International Handbook of Energy Security

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22. The road not taken, round II: centralized vs. distributed energy strategies and human security

Ronnie D. Lipschutz and Dustin Mulvaney

INTRODUCTION

Thirty-five years ago, in the midst of the energy crisis of the 1970s, Amory Lovins published an article in *Foreign Affairs* warning against the United States' plans to increase its reliance on nuclear power as a path toward reducing dependence on imported oil (Lovins 1976). Not only would a large nuclear program – an order of magnitude more nuclear plants are in operation in the U.S. today – raise significant safety and security risks, argued Lovins, preventing the theft of weapons grade nuclear materials would require a highly-centralized and authoritarian infrastructure, with corrosive effects on American democracy and individual freedom (see also Ayres 1975). A decade later, Langdon Winner (1986) echoed these sentiments and argued that technological artifacts such as nuclear reactors have important implications for social order because of their entanglements with questions of nuclear weapons proliferation. Both Lovins and Winner were essentially arguing that socio-technical systems, such as those that make possible electrification of human society, have social tendencies independent of human intention, and that differing technological paths would have different kinds of social impacts and, by extension, effects on human well-being and security.

Lovins also argued that, by contrast, solar energy technologies did not rely on either risky or far-away energy sources and were more amenable to decentralized modes of energy procurement and generation. These features, he claimed, would promote energy autonomy, democratization and even reduce the political and economic power of electric utilities and energy corporations. Solar energy is freely available to anyone able to capture it *on site*, making it suitable for decentralized, small-scale, distributed power generation (DG).[1] Photovoltaic (PV) technologies, in particular, enable people to electrify homes and businesses with limited reliance on or even no connection to the electricity distribution grid, fostering a sense of energy autonomy and freedom, and enhancing well-being and security. Already in the early 1970s, *The Whole Earth Catalogue* (http://www.wholeearth.com/index.php, accessed February 22, 2013), Stuart Brand's counterculture publication offering "designs for living," included plans and advertisements promising PV systems that could increase the energy self-reliance of communities and individuals (Turner 2006), and the country as a whole.

In the intervening decades, solar energy and PVs have become well-developed and mature technologies, proving cost-effective in a wide range of settings yet largely failing to fulfill the promises made by Lovins, *Whole Earth* and many others. Even today, as the cost of rooftop PV systems has enabled numerous middle-class consumers and companies to solarize their homes and businesses (Cardwell 2012), distributed generation (DG) still provides only a small fraction of the country's electricity needs. As far as reducing fossil fuel dependence, renewables have, so far, proved unable to substitute for much oil, which is not much used in the power sector but dominates in transportation (a shortcoming shared with nuclear power). Nuclear power is unlikely ever to achieve the lofty goals set in the 1970s, while coal and natural gas, two of the world's mainstays for generating electricity, remain remarkably cheap. Most of the world has found it economically and politically difficult to shift away from fossil fuels even in light of growing risks from climate change. What has gone wrong? Or, in the immortal words of China's Prime Minister, Chou En-Lai, when asked for his assessment of the French Revolution, replied, "It is too soon to tell" (McGregor 2011). Perhaps the solar revolution has not yet arrived, even if it is around the corner.

What is arguably different today are the rising risks and impacts of continued reliance on fossil fuels and nuclear energy, exacerbated by impending climate change. The Fukushima disaster of 2011 demonstrated not so much the hazards of nuclear power as the enormous social and economic vulnerabilities of heavy reliance on technologies that sometimes suffer catastrophic failures. Numerous predictions that global fossil fuel consumption will continue to increase during the coming decades, notwithstanding the threats and risks of climate change, suggest that concerted action to transform energy systems is unlikely to happen. Continued reliance on an aging power distribution infrastructure, evident in large-scale regional power blackouts, raise questions about greater concentration and centralization of power generation strategies. Finally, repeated warnings that cyberhackers, whether civilian or military, could gain control over or disrupt the power sector, with catastrophic consequences for the country's infrastructure, should not be ignored. All of these shortcomings are of concern where human welfare and well-being are concerned; the effects of extended power outages and broken distribution systems become only too evident in the aftermath of destructive hurricanes, tornadoes, floods, tsunamis and even human error.

None of this is to say that renewables are wholly safe and risk-free, or could wholly eliminate threats to human security. A full life-cycle analysis of various solar, wind and biofuel technologies reveals a host of associated problems, such as land use change, toxic materials, damage from mining of rare earth elements and other minerals, threats to species diversity and even waste disposal issues. If deployed in a centralized fashion, renewable power is as vulnerable to regional blackouts as any other fuel source. Vaclav Smil (2010) points out that renewables require more land due to lower power densities, which means that extensive deployment will invite more opportunities for land use conflicts with other species and communities. PV is ideal for DG and can be sited atop the human footprint, and can fulfill many regions' energy needs. A full tally of the ecological and social costs of renewable energy sources indicates that they offer greater benefits with fewer externalities than fossil and nuclear sources, especially if climate change is taken into account. More to the point, and somewhat reminiscent of Lovins's arguments, if deployed in a distributed, decentralized fashion, in the form of electricity micro-grids, there could well be a number of positive and socially-beneficial consequences that would not only reduce overall environmental costs but also enhance human security. An important caveat: these effects would not result from any inherent qualities of the technology but, rather, deliberate and intentional policy and design.

