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Energy landscapes of less than two degrees global warming

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INTRODUCTION

To accept that we live in the Anthropocene, as argued by Le Billon and Bridge in Chapter 4 of this volume, is to acknowledge that we humans are accomplished geoengineers – in terms of scale and effectiveness at least. Having acquired knowledge of the unintended climate consequences of the Industrial Revolution, the fossil fuel age and the large-scale degradation and destruction of (more) natural habitats puts us in a particular quandary, because we now know that future generations will be presented with the huge costs of our cumulative consumption. Research efforts in the last 25 years have produced an a-la-carte menu of mitigation and adaptation measures for reducing and internalizing at least some of these costs.

Because the Earth is not an isotrophic plane, this menu varies from place to place, in terms of availability and price of the mitigation and adaptation measures available. In some places the menu may be quite comprehensive and competitively priced, whereas in other places the options may be limited or the price rather high. The scale of the challenge is huge. The 2015 United Nations Framework Convention on Climate Change Paris Agreement to pursue 'efforts to limit the temperature increase to 1.5 °C above pre- industrial levels' speaks of 'urgency' to address climate change, highlighting the current 'gap' in emissions reductions (i.e. policies and efforts to date being highly inadequate) and the need for 'accelerated' emissions reductions going forward. There is an emphasis on the 'enduring benefits of ambitious and early action, including major reductions in the cost of future mitigation and adaptation efforts.' (UNFCC, 2015).

Since the atmosphere is a 'global commons' under threat, we cannot allow one country to pick a light mitigation menu unless there is another country willing to make up the difference. Moreover, it is not immediately clear how the bill should be split, given that some countries are much wealthier than others and that the menu items can differ so much in mitigation price across geographical space. This opens up debates on both historical and geographical fairness; who polluted more, who is suffering more from energy poverty, who will be most affected by climate change?

We are facing challenges in improving the management of our energy systems, not only because they are complex and we have to consider multiple and often conflicting priorities (the so-called 'energy trilemma' of affordability, security and environmental sustainability; see Sautter et al., 2008) but also because many aspects of the energy system are hidden. On the consumer side, the 'double invisibility' of energy has been noted (Burgess and Nye, 2008; Hargreaves et al., 2013). This refers firstly to grid electricity being an energy vector; we cannot see those electrons in our domestic and everyday life, unlike solid or liquid fuels, or bottled gas (and gas we can still smell or hear). Secondly, this invisibility refers to the way in which billing has been conveniently hidden from us through the widespread tradition of retrospective, cumulative bills. The roll-out of smart meters and in-home displays of real-time consumption and live costs (not unlike a metered taxi) is supported by many governments as a technical measure to resolve this invisibility and engage citizens with their consumptive choices.

But there are other forms of energy invisibility we should seek to address. We are largely oblivious to the externalities of energy production associated with our energy use. For instance, smoking chimneys and mining landscapes are only visible to those who live nearby. Heat loss or carbon dioxide (CO_2) emissions may be invisible to the naked eye of people standing next to where these are emitted. As a fourth invisibility, the spatio-temporal dynamics of the energy system are so complex that we cannot see the displacement effects and interdependencies. For example, on a sunny day, rooftop solar photovoltaic (PV) panels distributed widely across the country may produce so much electricity that the grid operator will switch off one particular power plant in a particular location; usually the oldest, least efficient and hence dirtiest fossil fuel power plant in the country or region. Similarly, a day with variable wind may mean that wind farms are operational but the grid operators may keep a 'spinning reserve' i.e. a coal or gas fired power-plant running in neutral and ready to be ramped up to make up for any potential short term shortfall of electricity if the wind falls away. Last but not least we are faced with the invisibility of inevitable landscape change. As a consequence of this fallacy of 'landscape permanence' (Pasqualetti, 2013) we tend to compare a proposed development with a visual snapshot landscape of this moment, rather than with the changing landscape over the project's lifetime and beyond.

