A Companion to Environmental Geography

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Chapter 31

Energy Transformations and Geographic Research

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The challenge of fostering just and sustainable societies cannot be met without fundamentally transforming global energy systems. Socio-ecological contradictions are increasingly apparent in 'conventional' energy systems predicated on exponentially growing demand met principally through expanding supplies of fossil fuels and massive nuclear and hydropower projects. Energy underwrites developmental aspirations, yet the twin specters of climate change and oil wars are generating public support for alternative energy systems with potential also to reduce related problems of smog, respiratory disease, acid rain, strip mining, oil spills, forced rural resettlement, and inequities in access to energy services. Despite these problems, virtually all 'business as usual' forecasts expect continued rapid growth in energy consumption and production regimes, reflecting the socio-economic power imparted to the network of technologies, policies, institutions, and practices that constitute conventional energy systems. These networks of power are continuously contested and reproduced, however, and just as key social movements of the 19th and 20th centuries were built largely on challenging the labour, environmental, and financial practices of coal and oil industries, so the nascent 'sustainable energy' movement presents a potential vehicle for contesting global inequality and underdevelopment in the present century.

With so much at stake and with such strong implications for virtually every field of geographic scholarship, it is surprising how little geographic research focuses squarely on energy issues. This disinclination may reflect a mismatch between the heterogeneous, social-theoretically informed methods and concerns of geographic scholarship and the all-too-often technical and economistic nature of social science energy research. Climate change concerns, however, have opened up new space for contesting energy policy and investment decisions around the world in ways that will shape the meaning and prospects for sustainability in human-environment systems. While geographers productively study energy issues from many perspectives (see review by Solomon et al. 2004), this chapter emphasises research that treats energy system sustainability as a contestable process in which political-economic and cultural factors co-evolve with changes in the quality, location, and environmental impact of energy resources.

Contesting the Next Energy Revolution

The concept of 'energy system sustainability' refers broadly to policies and practices that promote the evolution of systems to provide desired energy services in a socially just and environmentally sensitive manner. The struggle for energy system sustainability is central to any larger vision of sustainable economic development due to the fundamental role energy systems play in economic activity and the evolution of human and environmental systems (Simmons, 1989; Smil, 1999; Hall et al., 2003). Global development over the past three centuries cannot be understood without appreciating the central role played by energy system transitions – roughly from wood to coal to oil and electricity (e.g., figure 31.1) – reinforced and embedded in complementary cycles of innovation in transportation, industry, agriculture, communication and war making (Podobnik 2000). The nations that best exploited the scientific, commercial and military potential of these changes achieved wealth, empire and a world order predicated on continuous social and environmental transformation. The British and US empires of the 19th and 20th centuries were based on the ability to access, control, and develop the economic and military potential of each era's cutting-edge energy resource. Residing within the current notion of sustainable energy transformation, therefore, is the possibility for social and ecological revolution as unimaginable as that stimulated by the first electrical power systems in 19th century New York, Chicago and London.

One challenge to energy system sustainability is that once transformative energy resources – oil, coal, natural gas, nuclear fission and large hydropower – are now so socially, technically, and economically embedded in industrialised societies that they are highly resistant to displacement (Hughes 1987). In 2006, five of the ten largest Fortune 500 corporations were oil companies, while another four produced

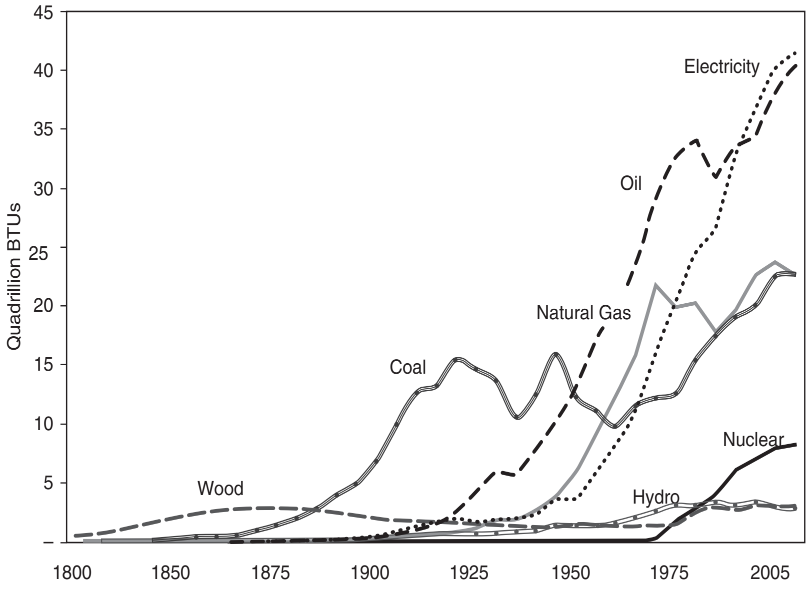

Figure 31.1 Energy transitions in the USA: primary fuel consumption. (Source: EIA 2007)

the automobiles that constituted their primary market (Fortune Magazine, 2006). 'Fossil fuel interests'– corporate and state alliances committed to those industries – are thus entrenched at the highest reaches of power around the world. As energy demand has grown, new energy resources have supplemented, rather than replaced, once dominant resources. Indeed, more coal is now consumed than ever before.