In this chapter, we undertake a comparative assessment of the impacts of centralized and decentralized energy sources and strategies, their inherent and constructed political and social qualities, and the environmental, health, safety and security implications of the two alternatives, especially as they affect "human security." In this instance, the term *human security* refers primarily to societies' and individuals' health and well-being, rather than national or military security. The two concepts are not mutually exclusive, but the latter has been plumbed in great depth for at least 40 years, while the former has not. We begin the chapter with a brief discussion of "human security" and what is encompassed by the concept. Although national security has been challenged as the basis for public and foreign policy since the 1980s (e.g., Ullman 1983; Lipschutz 1995), as we shall explain, the changing organization and structure of markets, in particular, has driven a shift towards greater focus on individual security in the context of broad practice.

We then turn to a discussion of the relative costs and benefits of centralized and decentralized energy strategies, with particular attention to the vulnerability of large-scale power plants and grids. As we shall see, while first order analyses focus on reliability, resilience and vulnerability, it is also important to consider second order environmental and third order life-cycle impacts. Such assessments are not quite as straightforward as they might seem, as illustrated by the parallel case of the miniaturization and decentralization of computing technologies, which have highly-sophisticated, low-cost devices available to many of the world's people. But they have also resulted in complex and potentially vulnerable networks as well as growing volumes of front- and back-end toxic wastes, with concomitant health risks. By contrast, large, mainframe computers and communication networks might not offer the freedom and creativity available from desktops, laptops and tablets, but they do concentrate many of the risks and hazards associated with the latter.

In the third part of the chapter, we turn to a more detailed description and inventory of centralized and decentralized *renewable* power production (the risks and hazards of fossil and nuclear fuels are relatively well-known, and we address them here only briefly). We also offer a few case studies of both, in order to illustrate comparative costs and benefits, especially from the human security perspective. To characterize the tensions and problems arising from large-scale centralized energy production systems, we examine the California desert, where several renewable energy projects have generated considerable controversy and opposition (Ivanpah solar, Genesis solar, and Ocotillo wind). We contrast these with decentralized projects and project proposals to integrate solar energy projects into the footprint of existing human infrastructure. Note, however, that the latter are, for the most part, conceptual and in the design phase, and so the full panoply of potential issues has not been inventoried from actual experience.

In the concluding part of the chapter, we summarize some of the risks and vulnerabilities to which both types of systems are subject, ranging from economic and political to social and environmental, and suggest areas of further research that could help to clarify the comparative costs and benefits of the two strategies. We also return to the issue of human security, and discuss how the two approaches might affect it. We should note that, although there are good reasons to value the individual freedoms that might result from less reliance on centralized power systems, most of the world's people lack the capital to access decentralized technologies, and over 1.5 billion people live in energy poverty, having no access whatsoever to electricity. The security benefits to the latter of *any* generating technology would be substantial.

DEFINING HUMAN SECURITY

Although the concept of "human security" has only entered the political lexicon over the past couple of decades, it is not a new idea. Human security encompasses not only health, welfare, and well-being, but also environmental and structural conditions that might affect social order and diminish people's quality of life. As such, people are "secure" when the circumstances of their lives provide access to basic necessities, such as food, water, energy, housing, healthcare, education, employment and income as well as protection against depredations and oppression by others, whether neighbors, governments or other countries. To this, we might also add those freedoms, liberties and opportunities that offer people at least the possibility of a full life and the right to decide how they will be governed, and by whom (see, e.g., Sen 1999; Newman 2010). By most accounts, there are as many as two billion people – and possibly more – who are not secure and lack one of these critical necessities (Lipschutz and Romano, 2012).

In this chapter, our particular concerns are with the ways in which the systems and mechanisms that provide energy – what might be called the "energy assemblage" – can affect human security. We have enumerated some of these effects above, but offer here a more detailed, albeit incomplete, list.

- Lack of adequate energy supplies, especially in intemperate climates, can have a direct impact on individual and community health; in those circumstances in which local fuel materials are in decline or depleted, the very project of accumulating them may have far-ranging social and environmental consequences.
- Situations in which supplies of potential energy are enclosed and access restricted to people – as, for example, in the case of dams and reservoirs – can result not only in water scarcity but also in denial of access to food, land, and other basic needs.
- The high costs of liquid fuels, such as kerosene, drives people to rely on wood, charcoal, dung and other biofuels, all of which can lead to deforestation and have deleterious health effects, especially if burned in poorly-ventilated spaces.
- The processes of extracting fossil fuels are very dirty and where poorly-regulated, as in the Niger Delta of Nigeria or the mountains of West Virginia, can undermine local living conditions and environments, not to mention general health and well-being.
- The manufacture of semiconductor devices, including solar PV cells, can expose both workers and environments to toxic materials released into the factory environment, water sources, arable land and the atmosphere, problems exacerbated with the rise in contract manufacturing.

- The operation of large-scale power plants continues to contribute to air pollution and, where coal is being burned, to large quantities of coal fly ash, even though, in some parts of the world, these have been greatly reduced over the past 60 years.
- While nuclear power plants have a fairly good operating and safety record – with a few notable exceptions – the safe and effective disposal of nuclear wastes, especially in the United States, has yet to be successfully accomplished, and there is a great deal of uncertainty about the long-term safety of storing spent nuclear fuel rods in "swimming pools" at reactor sites.
- Energy distribution systems are subject to accidents that can have deadly consequences, such as when oil and gasoline pipelines are sabotaged, or improperly monitored, and explode with sometimes considerable loss of life; high voltage transmission lines are much safer, although there continue to be concerns about the effects of exposure to them.
- Improper disposal of decommissioned energy systems and components, such as batteries, PV semiconductors and nuclear plant parts, can have both short- and long-term health effects, if not property contained.
- Excessive reliance on fossil fuels increasingly appears to be driving global climate change in highly-undesirable directions, which will have a broad range of negative effects on human security.