Given these multiple and interrelated invisibilities of energy, how can we better understand and assess the dilemmas of choice and change there where energy is produced and consumed? Geographers have already undertaken much research on landscapes of energy production, both fossil fuels and renewables (see Calvert, 2016). Drawing on the trope of 'reading the energy landscape', Pasqualetti (2013) identifies four major economic stages; the organic, mineral, electric and sustainable economy. This typology is comprehensive and highly suited for 'snapshot' descriptions of the energy supply side, i.e. visually detailed, spatially specific, one moment in time. Since the emergence of more-than-representational contributions to the discipline (e.g. Lorimer, 2005), the limitations of static and visual (landscape) representations have become more clearly recognized in geography, a critique which has now been extended to energy geographies (Haarstad and Wanvik, 2016).

This chapter is concerned with the question of how energy transitions (demand side + supply side) evolve over time and space, focusing especially on the early stages of the low carbon transition currently aspired to in international agreements on climate change. By examining the processes of change, the moral imperatives for action and the technical options for intervention, I aim to stimulate some new debates about the landscapes-to-be-produced by (aspired) climate policy compliance.

But first of all, let me explain why I am interested in the landscape. Our scientific understanding of nature and of humankind's pervasive influence on the surface, oceans, subsurface and atmosphere of the Earth means that it no longer makes sense to speak of binary divisions between nature and culture, human and non-human, ecology and technology; virtually each small part of our planet has the potential to be perceived as a peculiar hybrid of all of the above. In the short space of this chapter I could not hope to engage properly with the (changing) meaning of landscape in geography, other than to note it is usefulness as an 'organising principle' (Mason and Milbourne, 2014). I use the term 'landscape' loosely to indicate a broad geographical area that could be perceived to have certain specific characteristics, be they natural, human-made, social or cultural. Whoever does the 'perceiving' may chose the characteristics and the approximate delineation of their landscape. Rather than working with the spatial fixity of particular case studies, I use 'landscape' in this chapter as a vehicle for thematic and scalar focus - how do we engage with (the theme of) complex global issues like climate change mitigation and adaptation at a spatial scale that broadly corresponds with the geography of everyday life and our experiences and perceptions of land that may stretch in front of us towards a particular horizon?

The chapter is structured as follows. Firstly, I explore that which gives rise to (the snapshot of) particular energy landscapes, namely the specific processes of flow that characterize the subsequent energy transitions which have taken place in many countries since the Industrial Revolution. Secondly, I seek to identify the different criteria by which a particular area or landscape could be judged to be doing its fair bit in the pursuit of climate change mitigation. Finally, and consequentially I seek to draw attention to particular energy landscapes that could be expected to emerge in the 21st Century if we take seriously our commitment to limit global warming to less than two degrees Celsius.

ENERGY AND SOCIETY FLOWS SINCE THE INDUSTRIAL REVOLUTION

The control and domestication of fire has been the first big milestone of human civilization. It was not merely an 'energy service', providing our hunter-gatherer ancestors with heat, light and food processing at their camp sites. It was also a tool for large-scale landscape conversion and maintenance. It changed the ways in which we lived, what we ate, where we slept, how we socialized and how we dwelt in the landscape. It had huge cultural implications as well as opening the door for us to spread out further across the globe to conquer and convert new landscapes. Our ability to appropriate and utilise energy from the surrounding environment became both a revolution in habitat expansion and a revolution in mobility as we co-opted other species and learned to utilise the energy fluxes of the wind and flowing water.

If we think of energy transitions as socio-technical processes, focusing on the interplay of people and energy, then we can try to characterize different phases of development in terms of what is flowing across geographical space. During the original phase of pre-industrial self-sufficiency, (biomass) fuel was largely a freely collected and locally available energy source (Smil, 1994). Since the Industrial Revolution we can see flows increasing in distance, diversity and scale. Four phases since the onset of the Industrial Revolution are discussed in more detail below, each accompanied by a discussion of what may be yet to come if we are to address anthropogenic climate change.

Mines, Mills and Migrants

The onset of the industrial age only increased our hunger for energy, leading to an acceleration of exploration for and exploitation of new energy sources. Communities and cities sprang up where fossil fuels were extracted and where they were used in large quantities to melt and forge metal or produce other energy intensive industrial products in large quantities (e.g. cement; synthetic fertilizer). Despite the pollution and poor working conditions around mines and factories, they somehow offered better economic prospects for the many rural migrants who fueled this rapid urbanization, sometimes further stimulated by ecological or political crises affecting rural areas (e.g. the Irish potato famine).