The great social and economic power vested in conventional energy systems makes challenges to their hegemony fiercely contested. For more than a century, key developments in social welfare have been won through struggle against prevailing energy interests, beginning with basic labour rights advanced through coal mine actions. The rise of the modern environmental movement in the 1970s brought with it national-level policies, such as the US Clean Air and Clean Water Acts, that significantly reduced pollution and other local- and regional-scale impacts of fossil fuel use, at least in the developed world. Thus, while air pollution remains a leading cause of premature death in the developed world, London, for example, is no longer in danger of having 4,000 people die in one week from an inversion of choking coal smog as happened in 1952 (Davis 2002). Instead, the most dangerous health and safety threats have migrated now to places like Mexico City, Beijing, and Delhi. This success in mitigating or spatially displacing some problems of conventional energy systems, combined with low energy prices beginning in the mid-1980s, vitiated much of the social movement pressing for sustainable energy transformation in the US and elsewhere. In an ironic twist, the movement has been reinvigorated in recent years through a growing international coalition concerned with the impacts of carbon dioxide, a gas that among fossil fuel by-products would be completely innocuous if it didn't constitute two-thirds of the greenhouse gases (GHG) threatening to destabilise the global climate system. Geographic energy research takes place within this context of an ongoing global, yet highly differentiated, struggle for sustainability against the hegemony of fossil fuels, and the following sections explore how issues of resource adequacy and location articulate with political economic dimensions of this struggle.

Uneven Geographies and the Geopolitics of Fossil Fuel Hegemony

'America is addicted to oil' declared George W. Bush in his 2006 State of the Union message, as a sharp rise in oil prices and war in Iraq increased the political saliency of problems stemming from an economy reliant on petroleum for 40% of its total energy needs and virtually all of its transportation. The administration's principal policy prescription for addressing this dependence – satisfy it with more oil produced domestically – was, however, at odds with research by Cleveland and Kaufmann (2003) demonstrating the steadily diminishing *energy return on investment* (EROI) of the US and global oil industries. When US oil production peaked in 1970, the US oil EROI was 50, meaning that for each unit of energy used to produce oil, an 'energy surplus' of 49 units subsidised other activities throughout the economy. Over time, as the largest, highest quality and easiest to extract oil reserves were drawn down, EROI fell to ~15, and production levels never recovered, despite improved drilling technology and enormous federal subsidies. Proposals for achieving national 'energy independence' through expanded domestic oil production on a dwindling resource base are thus likely to simply flush additional 'billions of dollars . . . down a dry hole' (Cleveland and Kaufmann 2003, p. 488).

Similar forces are expected to drive the global oil market to a production peak in the next decade or two (Kaufmann, 2006), just as consumption levels in China, India, and other developing countries rise towards those of industrialised nations. While long-standing Malthusian fears of fossil fuel depletion leading to economic collapse have not yet materialised (Jevons, 1965[1865]; Meadows and Meadows, 1972), the 1970s demonstrated the vulnerability of the global economy to tighter oil markets and political instability in oil-producing regions. With two-thirds of all reserves in a handful of Middle East countries (figure 31.2), the strategic importance and highly uneven geography of oil have vested enormous power in a handful of state and corporate actors. Watts (2005) traces the evolution of a global oil complex back to the 1930s and the establishment of Iraq as a British client state serving the interests of British, French and US oil companies and governmental allies. Following World War II, nationalist movements in oil-producing countries led eventually to the 'OPEC revolution [that] ushered cycles of conflict, militarisation and revolutionary upheaval – the so-called energy wars – in the major oil-producing regions' (Watts, 2005, p. 378). Capital and conflict continue to cycle as oil-producing elites reinvest large sums of petro-dollars into Western multinationals that sell weapons and manage massive construction projects in OPEC nations and elsewhere. This 'virtuous circle' of oil, money and weapons creates an industry in which business as usual is largely an undertaking of undemocratic multinational corporations and 'petro-states,' with the US engaged to assure the flow of oil for strategic, economic and corporate oil interests. The political economy of oil varies greatly by region, but oil figures heavily in redefining the role of state and capital in places as varied as Russia, Venezuela and Kuwait. Watts (2004) uses experience in Nigeria to argue that places of oil extraction have become enmeshed in, and reconfigured by, a distinctive 'petro-capitalism' that systematically undermines development, democracy and community.

The resource depletion and uneven locational characteristics of oil increasingly apply to the natural gas market (figure 31.3) that began growing rapidly in the 1980s for heating and electrical generation purposes. Both the USA and the UK relied heavily on natural gas to meet new electrical power requirements in recent years, but domestic supplies of this cleaner-burning and lower-carbon alternative to coal are expected to fall short of future demand (Brown et al., 2006). Meanwhile, the emerging geopolitical significance of natural gas was demonstrated on New Year's Day 2006, when Russia cut gas supplies to Ukraine, only to reverse course under intense pressure from European Union member states whose energy supplies were also pinched. Ostensibly a dispute over pricing and payment, the disruption also expressed Russia's opposition to growing ties between Ukraine and western Europe (Klare, 2006).