The ways that the energy assemblage affects and undermines human security are very unevenly distributed, leading to frequent and severe cases of environmental injustice and racism. Those living in wealthy countries tend to experience fewer of these inequalities, and they often have recourse and income to respond to the majority of them. By contrast, the world's billions of poor people are much more vulnerable to the uncertainties of energy supply, risks and hazards. This is not to argue that renewable DG is, somehow, a panacea for the lack of security faced by those billions; there are many other sources of insecurity facing them that energy cannot address. From our perspective, a critical question for human security is how to provision electricity. How will choices that affect the degree of centralization versus decentralization shape the effectiveness of energy delivery (volume, time, reliability) and cost (health, social, environmental and economic)? As suggested above, a full understanding of the comparative costs, risks, hazards and vulnerabilities of energy alternatives, and their implications for human security, is far beyond our capacity or the space available in this chapter, but we endeavor to address the question as comprehensively as possible.

ROADS NOT YET TAKEN

Certain aspects of warnings issued by Lovins and others during the 1970s remain salient today, and are being recapitulated in contemporary debates around renewable energy, especially solar and wind. Lovins called for soft energy paths with soft social impacts, arguing that they would reduce inequality, social conflict, vulnerability, democracy, and freedom. New discourses of clean energy focus primarily on climate change impacts, sometimes at the expense of social impacts. Whereas, 40 years ago, it was the "energy crisis" and nuclear safety that provided the context for analysis and public policy, most of the emphasis on energy transitions today is in the context of climate change and political instability, which has refigured politicians', scientists' and engineers' preferences in terms of the technological composition of future energy infrastructures. The new emphasis on "low-carbon" or "clean," rather than simply "renewable," energy sources has broadened the scope of energy scenarios on offer to include natural gas and nuclear for their lower carbon emissions profiles. Indeed, this emphasis has led even the coal industry to tout the benefits of "clean coal" and warn darkly of growing reliance on natural gas from fracking.[2]

The transition to new sources of energy has also been framed in terms of technological and distribution scales, on the assumption that meeting the challenge of global climate change requires a planet-wide and rapid response. The lack of progress in international climate change negotiations has raised widespread doubt that such a global energy strategy will ever be forthcoming. A further complication is that new energy technologies typically require 50 years to be fully integrated into supply and demand systems, while electrical infrastructure operates on a 40-year replacement cycle (one that has been lengthened for a growing number of power plants). The potential for "tipping points" and catastrophic climate change (Lenton et al. 2008) has underscored the importance of getting new energy sources to scale as rapidly as possible, which has led most countries to focus on large-scale, centralized renewable energy projects with short-term planning horizons and hastened approval processes. What is not so clear is where the large volumes of capital required to finance a new power infrastructure will come from, whether renewable or not. The International Atomic Energy Agency (Birol 2004), for example, has predicted a need, between 2001 and 2030, for about $350 billion per year to meet global electricity demand. While the net cost of a wholly renewable electricity assemblage might be greater, the price of individual DG projects would be far smaller than the $1–5 billion required for many large power plants.[3] Moreover, while larger projects may have lower levelized costs of electricity, the question is prices for whom? Renewables may not yet be able to compete in wholesale electricity markets delivered through centralized systems, but DG is already at grid parity for many electricity consumers who must buy electricity at retail rates (Denholm et al. 2009a). To take advantage of this, however, still requires considerable upfront capital.

What, then, does a DG system look like? The basic principle underlying DG is that any particular location that experiences a sufficient inward flow of solar or wind energy – complemented, perhaps, by heat pumps, micro-hydro, solar hot water heaters and biogas generators – can provide a significant fraction of that location's electricity (and energy) needs. These vary, of course, from basic cooking and light all the way to large-screen TVs, pool heaters and electric cars – which is why it is easier to meet the supply criteria in poor societies, where electricity demand is relatively low. In wealthier communities, it is often less costly to reduce electricity demand through efficiency and conservation than to install capacity to meet peak usage. To date, the most common deployment of DG systems is to supply a single house or building; it is more cost-effective and efficient in the long-run to design and size DG for a group of consumers, whether constituted by a neighborhood, a cluster of businesses or some other configuration. Not only does this make available greater rooftop area for PV panels, it also affords greater opportunities for internal load-leveling, behavioral change and user involvement in system operation as well as offering some flexibility during grid failures.

At the same time, however, renewable energy sources are intermittent. The sun does not shine 24 hours a day nor does the wind blow at a constant velocity. Sometimes, a DG system generates more than is demanded; at other times, less. There are various ways to address this mismatch. At the present time, most DG systems in the industrialized world are hooked into regional power grids, which rely on them to effectively reduce power demand. Critical to effective DG is energy storage, whether through batteries, off peak hot water heating, fly-wheels, pumped-hydro storage, or compressed air (Denholm et al. 2010). Load leveling, which redistributes tasks from high demand to low demand periods, can also reduce storage and backup requirements. What remains to be seen is how DG systems and larger utility grids will be integrated (Shirmohammadi 2010; Delucchi and Jacobson 2011) as well as the role that consumers will play in operating such systems (Fischer 2006).