This industrial urbanization phase is still observable in countries like China and India but it has now been all but completed in the early industrialized countries in Europe and North America. When the mines were declared to be economically exhausted by their private owners or the old factories closed due to international competition (i.e. the migration of many industries from the West to East and South Asia), local communities and cities were left stranded, struggling to adapt to new and harsh economic realities. These post-industrial cities are now a prime target for ecological restoration and experimentation with low carbon technologies, largely funded through state aid. What can we learn from these experiments that can help us to better plan growing industrial cities in Asia, or think differently about the potential transformation of other energy intensive cities, such as the low density, car-centric conurbations in North America? And how will cities and their economy be affected by international migration, which is likely to increase in the 21st Century in response to economic inequality, political instability and environmental degradation or disasters?

The State of/as the Grid

With growing urbanization and industrial electricity demand came an increase in wealth and an agenda to create a state-owned or state-controlled national grid, providing electricity for all (tax paying and bill paying) citizens. In most countries, this provided a guaranteed market for the further expansion of consumer capitalism, but Vladimir Lenin's famous quote that 'communism is Soviet power plus electrification of the whole country' (Banerjee, 2003) demonstrates the huge symbolic value of nation building implied in the process of electrification. The ubiquitous development of national grids across all but the poorest nations (admittedly long after the death of Lenin), suggests that that electrification is seen as a hallmark of modernity (Appudarai, 1996). The national grid as a 'grand project' is analogous with a vision of the state as strong, centralized, techno-centric and distributive. Whilst the initial growth stages of the grid were often driven by private sector funding and the energy needs of industry and mining, the later growth stages of the grid towards a mature status quo as the 'national' grid reveals a progressive dimension in its ambition to reach (more or less) all people, and (by cross-subsidising) to charge the same consumer price to all, regardless of location. Regardless of the size and influence of the private sector at the time, it was a victory of modernism and state centric power against the obdurate geographies of nature, converting the irregular shapes of the national territory into an isotropic plane of modern energy access. With some exceptions (notably in sub-Saharan Africa), national grids have achieved their maximum geographical reach decades ago, serving all but those residing in very remote, illegal or impermanent locations. The networks of tarmacked roads, gas-pipes and telecommunications could be interpreted as weaker analogues of the 'grid-state'.

But despite decades of status quo, the future of the national grid as we know it is by no means guaranteed. There is a (left wing and right wing) radical fringe of society embracing the notion of 'living off the grid' as a way to ascertain autonomy and autarky, with reduced dependency on the government, big business or global supply chains. Privatization has increased geographical price inequality in western countries like the UK, whilst rolling black-outs that plague some developing countries are not always managed in a geographically equitable way. The development of new large scale renewable energy (RE) projects requires investments in new transmission lines through rural and remote areas and across national borders, sometimes towering over un-served rural communities, whilst the uptake of domestic PV in affluent countries like Australia carries the risk that some rural grid connections will over time become uneconomic to maintain (Wood and Blowers, 2015). Local RE mini-grids may provide an alternative model for electrifying rural areas that are yet to be reached by the national grid (e.g. in Africa). It is not always clear to what extent these different developments are competitive or complementary from a spatio-temporal perspective.

Mining Frontiers

Techno-economic innovations in mechanization and transportation since the mid 20th Century have meant that where new mines are still being opened in wealthy countries, only limited numbers of mobile jobs are created, i.e. the era of mining-towns has ended. Nuclear power plants were perhaps the last sites where new energy communities were created; in the global North, new investment in nuclear power has become rare and usually sites with existing reactors (and nuclear communities) are targeted (see Chapter 6 by Johnstone in this volume). Nuclear communities are unusual in that decommissioning of nuclear power plants is a very lengthy and expensive process, retaining jobs in the local community for many years after the plant has closed. But in contrast to this very slow decline over time, the world has also witnessed the dramatic cases of Chernobyl and Fukushima where vibrant nuclear communities were turned into completely abandoned ghost towns overnight.

With the exception of the impacts suffered by local communities in the new spaces of extraction (e.g. local people being displaced by large scale hydro developments or dispossessed of their 'marginal' land by biofuels schemes), energy exploration is no longer such a major force of social change or societal restructuring; new oil fields may be discovered in remote and deep sea locations and new methods are developed to extract unconventional gas and oil, but these are capital intensive rather than labour intensive sectors, providing fuel to mature markets and established consumers; remote mega-mining has added to the disconnect between most members of society and the impacts of (their) resource consumption.