The latest Iraq war has prompted a number of geographic analyses of linkages between the US invasion and 'oil imperialism'. Iraq has the second largest pool of proven reserves in the world and likely vast undiscovered reserves, as well, since only one-fifth of its known, accessible fields have been developed (Jhaveri, 2004). The direct profit potential of these resources is substantial, as is the potential they confer upon Iraq to join Saudi Arabia as a 'swing producer' capable of influencing global oil prices by managing marginal production. Harvey (2005) sees the US invasion as an expression of these factors and of the pressure states and multinational energy corporations feel to constantly expand their territorial and market reach. The costly, destabilising effect of the Iraq war, however, is

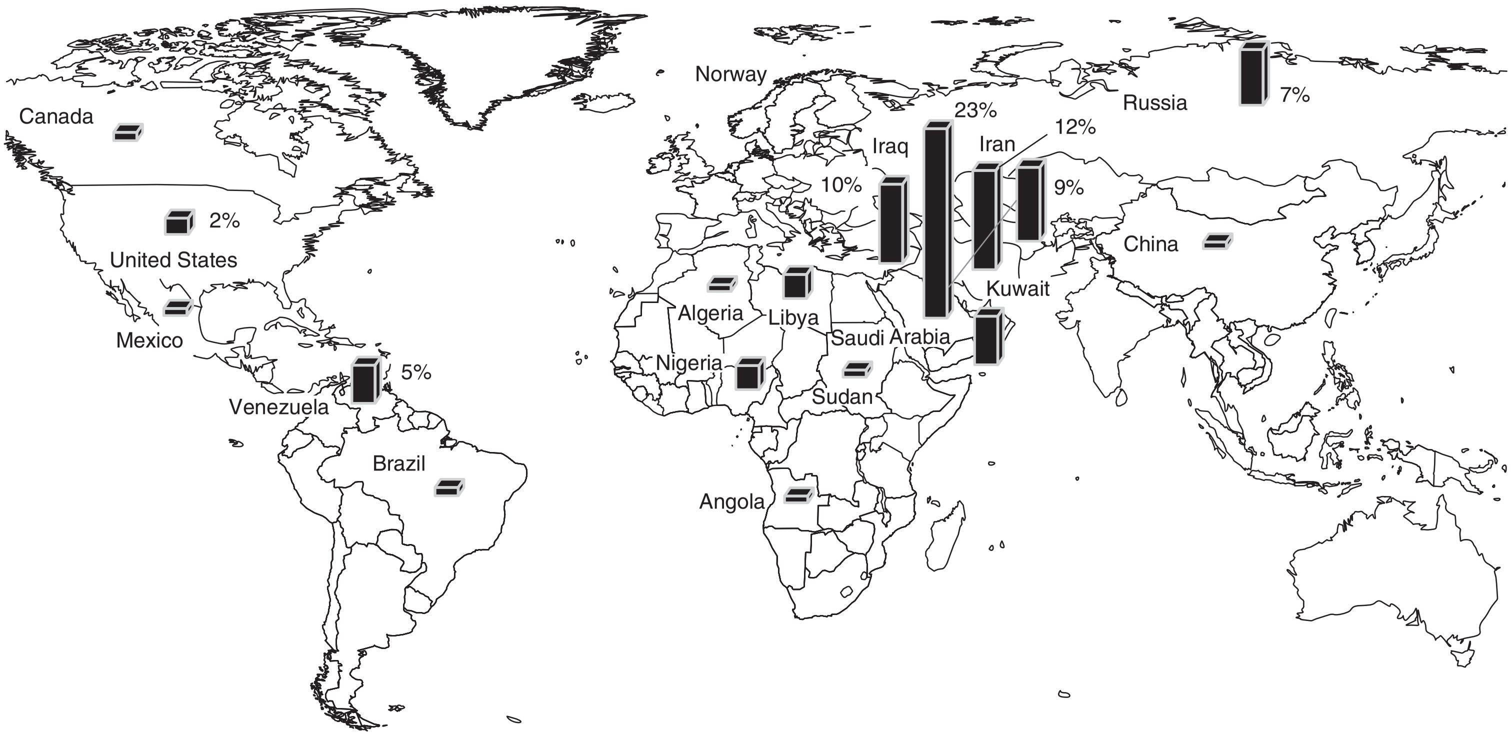

Figure 31.2 Oil reserves estimate 2006. (Source: EIA 2007)