While the technical capabilities to deliver decentralized or distributed renewable generation continue to improve and, in some instances, are more cost-effective than conventional sources, tensions with centralized renewables and their operators are growing in prominence (Marnay and Bailey 2004). For technical, financial and management reasons, electric utilities, power generators and even governments prefer to pursue the traditional unidirectional model of power delivery: large mega- and giga-watt generators with extensive and interconnected distribution grids ultimately feeding electricity to end users. Where DG is being embraced by public policy, popular imagination and a broad range of small-scale development projects, investor-owned utilities in the United States are coming to regard DG as highly-problematic, for several reasons. First, as a result of deregulation, electric utilities are less and less involved in the business of generation and more and more in purchasing power from independent companies operating large plants, on the theory that this introduces competition to the power market. Assuming that they would provide their surplus power to the grid, DG would simply multiply the number of *small* independent generators with which a utility would have to deal, greatly complicating both business and technical aspects of managing the system. Second, a plethora of DG systems linked into a larger grid could introduce load instabilities due to changing demand and excess power when it might not be needed elsewhere. Third, and perhaps of greatest concern to utilities, is their complaint that customers with PV systems expect to be paid for the surplus power they put into the grid but not have to pay for the capital and maintenance costs of transmission and the distribution infrastructure.[4]

Resistance to DG is therefore considerable, and utilities appear to prefer centralized renewable generation. Large organizations tend to develop "standard operating procedures" tied into particular forms of technology and experience; changing those practices impose significant transaction costs and involve steep learning curves. It is much easier to keep doing what one does reasonably well – although, as American auto companies have learned, this can be a path to perdition – rather than adapting to new technologies, rules and practices. This suggests that centralized systems are subject to entrenchment, owing to the substantial periodic investments required to maintain them. It also points to another reason that utilities and power generators have shied away from DG.

As we noted earlier, centralized power generation is not without costs and risks, including environmental and other impacts and implications for human security and safety. Decentralized energy is not a panacea for all risks and hazards, and there is no predetermined relation between technology and democracy, as Langdon Winner (1986) has warned. But there are good reasons to pay attention to the comparative risks and benefits of energy system design, scale, and organization and their implications for human security and well-being. Typically, such costs – which economists call "externalities" – only become apparent after a great deal of time, energy and money has been spent. For renewable DG, the short-term on-site risks and hazards are a good deal smaller than for centralized power plants, yet those will be much more widely-distributed. More homeowners are liable to fall off their roofs than technicians off power plant catwalks (but there will be fewer catastrophic accidents). The risks and hazards experienced by the DG owners and operators are voluntarily incurred rather than unilaterally imposed, as is the case with air pollutants, fracking and nuclear power. On a life-cycle basis, the greatest risks and hazards from renewable DG are to be found in materials mining and processing, manufacturing and, ultimately, disposal (Fthenakis et al. 2008). Unfortunately, externalities in renewable energy supply chains tend to be "out of sight, out of mind," and efforts to regulate them are still quite limited (McDonald and Pearce 2010). Redistribution of the health and safety impacts of electricity generation from the wealthy to the poor is hardly a new practice, but that is no reason to continue it (SVTC 2009).

Where DG could well have its greatest impacts is in those parts of the world now lacking reliable power supplies or any electricity at all. It is estimated that close to 1.5 billion people lack access to electricity, while many more are connected to power systems that operate only sporadically. Even small amounts of power – as little as 100 watts and one kilowatt-hour/day – can make enormous differences in the well-being and quality of life of the world's poor, while a few kilowatt-hours daily can be used to procure water, electrify maternity wards, and refrigerate vaccines. Given the high capital costs of building new centralized power plants and distribution systems, paying for the fuel and collecting tariffs from the very poor, locally-deployed solar, wind and biogas systems, with ordinary lead-acid batteries, can provide a very modest level of power at relatively low upfront cost (Narula et al. 2012). DG can also reduce electricity theft and the very real risks and health hazards that arise from stealing power from the centralized grid.

THE COSTS AND BENEFITS OF LARGE-SCALE CENTRALIZED RENEWABLES

To recap the essence of Amory Lovins's argument, centralized energy delivery and distribution systems pose a host of safety and political problems that could be avoided through a transition to decentralized, on-site renewable sources of energy. Lovins did not consider comparative life-cycle issues, nor did he offer any more than a deductive argument regarding the relationship between decentralization and democracy. Today there is increasing attention to the fragility of the global petroleum system, the emergence of climate change as a political issue, the ever-rising capital costs of centralized power plants, the water and carbon pollution problems arising from extracting unconventional fossil fuels such as shale and tar sands, and the complexity and vulnerability to disruptions of critical data transmission networks.

At the same time, the costs of electricity from smaller-scale renewable technologies continues to decline and their popularity continues to grow. Major changes have taken place in the organization of power production and distribution, especially as a result of deregulation and independent generation, but repeated attempts to incentivize a large-scale transition to DG have met with only limited success. Why? It might be useful to compare the power and telecommunication sectors to see how the combination of technology, social innovation and cultivation of demand have led to near-revolutionary changes. To be sure, the degree of miniaturization achieved through micro- and nanotechnology are, as yet, hardly applicable to the power sector, especially given the low power densities of renewable sources. However, there are useful parallels.

In the case of telecommunications, we see how the American state, in particular, played a significant role in jumpstarting technological innovation, through the defense sector. Not only was the early development and demand for semiconductors funded and stimulated by government demand, the Internet also was born out of a government-sponsored project to develop a secure and invulnerable communication system and to further rapid contacts among research scientists. The original microelectronics companies – Hewlett-Packard, IBM, Xerox and others now forgotten – were government contractors before they were commercial providers of technology. While they have not proven as agile in the market as later startups – especially Apple – they did provide an important organizational bridge between state and market demand. Ultimately, the decreasing size and rising capacities of computers and other electronic devices, stimulated further research and consumer demand, bringing the devices into the reach of even the very poor. The growing availability of various forms of narrow and broadband communication have stimulated network growth and transmission speeds, again leading to further innovation across a broad range of technologies and practices. This is not to argue that the result has been wholly salutary; such complex systems lend themselves to both productive and destructive activities (Noble 2011).