It is interesting to ask if ideas of 'green' mega-mining are any different in that respect. In other words, will visions of huge desert solar farms (Samus et al., 2013) and huge off-shore windfarms linked to cities by transcontinental super grids (Leach, 2015) suffice to achieve our desired transition to a low carbon society? There are several arguments to suggest that the answer to that question is 'not quite' or 'not just yet'. First of all, frontier technology is new. It has teething problems and is produced at a higher unit cost due to low economies of scale and limited competition. Hence it is relatively expensive and risky; illustrated by the accidents such as that of the Deepwater Horizon in the Gulf of Mexico, or big onshore footprints such as the Canadian tar sands. It also requires planning and development of huge energy transport infrastructure across (many) national boundaries. This is a huge investment programme with very significant political risks and transaction costs. Consequently, it is hard to tell if, when and how it will be implemented. At some stage in the future, mega-mining projects of renewable energy may well emerge and transform existing national electricity grids into inter-continental low carbon energy systems, but in the meantime, as the 2015 Paris Agreement states so clearly (see the Introduction), we need to devote attention to quick results. This means we need to focus in the short term on the accelerated deployment of proven technologies that can be linked up to existing infrastructure. Amongst others, this means more wind turbines in windy-enough locations close to existing grid connections. This reversal of the energy frontiers will undoubtedly bring more landscape-energy conflicts.

Hyper Mobility and the Age of Digital Data

The rapid increase in the mobility of affluent populations is closely associated with reduction in the cost of transport as a proportion of income. Hypermobility relates to commuting distances, driving holidays, low density urban sprawl in car-centric societies and the strong growth in budget airlines moving ever larger numbers of people for the purpose of work, leisure or the maintenance of friendship and family relations. Transport is one of the few sectors in the global North that continues to grow in terms of energy use. Big investment and strong policies for modal shifts towards public low carbon terrestrial transport might be able to arrest this development but clearly hypermobility needs to be seriously curtailed if we are to achieve the stringent targets of emission reduction. This is a huge challenge given the tremendous popularity of car culture and of travel and holidays in general, as well as the transport-intensive spatial layout of our cities and the dispersal of our places of work, living, shopping and recreation.

Hyper mobility warps our perceptions of the world around us, replacing our experiences of familiar landscapes from anthropomorphic perspectives with experiences of queuing, confinement and (if we are lucky) bird-eye views of the world below us. We may roll along highways at speeds greater than that of a cheetah in full sprint, or sit in traffic jams for hours or longer. Globalized hypermobility has of course created huge expanses of tarmac, connecting islands and even continents across bridges and tunnels. In the past, our biggest buildings were places of worship at the heart of our cities. Now the biggest buildings by volume in the world are those that manufacture the biggest planes or cruise ships and the buildings with the biggest spatial footprint are the distribution centers of supermarkets, stretching for hectares across what used to be rural land next to hubs of our national highways.

The flow of data is closely related to human mobility when we consider communications. But the Information and Communications Technology (ICT) Revolution also encompasses securitization, environmental monitoring and scientific research. It now includes the creation of global data centres in areas of the global North that until recently we would have considered to be remote and economically fragile. Like electricity hungry heavy industries in the past (e.g. aluminium smelters), the energy hungry architecture of ICT is now migrating towards remote but politically stable locations where there is an abundance of renewable electricity, allowing the latter to be consumed locally so that data can be sent instantaneously across a global grid, the internet. At this moment in time it is not clear to what extent increased data mobility (low carbon or not) will eventually help to significantly reduce human hyper mobility (which is carbon intensive).

The ICT revolution has also enabled significant efficiencies in the use of physical infrastructure, including examples in mobilities such as car sharing, city wide bike rental schemes and the introduction of congestion charges. We can even ask to what extent the ICT revolution has encouraged or enabled the emergence of alternative, more low carbon lifestyles, e.g. to what extent does working from home save energy, time and the use of fossil fuel? And is it possible that some modern mobile lifestyles (e.g. by mobile home retirees; canal boat homes) are lower carbon than more conventional sedentary lifestyles? Certainly, mobile lifestyles limit the size of the living space that needs to be heated or cooled, whilst it allows people fewer domestic appliances, potentially of lower power ratings. Ironically, it has now become possible to live off-grid from an energy point of view (e.g. relying on your own solar panels) whilst enjoying fast connection to the (global) internet.