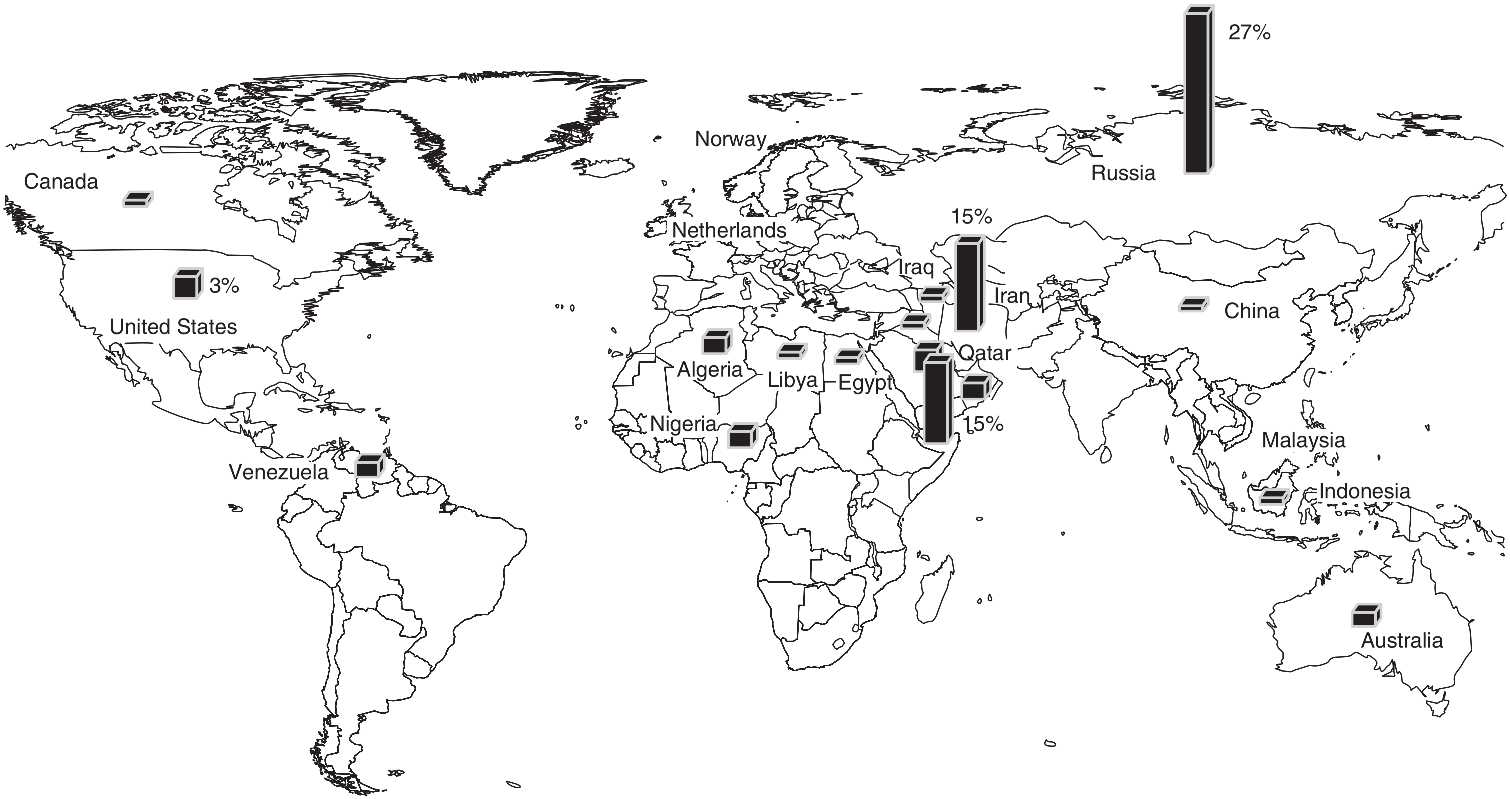

Figure 31.3 Natural gas reserves estimate 2006. (Source: EIA 2007)

certain to dampen enthusiasm for the ‘primitive accumulation’ strategy of securing oil through direct invasion. Instead, nations and multinational energy partners are likely to recommit to a diversified portfolio approach of direct investment, influence-buying, and military exchanges such as China is currently pursuing in Africa (Carmody and Owusu, 2007). Such strategies, however, are embedded in a global oil marketplace that, come a post-peak era, will be far harder to manage and navigate than before.

Whereas global oil reserves are localised and peaking, coal reserves are widespread and abundant (figure 31.4). If extracted at 1995 rates, global measured recoverable reserves would last 250 years (Smil 1999). Most coal (90 percent) is consumed in the country of origin, and so too the politics of coal have typically operated within national boundaries, but potently so – think of US coal miners contesting virtual indentured servitude in 19th and 20th century ‘company store’-era Appalachia, or the signal importance of Thatcher’s defeat of coal unions in restructuring the UK economy in the 1980s. Climate change, however, is bringing coal into the international arena, not as a matter of production access, as with oil, but instead as a matter of regulating consumption, because coal is dirtier and emits 20 percent more carbon than oil and 60 percent more than natural gas. The imminent threat from coal is that, unless curbed by carbon reduction policies, its use will continue accelerating because it is comparatively cheap and simple to use for electrical power generation.

Coal-fired power plants are often sited in rural areas near mining operations that increasingly use *mountain top removal* techniques that are every bit as ecologically subtle as the name suggests. Resulting power is than transmitted over power lines hundreds of miles to urban consumption centres. China’s coal and power industry is quite inefficient (Xie and Kuby, 1997), yet a new coal-burning power plant, with the capacity to serve all the households in Dallas, opens in China every week to ten days producing not just GHGs, but also acid rain and choking smog responsible for an estimated 400,000 premature deaths annually (Bradsher and Barboza, 2006). In the USA, 150 new coal plants were in the proposal phase as of 2006 (Madsen and Sargent, 2006). The pace of future investment in such plants, each with a potential lifespan of decades, will impact both national politics in places like China, where smog is increasingly contested by a nascent environmental movement, and global climate-change progress. Prospects for capturing and sequestering carbon emissions underground, though much touted by coal and electrical power industries, appear limited, at best.

Climate Change and the Politics of Energy Sustainability

The hegemony of fossil fuels remains firmly anchored in strong, if crisis-prone, networks of capital, power, and sunk investment. Climate change concerns, however, accelerated by public concern over the Iraq war and higher energy prices, have engendered a sophisticated, multi-scalar sustainable energy advocacy network. It has succeeded in creating the rudimentary international and local institutions and policy frameworks with which to mount a serious challenge to the ever-upward spiral of oil, gas and coal consumption. The network dynamics and strategies of this movement are critical to reconfiguring how the roles of states, markets, and civil society are conceptualised and institutionalised in the pursuit of sustainable development.