In the case of DG, if various PV and wind generators represent the technology – both of which have grown out of initial developments in the military sector – and national and transnational electricity grids represent the network – albeit not quite so unitary as the Internet – it is the social organization of electricity markets that have yet to undergo significant transformation. The Internet was never run as a public utility, subject to the kinds of government regulation that entails, and so it has not had to throw off that institutional form.[5] By contrast, deregulation in the power sector has not sought to break up large utilities, whose commitments to large-scale generation remain steadfast. On the Internet, anyone can hang out a shingle and try to sell goods and services; so far, small-scale generators are not permitted to do so (how this might come about is a public policy question we cannot as yet answer). We could imagine arrangements in which DG plants were permitted to contract with other DG plants nearby in some kind of power exchange, although this would require cooperation of the owner-operator of the distribution system.

One result of this centralizing tendency in renewable generation is a rush to stake out solar- and wind-intensive sites, with strong encouragement and incentives from government. According to Dian Grueneich (2012), 29 states, two territories and the District of Columbia have developed Renewable Portfolio Standards, while the DSIRE database (2012)[6] indicates that every American state and several territories offer financial incentives to renewables. The future for centralized renewables looks bright, albeit with visible and growing smudges. As of mid-2012, across the United States some 31.5 GW of solar (SEIA 2012) and 60 GW of wind (AWEA 2012) generating capacity, with a footprint of some 8,350 square miles[7] (Jacobson and Delucchi 2011) are in operation or in the planning and construction stage. Already, a number of shortcomings and problems are becoming evident, generating opposition and stoking what some have called a "Green Civil War" (*New York Times* Editors, 2012). Controversial large-scale solar energy and wind projects are impacting sensitive ecological habitats and literally running over endangered species as well as widespread public concerns (Solar Done Right 2012). The imaginary of those who promote large-scale solar is best captured by the "Solar Grand Plan," whose supporters argue that public lands in the desert southwest would be well suited for solar electricity generation (Zweibel, et al. 2008). Indeed, the U.S government is setting aside tens of millions of acres of public lands in the Southwest for such projects (Fears 2012), in the expectation that dispatchable solar and wind projects will be developed by private firms to deliver electricity to utilities. What do such projects look like, and what are their environmental and social impacts? Here, we offer three cases.

Ivanpah Valley and BrightSource

The Ivanpah Valley is situated about 25 miles south of Las Vegas in the California desert, just outside of the California-Nevada border town of Primm, Nevada. The valley is vast and gently sloping, 30 miles across from north of Primm to the headwaters of the New York Mountains to the south. The valley's higher elevation flatlands, such as near Cima, California (population: 21), contain the densest population of Joshua trees (*Yucca brevifolia*) in the world. Creosote (*Larrea tridentate*) chaparral dominates the lower elevation flatlands such as those at the proposed project site (a clonal colony of creosote nearby is considered by some to be the oldest living organism on Earth). The Ivanpah solar project site is adjacent to the Mojave National Reserve and known to desert ecologists as an important habitat for the threatened desert tortoise (*Gopherus agassizii*) among several other important reptile, mammal, and plant species.

BrightSource is a solar energy company whose founder, Arnold Goldman, received the World Economic Forum's Technology Pioneer Award for his work on solar power tower technology. He was the designer of 10 solar electricity generating systems (SEGS) built from 1984 to 1990 by Luz Industries, called SEGS I through IX (only nine were built), that still operate in the California desert today, providing over 350 MW of power. As early as 2006, BrightSource filed a petition to acquire about 8,000 acres of public lands in the Ivanpah Valley. Upon hearing of the project, most local ecology and public lands groups opposed the project, yet a number of national environmental groups endorsed the project because of its potential to mitigate GHGs from electricity generation. This became an important proposal, as it pitted local groups against the national organizations. For example, the desert chapter of the Sierra Club vehemently opposed BrightSource's Ivanpah project, while the national chapters chastised the local groups for lacking a commitment to efforts to slow climate change.

While numerous ecological impacts were noted during the siting hearings, the major impact identified was to the desert tortoise. The United States spends more money protecting the desert tortoise than on the grizzly bear, bald eagle, and gray wolf combined. The project would require the company to obtain an incidental take permit, implying that the project will harm up to a specified number of the threatened tortoises. To estimate the number of take permits required to construct the facility, consultants initially surveyed the project and suggested that the project would impact 12 to 24 individual tortoises. Yet, when preparations for construction were initiated, more than 36 tortoises were discovered living on less than one-third of the proposed project area, which triggered a re-consulation with permitting agency (the US Fish and Wildlife Service) as stipulated in the permit. By the time the entire project site had been cleared, more than 150 desert tortoises had been found (BLM 2011), consistent with desert activists and ecologists' claims that the Ivanpah Valley should be designated as an Area of Critical Environmental Concern, a designation that would offer greater protection for this sub-population of desert tortoise.

To lessen the impacts on endangered species of this particular $2.2 billion dollar project, the company has spent over $56 million on various mitigations (BrightSource Energy 2012). In this instance, a centralized renewable system has experienced a double whammy: it has been made economically vulnerable and rendered a population of desert tortoise less resilient to the impacts of climate change. Scientists suggest that the Mojave Desert will be impacted by climate change more than any place south of the Arctic. For species to adapt, they may have to migrate in response to changes in heat stress and precipitation. Large-scale projects such as these not only pose physical threats to animals, they also present obstacles to species migrations in the future. Some have argued that such ecosystems must be sacrificed in the name of climate change mitigation. Others contend that decentralized systems of energy procurement and generation would obviate these impacts.