In summary, having looked at the nature and extent of flows of humans, material, energy and data, I have identified four broad phases of energy transition observable since the Industrial Revolution. None of these phases have ceased to be, but they manifest themselves more readily in different parts of the planet, and in different types of landscapes. To what extent can we expect that climate change policy compliance, as expressed in the Paris Agreement, will lead to the formation of new types of energy landscapes? In order to explore this, we first need to examine more closely the moral imperatives behind climate policy.

THE MORAL GEOGRAPHIES OF CARBON EMISSIONS

Climate policy must be one of the most radically ethical policies ever adopted at the national and international level. It is a policy to protect the lives of the future children of the children of people we have never met. It is a policy informed by hugely complex and evolving models, both of the trends in global warming and of the consequences of global warming. The international Agreement drafted in Paris in December 2015 to keep global warming under two degrees Celsius may be seen in many different lights, e.g. as a big political step forward; as a confession of failure to avoid significant damage to date; as an arbitrary number established for political reasons; or as an exercise in wishful thinking.

An exploration of low carbon landscapes is not complete without the question of morality. Indeed, any human interaction with 'nature' is measured against moral standards of appropriate behavior (Setten, 2004). It is often when faced with the local impacts of climate policy interventions that citizens start to engage with, question, learn about and (sometimes) resist. Pasqualetti (2000) aptly refers to siting conflicts of renewable energy facilities as the 'stage for a morality play'. The local planning process is often the only opportunity people get to engage directly with national debates about the direction of development (Owens and Cowell, 2011) and in many countries the planning process is inherently adversarial in nature, more likely to produce clear loser and winners, rather than win-win solutions or strategic compromises.

Conflicting views and lively debates are inevitable when 'living' landscapes are confronted with potential new developments but are deeply infused with visions of the past (Ingold, 1993). The low carbon landscape is almost never presented as an aesthetic vision, which might refer to the (less energy intensive) past. More likely it serves as a metaphor for a better relationship-through-nature between energy affluent consumer-citizens of today and future human generations.

When technology is mobilized to reshape landscapes, this production of landscape reflects the moral attitudes of its creators towards nature (Zwart, 2003). Reflections on the moral geographies of landscape are quite diverse, but there are some clear analogues to the current debate about low carbon landscapes. For example Matless (1997) examines the moral geography of the English landscape as the traditional model of large-scale land ownership by the elite was challenged by societal change and demand for recreational access. He identifies how in the pursuit of outdoor leisure in the UK in the 1930s, key questions of citizenship were raised, as well as reflections on how to improve it. The parallels are clear; the pursuit of low carbon landscapes must go hand in hand with efforts to improve environmental citizenship if we accept the 'deep emissions cuts quickly' logic of the Paris Agreement. In other words, we must find ways to link the increase in production of renewable energy (and the resulting landscape change) with efforts to reduce the consumption of energy and material resources and accept if not embrace the resulting landscape changes (Selman, 2010). We must use analytical, discursive and other means at our disposal to develop, improve and internalise this link between production and consumption that has been rendered invisible by the flows described in the previous section, i.e. urbanisation, development of the national grid, emergence of global supply chains for fuel, raw materials and processed goods.

We can identify several moral priorities that we should assess and seek to address within the boundaries of existing administrative geographies. Assuming that an area is not producing fossil fuels and leaving out the discussion about the feasibility of carbon capture and storage, we can judge the contribution of a geographical area towards mitigating climate change through the deployment of four different but complementary low carbon performance criteria:

1. Over-consumption of power (relative to people elsewhere);
2. Mis-consumption of power (energy wastage, e.g. poor home insulation);
3. Under-production of renewables (relative to technical potential); and

4. Mis-production of power (e.g. non-use of thermal output of coal-fired power plants; switching off wind turbines because of low electricity demand).