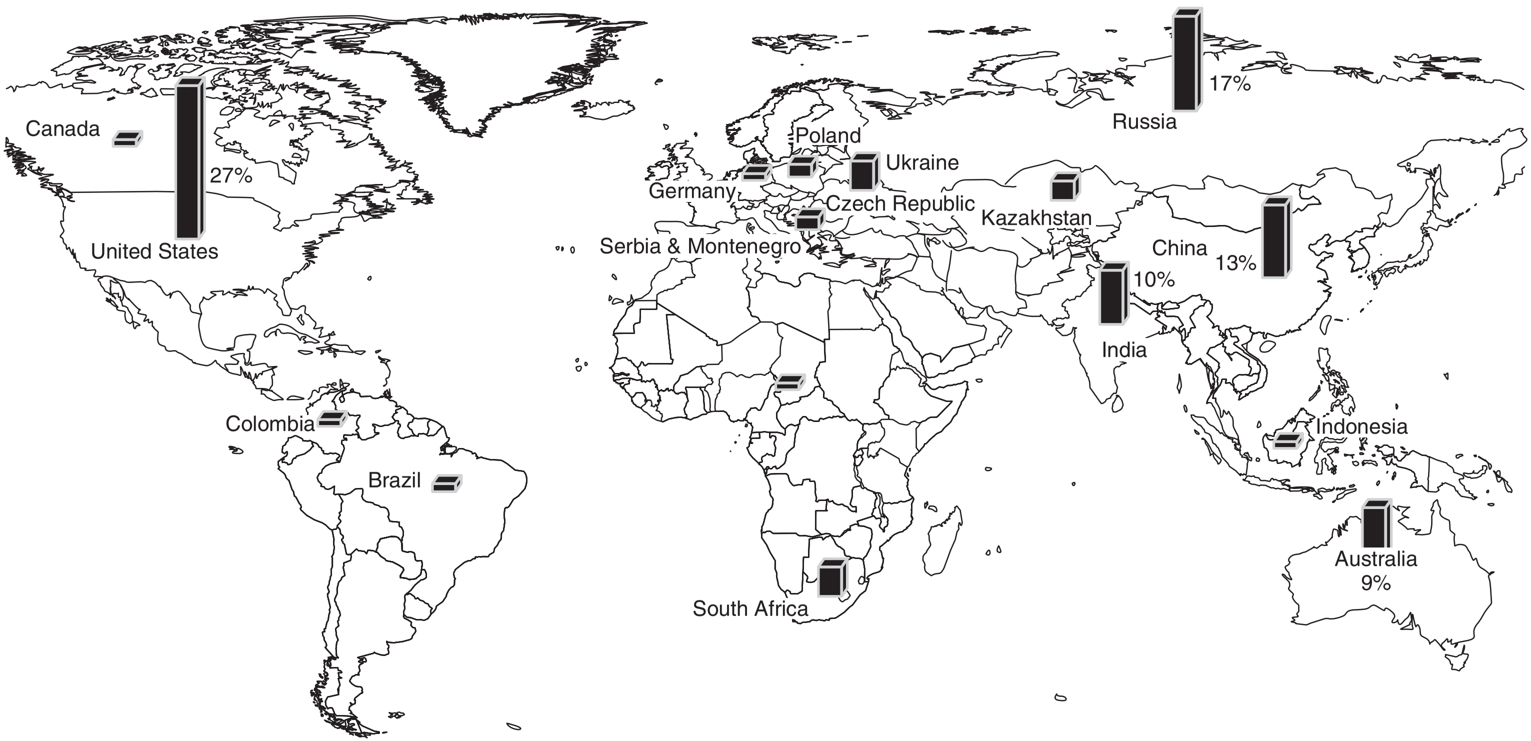

Figure 31.4 Coal reserves estimate 2005. (Source: EIA 2007)

At the international scale, 172 countries have ratified the Kyoto Protocol that commits industrialised nations to reducing their GHG emissions by an average of ~7 percent below 1990 levels by the year 2012. Few nations, however, are on target to meet this goal. Emissions also continue growing in the USA, which along with Australia has rejected the protocol, and in developing countries, which are not yet required to reduce emissions. While having little impact on emissions levels, the Kyoto process is a grand experiment in new institutional arrangements for pursuing international environmental and economic sustainability. The Protocol relies heavily on market-based 'new environmental policy instruments' (Bailey and Rupp, 2005), most notably emissions 'cap and trade' provisions that allocate tradable GHG emission permits so that those who are able to reduce emissions at relatively low costs might sell permits to high-cost emitters, thus reducing the total cost of compliance but introducing complex institutional and ethical considerations (Solomon and Lee 2000). The European Union Emission Trading Scheme and the UN Clean Development Mechanism are presently the two largest institutions facilitating the trading of emissions and emissions credits, and serious questions have been raised as to the effectiveness and transparency of each. Supporters argue problems to date are growing pains to be expected in the complex process of creating a functional GHG market, while others argue the concept of 'pollution trading' is flawed and inherently subject to political manipulation by industry (Davies, 2007). Despite the Kyoto Protocol's strong geographic and social justice implications, it has not been a direct subject of much geographic research.

In the USA, federal intransigence drove environmental activists to focus increasingly on states and localities as potential sites of policy innovation, particularly in the electricity sector that accounts for 40 percent of all US GHG emissions. This effort got caught up in the wave of neoliberal electrical sector privatisation and deregulation that reached America's shores in California following a decade of decidedly mixed results elsewhere (Bacon, 1995). Restructuring overthrew the model of state-regulated territorial utility monopolies that had guided electrical power infrastructure development for a century and replaced it with one based on competition and 'consumer choice' in buying electricity from newly deregulated independent power producers. The California model was a short-lived failure that cost the state and consumers billions of dollars due to 'a confluence of poor market design, fraud, transmission bottlenecks and weather-constrained hydropower supplies' (Solomon and Heiman, 2001, p. ••). Nevertheless the political horse-trading that accompanied 1
power sector restructuring in some two dozen states also ushered in new, more progressive climate-related energy policies, many based paradoxically on new institutions of state intervention. California, for example, recently embraced Kyoto-like mandatory emissions reduction targets, and a number of states support renewable energy and conservation through regulation and financial incentives. While there has been a strong process of policy diffusion and regionalisation embedded in state policy strategies in the USA (Peterson and Rose 2006) and elsewhere (Kent and Mercer, 2006), translating state 'leadership' into serious national progress remains enormously challenging (Heiman and Solomon, 2004; Heiman, 2006). With sustainable energy progress increasingly defined in terms of carbon and GHG trends, geographers have analysed the relationship of state emissions trends to demographic, economic and policy concerns (Rose et al., 2005). Although typically seen as a straightforward empirical exercise, Demeritt (2001) has deconstructed 'greenhouse gas' as a metric of climate change accountability, while Jiusto (2006) shows