Genesis Solar Energy and Ford Dry Lake

In 2009 a subsidiary of Next Era Energy Resources proposed building a solar energy trough system in the Colorado Desert, close to the Colorado River boundary between Arizona and California. A number of issues similar to those raised at Ivanpah appeared at this site, although the area is also of significance from a cultural heritage perspective. Giant intaglios, figures tens of meters across in so-called desert pavement – small pebbles firmly settled atop desert soils – are found throughout the area. Native Americans have occupied this region for thousands of years and it is believed to have been an important area for settlement by the ancestors of the Aztec, Mayan, and Incan civilizations, as humans migrated across the Bering Strait and toward Central and South America. Native American elders earlier warned that the solar plant was sited near a desert watering hole along an ancient trail connecting the Colorado River to the Pacific Ocean. Not long after construction began on this multi-billion dollar plant, a Native American burial ground was found on the site. Native American tribes justly claim that there was no prior consultation with them on the site, a requirement for public lands through a special arrangement with the U.S. government.

The project has also had critical ecological impacts on an undistributed desert ecosystem, the site of several resident Mojave kit fox populations, another threated species and the smallest canine in the world. To comply with the rules established prior to construction, the developer was required to evict the kit foxes, which they did by spraying coyote urine into their dens. Shortly after construction commenced, however, seven dead foxes were found on the site, killed by distemper, a disease previously never detected in the kit fox population (Sahagun 2012). Presumably, the attempt to drive away the animals played a role in their contracting the disease.

Centralized power systems are also vulnerable to localized weather events (so are DG systems, but the effects on total generating capacity is likely to be much less). Although deserts are dry by definition, they are also subject to flash flooding. Activists had warned argued that siting the project in a desert alluvial fan would make it vulnerable to flooding. In July 2012, a flash flood did several million dollars worth of damage to the project site.

Ocotillo Express Wind Energy Project

Large-scale wind farms already have a significant presence in the California Desert, especially near the San Gorgonio and Tehachapi passes that link the northern and southern parts of the state. The Ocotillo Express project is a wind farm south of Palm Springs, California, in close proximity to the Coyote Mountains Wilderness Area, the Jacumba Mountains Wilderness Area, and Anza Borrego State Park. Pattern Energy proposed to raise 112 wind turbines across 10,000 acres of undisturbed desert ecosystem, connected to the Sunrise PowerLink, a recently-approved and controversial high-voltage transmission line that will carry energy over the 117 miles from the Colorado Desert to metropolitan San Diego. Sunrise Powerlink has been justified as providing San Diego access to the abundant renewable energy resources around the Imperial Valley region of California.

Wind farm footprints differ from those of solar plants, as turbine spacing allows for multiple uses include ranching, farming, and open space conservation. A major ecological consideration, however, is that turbine blades often strike birds and leave a pressure wave in their wake causing significant mortality in bats, of which 12 species are found in the area. The Ocotillo Express region is home to golden eagles and other raptors such as burrowing owls. Because wind turbines are known to pose particular hazards to golden eagles, the developer must obtain an incidental take permit for "taking" (killing) a number of the birds over the life of the project. Under federal law, it is illegal to intentionally kill eagles (or even possess eagle feathers and parts), and recent legislation prohibits the Fish and Wildlife Service from issuing taking permits for eagles. Several California desert tribes, including the Quechan, Kumeyaay and Cocopah Nations oppose the project because the landscape is a sacred part of their cultural heritage and close to a recently-discovered prehistoric cremation site (which has subsequently been withdrawn from the project area).

All three projects were specially designated as "fast-track" projects for their potential to quickly add renewable energy to the grid. As various ecological and cultural resource conflicts gain legal and political traction, however, it is less evident that such efforts are the most expeditious way to deploy renewables. Activists argue that the wind resources to make the project financially viable are actually not available, since the turbines would be sited on the leeward side of the coast range (developers have supplied data to the contrary). Unlike solar power plants, there is less flexibility in siting wind farms. Ridge tops are windiest but also most visible, so that wind farms tend to be particularly controversial on aesthetic grounds. Distributed alternatives for wind power are fewer but research suggests that larger wind farms with multiple turbines face more resistance than single turbines (Devine-Wright 2004). Micro-wind turbines have sometimes been touted as an alternative to large machines, but some argue that these are inconsequential energy suppliers except in low-demand, remote applications (Mackay 2009).

Not All Large Projects Have Significant Impacts

Not every large-scale solar and wind project has such negative ecological impacts, and not every project has generated public opposition. Denmark has gone quite far in deploying on- and off-shore wind farms, based on very large turbines (which can be easier for some birds to navigate – though the turbine tips move much more swiftly). There are serious concerns about the impacts of these wind generators on birds and the ideal sites for turbines are usually also important flyways. Where objections have been raised, it is primarily about impacts on the "viewscape," as in the case of proposed windfarms off the Massachusetts coast and islands (ironically opposed by Robert Kennedy Jr. who lambasted environmentalists for opposing BrightSource, the case described above). But there is no reason why large-scale projects in ecologically-sensitive areas are the only way to go. There are numerous degraded landscapes throughout the desert southwest – abandoned mines, agricultural lands, etc. – where large-scale projects might be more appropriate. For example, the Aqua Caliente project will provide 290 MW of electric power on 2,400 acres of former agricultural lands, where no endangered species or cultural resources are present. But activists engaged in these issues emphasize the need to develop distributed energy resources first. It has been estimated, for example, that the technical potential for rooftop photovoltaic generation in California exceeds 70 Gigawatts

(GW) (CEC 2007), compared to a peak summer demand of less than 60 GW (CEC 2011).