To these four we can add the under-consumption of energy; addressing fuel poverty is not a low carbon criterion but represents a basic right to energy services[1] (For more details on energy poverty, see Chapter 31 by Simcock and Petrova in this volume). Of course, the operationalization of each of these criteria raises analytical and inherently political questions about standards and measurements. They also raise questions about technology and infrastructure, in terms of the material aspects of our incumbent high-carbon energy regime, the characteristics of disruptive low carbon interventions and the tools available to analyse and visualize the potential for rapid improvement. Whilst the analysis of each of these criteria will point us towards the need for action, a combination of these priorities within a geographical area will help to make the nature of the intervention logic more concrete and urgent. In a hypothetical islanded system, these five criteria must be combined to yield an action plan, which can resolve fuel poverty and reduce the carbon footprint to achieve the necessary carbon cuts specified in the Paris agreement. However, most administrative geographies are anything but islanded and the inter-area differences in these performance criteria can and often must be balanced out. Closely aligned to the flows discussed earlier, potential balancing mechanisms can be defined by the nature of what is to be reconciled within an administrative geography and/or across geographical boundaries, i.e. we can shift:

1. Energy (e.g. export renewable energy from areas of high renewable energy potential and low population [aggregate energy demand] to those with low renewable energy potential and high population);
2. Energy hungry industries, old (heavy industry) and new (data processing);
3. Financial resources (e.g. cross-subsidising the energy poor with taxes levied on the high-energy use of wealthier sections of the population);
4. Carbon reduction commitments (i.e. off-setting); and
5. People (e.g. migration to locations with higher renewable energy supply or lower domestic energy requirement due to a milder climate).

Trans-boundary trade in low carbon energy (bioenergy, wind, hydropower) is already business as usual. We have seen the shift of energy and labour intensive industrial sectors from the West to Southeast Asia and as some Asian countries become more affluent, we can see some of the same industries moving once more other more emerging economies. Cross-subsidising of grid electricity within a nation state has also been quite common, but is likely to be under more pressure under neo-liberal reforms. Offsetting has seen many small initiatives, some of which received a lot of negative press and migration is a very sensitive political topic. It is worth noting that despite the myriad of observed abuses and operational concerns, the uneven geography of the world we live in means that offsetting is an essential balancing mechanism.

The moral concerns about existing offsetting schemes have largely to do with accountability (non-additionality, non-permanence, negative social or environmental impacts) and inequity, notably that it allows wealthy off-setters to continue to live an energy intensive lifestyle. These concerns should be allayed if all of the above performance criteria are used together. Local offsetting may reduce further some of the concerns because the costs and risks are shared more equally between local citizens. And the ICT revolution has enabled the emergence of new offsetting mechanisms with higher levels of transparency despite geographical distance. Given the huge challenge of meeting the targets in the Paris Agreement, many administrative geographies may have to use all balancing mechanisms available. So, if a national government is reluctant to allow migration, then this puts more onus on the other balancing mechanisms available, i.e. less migration might mean more offsetting. This is an especially stark choice in the short term, given that it is quicker to mobilise capital or pay for offsetting than to build new transboundary electricity grids or facilitate orderly migration at scale.

THE CONSEQUENCES FOR OUR LANDSCAPES

In the preceding sections I have discussed how the mobility of people, materials, information and energy have evolved since the Industrial Revolution, and asked how these trends are likely to evolve in a low carbon energy transition. I have also identified a set of performance criteria by which an administrative geography can set its priorities for interventions to make its fair contribution to a global low carbon transition. Given the uneven geography within a single spatial administration (local council, province, nation state) and across adjacent geographical jurisdictions, different balancing mechanisms need to be deployed to address unsatisfactory performance of one or more of these criteria within one or more administrative geography areas whilst collectively remaining on target to achieve the necessary global reductions in emissions to limit anthropogenic climate change to less than two degrees Celsius.

So how can or should these flow phases, performance criteria and balancing mechanisms come together *in situ* to create energy landscapes of less than two degrees global warming? This is a big and perhaps rhetorical question and I do not pretend to have the answers. Some contributions to this question are already relatively well developed by geographers (and others), for example visions of low carbon smart cities and smart re-localisation of some products and services. Other contributions are undergoing rapid development, for example research into the water-energy-food nexus (see Chapter 30 by Leck and colleagues in this volume). However, as a final discussion in this chapter I would like to propose three emerging landscape themes:

Landscapes of Sustainable Intensification of Renewable Energy Production

Given the urgency and scale of intervention required, we need to prioritise the uptake of renewables that offer the lowest installation and maintenance cost per kWh and high potential for deployment. The cheapest form of renewable energy is onshore wind. And the cheapest places to construct and operate wind turbines is in windy locations close to existing substations on the national grid. That basically means we need to fit as many wind turbines (or for that matter, PV panels etc.) as possible in our landscapes of everyday life, be they industrial, infrastructural, urban, peri-urban or rural landscapes. Rather than waiting for private investors to propose and develop renewable energy plants, there is a need for a planned approach of assessing how much MW capacity we need and then allocate enough target areas that should be prioritized for the development of renewables. This could be a prioritization exercise to pick preferred siting criteria with calculated total RE potential, up to the point that we have achieved our target for RE production (for ideas on how to do this see Chapter 27 by Stremke and Picchi in this volume). This programme of intensified RE production in and near population centres should not overrule all other considerations, but avoided locations must similarly be mapped and their production potential assessed so that we know for example how much RE we are forsaking in order to protect the visual appearance of heritage buildings or locations with iconic scenery. This information will help to ensure that we understand the financial and RE trade-offs of blanket protection of historic city centres or national parks. Sustainable intensification takes place in crowded landscapes, full of property boundaries, competing uses and diverse user groups. It may be associated with institutional and legal innovations to stimulate the development of RE facilities in 'complicated' spaces such as shared roof tops, temporarily available spaces and underground spaces.

Offsetting Landscapes

Whilst energy storage is a technical solution that bridges a temporal gap between energy supply and energy demand, offsetting can be seen as an accounting solution that bridges a spatial gap between an act of energy consumption and its equivalent act of emissions reduction. It is the aforementioned ICT revolution that has enabled us to bridge that gap, through the emergence of models to calculate emissions and storage, the means for registration, payment and communication and the tools for monitoring.

The rationale for offsetting is simple; it may offer cheaper ways to achieve emissions reduction, so that the total emission reductions can be maximized from a limited budget. This efficiency argument does not stipulate a mechanism for the exchange, neoliberal, state-led or otherwise. Some sectors of energy use are easier to decarbonise than others. For aviation, in particular, we do not have viable technological alternatives. Experiments with flying planes on biofuels are challenging because the potential for biofuel production that does not compete with food production is limited. Moreover, there are often better uses for biomass, e.g. in green chemistry or building materials that lock carbon in place for decades or longer. Burning something (like biofuels) is usually the poorest way of extracting value from it; hence energy recovery sits at the bottom of the waste hierarchy[2]. Offsetting will not be free of impacts, so these offsets need to be properly measured and costed, compensation and mitigation agreed with affected communities, and known excesses of appropriation, exclusion etc. must be avoided, whilst any offsetting must be part of a wider and integrated strategy to reduce emissions, including demand reduction. One way to increase the likelihood of good offsetting projects is to start from the perspective of the needs and priorities of the communities and countries that may play host to such interventions. Funded through carbon taxes, offsetting could be just one international funding mechanism for domestic programmes on sustainable land use change, switching from fossil fuels to renewables or utilizing locally available geological storage options. Good offsetting will not only produce new energy landscapes, it will also require the emergence of new and strong institutions that can fairly and competently govern this exchange. One institutional challenge is to ensure that offsetting arrangements are not just accountable for experts but also transparent for public scrutiny; again, this is a challenge of making visible the different and interlocking components of the low carbon transition. At the national or regional level, offsetting could be made visible through the explicit twinning of towns, provinces or nations. At the individual level, it is also possible to trace the offsets to specific projects, so that an individual act of consumption (e.g. buying a plane ticket) becomes explicitly and visibly linked to a specific landscape where a particular offset project is taking place. The flip-side of this creative approach might be that some people may feel (too) good about supporting a certain project through their consumption, potentially creating a perverse moral incentive to consume more.

The Post-Project Landscape; Participative Planning for Restoration and Adaptation

The aforementioned 'landscape permanence' assumption needs to be exposed (as it is often implicit) and challenged. Not only is the living landscape and its perceptions always changing under a range of different drivers and influences; we also know that in the absence of huge mitigation and adaptation efforts, landscapes will undergo further dramatic change as a result of the impacts of climate change. One way to challenge this assumption of permanence is to request that project development proposals provide plans and details for the post-project landscape, thus drawing direct attention to both exogenous landscape changes in the background and the temporary nature of the project itself. Secondly, this longer-term planning approach has the potential to finally combine the two halves of climate policy - mitigation and adaptation. Research on landscape adaptation has become more rich and diverse in recent years (e.g. managed retreat of the coastline; flood storage; fire risk management) and the need for longer term integrated planning could hardly be stronger.