how seemingly technical choices in the design of indicators to account for emissions associated with interstate power flows produce dramatically different pictures of state emissions levels and trends and embody sharply different state policy incentives.

In contrast with these 'bottom-up' strategies for addressing climate change, the UK set ambitious national climate goals that required local and regional authorities to develop new energy management capabilities. McEvoy, Gibbs, and Longhurst (2000; 2001) looked at these new sub-national responsibilities and concluded that their potential to 'reduce energy costs, increase local employment, mitigate both local and global pollution, and achieve social goals through the relief of fuel poverty and improved living conditions' (2001, pp. 18–19) will likely go unrealised barring a radical commitment to sustainability in every aspect of local development and more effective intergovernmental collaboration.

In the developing world, where many lack basic energy services and investment capital is limited, priorities for energy sustainability differ and countries face difficult tensions in their energy investment decisions. Taylor (2005), for example, shows that although a major rural electrification program in Guatemala has brought grid access within spatial reach of 90 percent of the population, many rural people simply cannot afford to buy power or electrical appliances. The investment therefore offers little immediate benefit to rural people and leaves unaddressed a crisis in fuelwood supply that represents half the national energy balance and the essential cooking and heating fuel for almost all rural Guatemalans. The study is an interesting example of political ecology concerns and methods – village-level surveys exploring how changing land-use patterns and institutions increasingly limit rural people's access to fuelwood – combined with national energy policy analysis. The gendered, social impacts that come with land degradation and institutional restrictions on access to lands where biomass fuel harvesters compete with others have been well studied by geographers (e.g., Robbins 2001), but rarely in an energy policy framework. Such work will be increasingly important as the Kyoto Protocol fosters financial flows and regimes of accountability for 'clean development' carbon offset projects in the developing world that, while often of questionable value, reduce pressure for curbing fossil fuel use elsewhere.

Nowhere are the unevenly distributed spatial consequences and contradictions of low-carbon energy development more apparent than in the case of large hydropower dams, now pursued mainly in developing countries with large untapped hydropower potential. The scale of such projects can be staggering: China's Three Gorges project has inundated over 1,000 square kilometers and 'displace[d] the most people in a single project in human history' (Heming and Rees 2000,
2 pp. ••). The developmental discourses and politics legitimizing energy megaprojects are explored by Magee (2006) in China's Yunnan Province, where the physical and discursive construction of a 'powershed' of eight hydropower dams served also to reconfigure institutional relationships and decision-making processes among state and provincial agencies and power utility companies. Such projects illustrate tensions between the need for electricity, irrigation and flood control and the upheaval often experienced by rural communities and river ecosystems with few effective civil society institutions to represent their interests. Ironically, in the USA, problems of a massive, ageing hydropower infrastructure have made *eliminating* rather than erecting dams the principal policy focus (Kuby et al. 2005).

Consuming Passions

Given the momentum imparted to conventional energy technologies, the quickest, cheapest and most equitable way to reduce global GHG emissions is to reduce the high rates of energy consumption in developed countries (figure 31.5). In one of the most comprehensive assessments of US national energy policy and technology potential, Brown and colleagues (2001, p. 1179) 'conclude[d] that policies exist that can significantly reduce oil dependence, air pollution, carbon emissions, and inefficiencies in energy production and end-use systems at essentially no net cost to the US economy,' largely by eliminating a large national 'efficiency gap' between actual and optimal investment in energy efficiency due to well-understood market failures and barriers (Brown, 2001; Banerjee and Solomon, 2003). The problem is not that the potential for significant efficiency gains is uncertain – the 'energy intensity' (energy use per unit of economic output) of developed countries has declined for decades as technologies became more efficient, economies shed certain high-energy industries, and government environmental policies encouraged energy efficiency. Indeed, from the mid-1970s to mid-1980s, when these factors were accelerated by energy price increases and a sense of national urgency, US GDP grew by one-third with no net increase in energy use and emissions. Rather, curbing global energy consumption requires dealing with a structural economic problem that is compounded by political and cultural forces.

The structural problem is that economies predicated on continuous growth create constant pressure for increased energy use to produce more goods and services. Although there is an increasingly influential discourse of ecological modernisation based on ideas of the triple bottom line and technical improvements to 'do more with less' (see Mol's chapter), the political constituency seeking to support economic growth by expanding conventional energy systems is typically better funded, organised and politically connected than are the ecological modernizing advocates of conservation and efficiency improvements. For example, until 2007, automakers and auto labour unions had for two decades successfully defeated legislation that would have improved US automobile fleet efficiency. Beyond politics, Hinchliffe (1997) finds cultural reasons, such as the distance many people feel between their own actions and the causes and consequences of socio-economic problems, for why individuals and communities might act neither as economic rationalists nor as environmentally conscious consumers in their energy behaviours. Lovell (2005) uses science and technology studies (STS) concepts to explain why public investment in low energy social housing may not be a sound strategy for diffusing efficiency innovation across multiple housing sectors. Both political and cultural insights help explain why, even in Europe, where support for progressive climate action is strong, efficiency 'policy is progressing too slowly and . . . (t)he most effective policy – minimum standards – is being replaced with the much weaker industry-promoted voluntary agreements' (Boardman, 2004, p. 1932).