Tackling Energy Poverty, Improving Human Security

The three projects described above are all located in the Global North, where electricity supplies are plentiful, if sometimes costly, and consumers suffer few, if any, power shortages. The same cannot be said across vast swath of the Global South, where urban and industrial demand for energy is rising rapidly. The common response is to build large-scale plants, whether hydroelectric, coal or nuclear. We will not reiterate the risks and hazards of these energy sources, except to note that, quite often, those most affected by the negative externalities of nearby energy production facilities often realize the fewest benefits from them. For the most part, energy, especially electricity, is directed to those areas where there is at least some semblance of a distribution system and consumers with some potential to pay for the energy. Europe has made plans to build large-scale solar generating plants across North Africa, sending most, if not all, of the power across the Mediterranean. The host countries will realize royalties from use of their solar resources, but their people, and especially the poor, are unlikely to gain much access to that electricity.

By contrast, DG has already made an impact across the Global South, especially in areas remote from power grids, enhancing human security while obviating many of the externalities associated with centralized systems. PV electricity has reached grid parity in areas where there is currently no electricity infrastructure, with such efforts dating back to the 1970s, when a humanitarian named Father Verspieren sought to electrify remote parts of African with PV (Perlin 1999). Today, organizations such as 'Engineers without Borders' are making great strides in installing PV, biogas, and micro-hydro systems in remote villages, providing light to hospital maternity wards and refrigeration to keep vaccines cool. There are major challenges in using DG PV for rural electrification including bringing down the cost of delivering these systems to remote parts of the world, as well as ensuring that local communities are adequately trained to operate, maintain and repair systems. Nonetheless, there are also major successes. In *Chasing the Sun*, for example, Neville Williams (2005) recounts efforts to electrify and light places mired in energy poverty. His Solar Electric Light Fund has helped assist anti-poverty NGOs to raise the standard of living for thousands of people who, in the absence of any adequate electricity infrastructure, previously relied on wood and charcoal for cooking, and kerosene for lighting.

THE COSTS AND BENEFITS OF RENEWABLE DISTRIBUTED GENERATION

A key political principle in operation around the world today is *subsidiarity*, the proposition that policies and practices should be implemented by the least centralized authority. Historically, the inefficiencies of utility competition in the same market as well as economies of scale drove the consolidation and enlargement of energy-producing companies. Moreover, as air and water pollution came to be of growing concern, regulation of a few large point sources was much more straightforward than many small ones. But such pollution disappears with renewable DG. Moreover, while economies of scale operate on the production side of renewable technologies, it is not relevant on the supply side, where much of the retail cost of electricity, in particular, is attributable to distribution, operation and maintenance of the utility grid. If such grids remain in existence, for example, in order to provide backup power to DG during periods of low renewable generation, the costs of maintaining the grid and backup generators will have to be paid, most probably through some kind of tax or tariff on DG systems.

Economies of scale are not wholly absent from DG, however; the particular design and sizing of a DG system will make a difference in terms of reliability, flexibility and vulnerability and, by extension, for human security. The relatively high cost of single unit systems, such as rooftop PVs supplying a single house, the intermittent nature of wind and solar energy and the problem of energy storage for high load and low energy flux periods today make DG feasible only for consumers with adequate access to capital. One consequence is that those most in need of low-cost, reliable energy – the poor and elderly – can least afford renewables.

One potential approach to these shortcomings are renewable energy "microgrids," combined power and heating systems that serve, as noted earlier, bounded neighborhoods and districts. Such a microgrid might, for example, include rooftop PV and solar water heaters, wind microturbines, heat pumps providing district heating, cooling and hot water, energy storage in the form of batteries, water tanks, compressed air and electric vehicles, possibly a biogas digester, and various monitors and controllers. Of course such major overhauls in energy supply technology must be complemented by demand management, including conservation improvements in buildings, replacement of inefficient appliances, real-time energy use information, incentives for load-shifting as feasible, timed devices on washers and dryers, and so on. If necessary, a microgrid can be hooked into the larger utility grid, pumping surplus power into it and drawing power from it when local supply drops below demand.

One important impact of climate change is higher temperatures in urban areas, from the urban heat island effect. The urban heat island effect is caused largely by human-made developments that emit thermal radiation at night, preventing cities from cooling the way that suburban and rural areas do. This presents an opportunity for DG to be deployed to make cities more resilient to the impacts of climate change. DG PV can be used to cover parking lots and buildings, thereby lessening the quantity of solar energy absorbed by pavement and other thermal masses that are primary constituents of the heat island effect. These systems would also reduce the losses from transmitted electricity, and allow for better integration of peak shaving strategies such as PV-powered air conditioning for large buildings.