Furthermore, *participative* post-project planning can help to open up the more positive question of what people would actually want 'their' landscape to look like, a decade or two into the future. Some technologies like PV arrays and small wind turbines can be fully removed, leaving no permanent marks on the landscape. Larger wind turbines and hydropower plants leave 'concrete' evidence of their presence. Dam removal programmes are growing in number and are stimulating ideas and debates about post-dam ecological restoration (e.g. Doyle et al., 2003), but more thinking needs to go into post wind farm landscapes. Repowering has been a popular option for developers but it will not be suitable or appropriate everywhere. The concrete foot of wind turbines is in scale quite similar to the bunkers left all over Europe by two world wars; they have become permanent landscape features, sturdy and harmless monuments of a past era, not entirely unlike the standing stones erected three or four thousand years earlier. We need to open up the debate about the use of the landscape post-project; if the access roads will be removed or opened up to new forms of access, if the exclusion zones near the base of each turbine will make way for other built structures, for leisure, art of utilitarian use, and by whom. Communities that have hosted a wind farm or hydropower dam (willingly or otherwise) deserve recognition and should gain ownership or better user rights of these post-project sites.

CONCLUDING THOUGHTS

Geographers have shown a healthy interest in emerging energy landscapes of unconventional fossil fuel extraction (e.g. fracking, oil sands) and renewable energy generation and have explored the conflicts that arise in such landscapes. This chapter has sought to examine what kind of new energy landscapes may emerge if the quest for mitigating anthropogenic climate change is stepped up to the (radical) level required to actually arrest global warming at/below 2 degrees Celsius.

International climate policy allocates emission reduction responsibilities (targets) on a national basis, in accordance with the principle of 'common but differentiated responsibilities'. This moral obligation requires spatial balancing of renewable energy production. Some landscapes may have to be 'filled' with renewable energy installations and still be places of excessive greenhouse gas emissions. Other landscapes may have an over-capacity for renewable energy generation, opening the door to mechanisms of offsetting and the possibility and risk of 'mega-mining' of renewable energy in high yield locations. I have chartered some of the socio-technical trends evident in energy transitions, paying close attention to the acceleration of flows of people, goods, energy, finance and data. Looking ahead, I have sought to expose some of the dilemmas involved in striking the right balance between spatial concentration and distribution of production and between the need to create explicit production-consumption links across space, whilst arguing for the need to develop integrated, longer-term and inclusive approaches to landscape planning that address both mitigation and adaptation.

But I also sought to recognise that a focus on landscape as the unit of analysis and of balancing may disguise important processes. Administrative geographies are often not fit for the purpose when it comes to solving more-than-local social and environmental problems. This is particularly clear when dealing with trans-boundary issues. Mobility and migration are a point in case; nomadic and mobile people have often become stigmatized, ostracized and dispossessed in modern nation states. And yet migration has often been a highly effective adaptation strategy for living with nature's variability and unpredictability. The threats of climate change will add to the need and desire of people to move. We need to develop more flexible and imaginative ways to cope with and manage the flow of people within countries and across national borders, enabling mobile lower carbon lifestyles in the global north and supporting planned migration (seasonal or permanent) as an adaptation strategy for those most at risk of sea level rise and other severe local impacts of climate change. Climate policy will need to engage much more with the difficult question of adaptation landscapes, featuring both new human habitats (e.g. floating cities, planned resettlement zones, seasonal camps) and shifting ecological zones, with managed pathways and safe corridors for the migration of humans and non-humans. Clearly the emerging moral geographies of climate migration and adaptation are an important and complex area for further exploration and debate. Add to this the intellectual expectation of conceptual consistency in understanding mitigation and adaptation and geographers will have their work cut out for many years to come.

NOTES

1. This is a very important moral criterion, but not the focus of this chapter. In the language of the Sustainable Development Goals (SDG), this chapter focuses more on 'climate action' (SDG13) than on affordable energy (SDG7).
2. I am only aware of one exception to this generic argument; smokable drugs.

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