservoirs. With the Fukushima accident, nuclear plants have also been scaled back. Even the extension of wind power has become more uncertain, as integrating large amounts of wind into China's inflexible, coal-dominated power systems has met with considerable resistance (Hippel et al., 2012).

One of the reasons for the current backlash in the renewable energy sector in China has been that wind power rather than solar has been the preferred new renewable energy source for the domestic economy -- in contrast to India (Spratt et al., 2014) and Japan (Moe, 2015). Further developments in the manufacture of solar PV has largely been for export markets, with modest residential demand at home. Chinese leaders have promoted renewables mostly to facilitate rapid economic growth and to increase energy security, but with little structural change to the energy system and its reliance on fossil fuels for electricity generation. As has been the case elsewhere, renewable energies have been added to the grid at the same time as fossil fuel industries have been expanding dramatically. As a consequence, the percentage of generation through renewables has not increased significantly (Moe, 2015). This has meant that, despite the enormous increases in renewable energies used to generate electricity, an energy transition has so far not occurred in China. However, the current public declaration on the need to build an ecological civilization and the establishment of more targets for economic growth that include environmental concerns, are promising signals.

More examples could be drawn upon to show that energy transformations are brewing in many countries despite many hurdles. These developments make clear that the barriers to more sustainable energy and electricity systems are no longer technical or economic. The core barriers to the energy security the Anthropocene requires are political and regulatory, driven by powerful lobby groups who seek to defend the status quo. Currently, as we have already noted, the global tendency is for renewables to be added to the energy mix rather than to replace the fossil fuels. This is not contributing to the radical decarbonization we need to achieve.

Conclusion

Without a radical de-carbonization of these energy systems the challenges of the Anthropocene will be exacerbated rather than reduced. The obstacles to reversing this situation are inherently political. The fossil fuel industry, by lobbying at the international and national level, has been able to significantly influence state policy on global warming in ways that favor a further carbonization of our global economies (Newell & Paterson, 1998).

Established energy alliances regularly trump green ones. Avoiding predicted environmental catastrophes require the development of stronger green alliances. We need to re-imagine energy security by exploring opportunities for building transformative green alliances within different institutional environments. This issue of alliances is one that transition theorists have begun to explore as they have considered the condition required for shifts in energy regimes (see for example, Geels 2014). If human societies are to rise to the challenge of integrating energy and ecological securities more work will be required to establish how different economic systems, and particularly in our contemporary global economy, how different "varieties of capitalism" are responding to the challenge of realizing more ecologically sound civilizations (Soskice and Hall 2001; Buzogány and Ćetković 2015). Our capitalist societies have so far externalized ecological risks. Responding to the challenge of the Anthropocene requires us to build economies that internalize these risks. This will require reshaping our entanglements with Earth systems. Crucial to this will be re-building energy systems based on a profound recognition of our entanglements.

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