A number of ancillary questions arise with such DG microgrids. Who will manage and maintain them? This could be done either by a committee of users, some of whom would need to be knowledgeable about or trained in system mechanics and requirements. Alternatively, management companies providing such services – a potential new source of green employment – could be hired for the task. How will microgrids be financed? Utilities might find it in their interest to pay for microgrids, billing users for electricity consumed. Or, local power cooperatives may develop and choose to withdraw from existing energy distribution systems. Currently, some solar companies will finance solar PV systems upfront, either retaining ownership or through a long-term loan, in return for payments for electricity generated and saved. Another approach involves bank financing of cooperative ownership shares: on the island of Samsø in Denmark, shares in wind turbines were financed through 10–20-year loans repaid through the monthly revenue from the sale of wind-generated electricity. What risks and hazards are associated with microgrids? Clearly, no technological system is failsafe and foolproof. People fall off roofs; birds try to fly through wind turbines; blackouts don't disappear; toxics are not eliminated from either the front or back ends of renewable energy life cycles. Overall, however, the net benefits of DG as opposed to centralized renewables, especially in terms of human security, appear to outweigh the costs, especially for the poor.

Which Road This Time?

Energy supply systems and companies are notoriously slow to change: there are no longer Seven Sisters in petroleum, but their descendents continue to operate globally and with relative impunity. Oil remains the mainstay of transportation while coal dominates electricity generation with natural gas rapidly catching up. New large hydropower sites are limited, and low-head and run-of-river hydro attracts little attention or enthusiasm. Notwithstanding talk of a "nuclear renaissance," that resource seems unlikely to expand very much in the future, especially in light of the Fukushima accident(s) and commitments by several European governments to a fully-renewable electricity grid by 2050. Other non-carbon based energy sources are almost all seen in terms of centralized plants, and none of them has effectively made the jump from demonstration to commercialization, although this could change in the future.

A considerable fraction of current and future growth in renewable energy is in the form of centralized facilities. We have suggested that decentralized renewables, in the form of distributed generation systems, hold numerous advantages over centralized solar and wind plants. We have also proposed – and there is solid evidence to support this second claim – that small-scale renewables hold considerable potential for addressing the energy poverty and health-related problems facing billions of the world's people. This does not mean that such technologies can be transplanted easily – experience over the past four decades illustrates the need for local capacity as well as a reliable supply of spare parts – but microgrids can reduce the need for capital-intensive power plants, and can be installed much more quickly than large-scale transmission corridors.

What of Lovins's argument regarding the authoritarianism of centralized power and the democratic tendencies of decentralized renewables? For better or worse, the history of the past 40 years offers only limited evidence of support for his claim. Centralized power seems largely indifferent to political institutions, although there is ample evidence that the reverse is not the case. Moreover, there is evidence to support the proposition that democracies tend to pay greater attention to the environment than do non-democracies but, once again, this has little to do with scale. But these observations say little or nothing about causality. Many claims have been made for the liberating and democratizing qualities of the Internet, surely one of the most decentralized technological infrastructures to have ever existed. In some instances, social activism through such media seems to have assisted, if not enabled, democracy movements and challenges to authoritarian governments. But the Internet has proven, too, to be easily monitored and managed, especially if a government is not especially concerned about the effects of such control on commerce. To become entirely autonomous, as growing numbers of many defense-related and corporate intranets have done out of the need to protect themselves against hackers, is to be cut off from the world. The parallel with renewable DG is not entirely accurate, but any organized government determined to impose its authority on a population could probably mobilize the force required to garrison and control DG facilities.

We have argued that renewable DG does have the potential to make major impacts on quality of life and human security for billions of the world's inhabitants. Some will argue that the costs of an effort to provide these benefits to the global poor are too great, and that economic growth in the Global North and South will, ultimately, provide more opportunities. Yet, this begs the question. Much of the North's aging electrical infrastructure will have to be replaced over the coming years, while the demand for energy in the South will certainly continue to increase. In other words, literally *trillions* of dollars will be spent on constructing new power plants and distribution systems. The diversion of even a fraction of this investment could go a long way toward penetration of renewable DGs throughout the world, reducing their cost and increasing their reliability, and ameliorating the poverty now experienced by so many. This could also have the additional salutary effects of reducing greenhouse gas emissions, mitigating some degree of future climate change, lessening political and military pressures on supplies of cheap oil and setting the stage for global sustainability. These goals might seem utopian to some, but there is no *technological* or *economic* reason they cannot be achieved over the next 50 years.

Not all roads lead to political utopias, and choosing the path to greater freedom ought not to depend on whether a vehicle's steering tends to the left or the right. What is important is a people's political capacity to make and effect decisions, such as whether to go down the centralized or decentralized path. Technologies are political; technologies have politics; but technologies do not determine what forms political practices will take. That requires activism, action and determination. That, however, is a topic for another chapter in another volume.

NOTES

1. Of course, electricity generation using fossil fuels can also be highly localized, although this generally requires transport of the fuels from sites of production and processing to end use. "Small" electricity and heat-generating nuclear plants have been proposed and designed at various times over the past 50 years, but none has ever been made commercially available.
2. The current glut of fracked natural gas in the United States has led to a collapse in prices that is undermining the economic viability of renewables, much as happened following the collapse of oil prices in the 1980s.
3. The cost of electricity would depend on a range of factors, so it is impossible in this chapter to compare relative prices from conventional, nuclear and centralized vs. DG generation in 2040.
4. This problem arises because surplus power causes the electric meter to "run backwards." In effect the customer is "storing" electricity in the grid for future use, without paying anything for that function.
5. Which is not to say that growing concentration of assets and control is absent from

global telecommunications and the Internet. But these large corporations are, for the most part, not allotted restricted territories in which they can operate.

6. DSIRE is the "Database of State Incentives for Renewables & Efficiency," maintained by the North Carolina Solar Center at North Carolina State University, and funded by the U.S. Department of Energy.
7. This may under- or over-estimate the actual footprint of this renewable energy capacity; the calculation is based on estimates made at the U.S. National Renewable Energy Laboratory (NREL 2004; Denholm et al. 2009b).

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