Mammals in the Land of Dinosaurs: Prospects for Renewable Energy Resources

Despite the high value of energy conservation and efficiency, they do not eliminate the need to develop low-carbon alternatives to fossil fuels. The best positioned, but most problematic, of these alternatives is nuclear power, for which climate change

Figure 31.5 Primary energy consumption 2004. (Source: EIA 2007)

has been like a fresh spring rain promising renewal through state subsidies and carbon trading credits. Following accidents at Three Mile Island and Chernobyl, nuclear power became for many a paradigmatic symbol of technological hubris ('cutting butter with a chainsaw') posing a range of hazards – in uranium mining, plant operations, radioactive waste disposal, plant decommissioning and nuclear proliferation – that remain largely unsolved (e.g., Pasqualetti and Pijawka, 1996). Although a new plant has not been started in the USA since the 1980s, the industry remains strong in France, and elsewhere, nuclear politics and perceptions are shifting. Sweden, for example, recently put two plants into 'early retirement' before halting its program of nuclear phase-out (Lofstedt, 2001). In Iran, President Ahmadinejad's claim to an 'inalienable right' to develop nuclear power – building upon a program begun with US support prior to the 1979 revolution – has been viewed by many as a pretense for pursuing nuclear weapons development. The regimes of control needed to manage the contradictions of nuclear power make it an inherently anti-democratic technology (Lovins, 1977; Winner, 1986), and the enormous associated costs and risks have private capital refusing to invest absent massive state subsidies in everything from R&D, facility development and radioactive waste disposal to limiting liability in the event of catastrophe. These subsidies are antithetical to neoliberal principals of market competition underpinning power sector restructuring and threaten to divert investment capital away from more sustainable alternatives. Nevertheless, they are gaining serious traction, even among longtime nuclear critics.

Whereas nuclear power reinforces the conventional 'hub and spoke' geography of electrical power grids, renewable energy resources such as solar, wind, small hydro, geothermal and biomass can often be exploited with small, mass-producible technologies distributed throughout the grid. Although accounting for little more than 2 percent of the global commercial energy mix, the resource base for renewables is immense. The wind power potential in just three states (North Dakota, Texas, and Kansas) could meet current US electrical power demand (Pasqualetti, 2004), and solar potential is similarly great. While technical challenges are not insignificant – wind sites are often far from transmission lines capable of handling large, variable generation sources – each type of renewable resource also presents different political potentialities and liabilities.

Wind power, for example, is the fastest growing source of electricity in the USA because the technology has advanced rapidly to become economically competitive with conventional power resources and has been encouraged through state policy (Pasqualetti, 2004). However, as wind turbines become larger and more visible, they become increasingly controversial. Large wind farm proposals, for example, often generate conflictual discourses pitting the benefits of clean energy and rural economic development against those of landscape preservation, tourism, and other land-use options. Pasqualetti (2000) explores how competing social and cultural interests intersect with technological and ecological constraints to produce 'landscapes of power' in the American West and elsewhere. With his collaborators Pasqualetti (2002) offers guidance for reducing conflict that can impede windpower development even in supportive areas like Germany and California. By contrast, Mercer (2003, p. ••) fears geographers and others are giving inadequate weight to 3
'the place of landscape values within the ecologically sustainable development paradigm.'

Unlike windpower, solar photovoltaic (PV) technology is rarely controversial as economies of scale in siting are comparatively few, so that PV arrays need not be overly large or agglomerated. Indeed, their most promising applications are as highly distributed micropower generators located very close to sources of consumption, such that they *reduce* rather amplify burdens on transmission and distribution systems. PV is reliable, long-lived and technically feasible even in locations of moderate sunshine, but comparatively expensive. Thus, PV growth forecasts are meager (Energy Information Administration, 2005), despite increased state and federal policy support that only marginally offset historical subsidies for conventional energy sources. New thin film and other technologies for integrating PV into roofing shingles, exterior siding and other building components will likely open up other applications. Furthermore, PV production is based on techniques and principles of the semi-conductor industry, suggesting far greater potential for continuous, shorter cycles of innovation and deployment than conventional power technologies like coal and nuclear. Other solar energy applications, such as daylighting and passive space and water heating, often pay back quickly, but remain underutilised due to design ignorance. Geographers have taken surprisingly little interest in solar energy issues, such as contextual analysis of solar power in the Third World, where the developmental vision of green, independently generated power can conflict with local perceptions of solar as an inferior and theft-prone 'poor people's' substitute for 'modern' grid power. Cultural perceptions in the West can likewise inhibit solar development. California is proposing renewable energy requirements in new construction that will make sound energy investments as routine and 'sensible' as buying ever-larger homes packed with hot tubs, home cinemas and other energy-hungry amenities.

The contradictory politics and analytics of energy are also exemplified in the case of biomass fuels, which include everything from woodland forage to 'energy crops' to sewerage. While residues from agricultural, forestry and mill operations comprise 70 percent of the biomass energy potential in the USA (Milbrandt, 2005), it is ethanol for transportation, currently just 3 percent of the US renewable energy total, that has received the lion's share of attention, driven largely by a discourse of reducing dependence on imported oil. In current practice, ethanol does little to achieve this goal because it is mostly based on fossil fuel-intensive corn monocultures and federal and state incentives that reflect the interests of agribusiness more than sustainability. The estimated EROI of corn ethanol is less than 2 : 1, versus 15 : 1 for oil, meaning that most ethanol investment (in crops, money, labour and fossil fuels used as fertilizers) goes simply to reproduce the ethanol industry, rather than for other purposes (Cleveland et al., 2006). Potentially much more promising are cellulosic ethanol systems using switchgrass or other plants grown on marginal cropland with few inputs, and venture capital is pouring into such schemes. A geopolitics of ethanol is beginning to emerge as the USA and Brazil, the world leader in ethanol production based on comparatively high EROI sugar cane, seek a strategic ethanol alliance that will open up new opportunities for capital investment in Brazil and Latin American following defeat of the Free Trade Agreement of the Americas and counter-leftist Venezuelan President Hugo Chavez's petro-financed regional ambitions (Zibechi, 2007). A prominent promoter of the alliance is the Inter-American Ethanol Commission under the direction of Jeb Bush, brother of oilman and US President George W. Bush, underscoring in a small way the kind of shifting and contradictory allegiances that maintain, and may yet undermine, a century of oil hegemony.

Energy and Geographic Thought

As we have seen, the paradox of conventional energy systems is that they are, at present, essential to economic productivity and social well-being and yet enormously destructive, crisis-prone and unsustainable. While the thermodynamic potential of renewable energy resources far exceeds demand for energy services worldwide, it remains that in most places and in global aggregate, far more social investment goes to maintaining dependence on fossil fuels and other conventional resources than to developing clean and efficient alternative energy systems. The question is why?

One answer is that the conceptual underpinnings of the dominant economic theory informing conventional energy policy are fundamentally flawed. Geographers active in the field of ecological economics argue that energy insights are essential to conceiving alternatives to neo-classical economics that recognise human economies as embedded in environmental systems which provide essential services that must be adequately accounted for in economic decision making (Hall et al., 1992). Critical among these services are the supply of low entropy, high-quality energy resources needed for productive activity and the reprocessing of high-entropy waste from human activity back into sustainable cycles of ecological renewal. This line of research challenges the bases of mainstream economic estimation of climate change mitigation costs, and certainly those studies used by the Bush administration and others to claim that carbon reduction policies pose grave threats to economic well-being. It also challenges the wider assertion that 'economic growth is the best environmental policy' espoused by some opposing GHG limits, and echoed in academic research suggesting that industrialisation brings with it processes of ecological modernisation that reliably engender the capital, knowledge and politically empowered citizenry necessary to move countries along an 'environmental Kuznets curve' of decreasing pollution and decarbonisation (Selden and Song, 1994). The empirical basis for such claims is weak (Cleveland and Ruth, 1999), and offers little hope that 'autonomous' economic processes will resolve the problems posed by conventional energy systems (Richmond and Kaufmann, 2006). Similarly, the idea that neoliberal privatisation and deregulatory restructuring of energy systems will improve economic and environmental performance rests far more comfortably in the realm of theory than experience (Solomon and Heiman, 2001; Heiman and Solomon, 2004; Perkins, 2005). Clearly, better conceptual understanding of systems of energy, ecology and economics is needed to guide decision making.

Such work often lacks a critical, political economic perspective that can help explain the entrenched, though hardly static, power of fossil fuel and nuclear industries, and illuminate emergent strategies that might reshape these configurations of power (though see Kaufmann, 1987). Presently, geographic research, like most energy research, all too often seems to assume that the route to sustainability lies largely in sound technical analysis and sober planning. It tends to overlook the often brutal way in which 'policy' gets executed on the ground around the world. Beyond the perils of imperial oil lie largely unexamined, geographically contextual struggles over the future of energy industries playing out globally in highly varied ways. Similarly, the complex top-down and bottom-up scalar strategies of sustainable energy advocacy operating through cities, states and nations are crucial to understanding and enhancing transformational potentialities. One avenue to realising these potentialities lies in overcoming the discursive constraints that too often limit 'serious' policy analysis to narrowly technical and economistic discourses. Another need is to better understand and counter the processes of commodification that obscure the full social and environmental impacts of conventional energy systems and the power interests they serve. Climate change and the US engagement in Iraq provide unwelcome, but nonetheless important, new opportunities to make visible more of the trauma embedded in 'business as usual' energy scenarios.

Ultimately, the reality of energy transformation plays itself out on the ground and in the air, as social and technological networks become manifest in energy capital stock. 'Landscapes of power' are produced and reproduced at various scales through conflict over dams, wind turbines, coal and nuclear plants, and access to oil, forests, and fields. Presently, the gigantism of conventional energy systems produces, on the supply side, unhealthy concentrations of social power and ecological impacts, along with, on the demand side, profligate, disconnected, commodified consumers. Because investments planned for coal, oil and nuclear are simultaneously investments not made in wind, solar, or efficiency, virtually all business-as-usual forecasts suggest the age of massive, centralised energy systems and their problems is far from over. There are, however, indications that emerging within the interstices of conventional energy systems are possibilities for more highly distributed energy networks, ones that are composed of far smaller, more numerous, and 'smarter' technologies that could be aligned more closely with the ecological and social conditions of particular places (Lovins and Rocky Mountain Institute, 2002). This vision of the next energy revolution – one that emerges from a deep understanding of the transformative power of energy systems and a commitment to local empowerment – can surely arise only as part of a movement redirecting political and corporate incentives towards sustainable communities, small and large. A tall order, but one full of possibility for geographers.

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