Article

Journal of Planning Literature
1-16

DOI: 10.1177/0885412214542049
jpl.sagepub.com
SAGE

The Land Use Energy Connection

AQ1 **Nikhil Kaza[1] and Marie Patane Curtis[1]**

Abstract

AQ2 To date, most planners have focused on the relationship between urban form and energy consumption. They argue that compact housing and urban patterns reduce both household and transportation energy use and should be promoted to combat a variety of ills, including import dependency and climate change. However, planners also have a strong role to play in energy production, particularly with the increasing adoption of renewable forms of energy. Planners will play an integral part in harmonizing local land use regulations and policies that will either promote or hinder the adoption of these technologies. In this article, we review industry and government reports, regulations, professional standards, news articles, and peer-reviewed literature in disparate fields. We identify pertinent environmental and land use planning issues of different types of centralized, distributed, conventional, and renewable energy generation, the implications and externalities of their fuel extraction, transportation, transmission and distribution, siting of generation facilities as well as the disposal of the waste. While the literature is voluminous, these issues have received scant attention in the planning literature. We make the case that land use and environmental planners should have a strong interest in energy.

Keywords

energy, environment, land use

Introduction

While energy is at the forefront of many sustainability efforts, the planning profession has not directly engaged it at the local level (e.g., Lindseth 2004). The American Planning Association recently adopted an energy policy that explicitly recognizes the importance of the role of planners in local energy decisions to promote its vision of sustainable futures (American Planning Association 2004). Accordingly, the planning profession focuses predominantly on energy conservation measures that manifest as building efficiency and neighborhood design strategies. Land use conflicts with renewable energy and distributed generation are only very briefly alluded to, as they are considered nascent technologies and are treated primarily as engineering and technological problems rather than social ones. In so far as the institutional issues are considered, local governments generally cede to state and federal agencies. We argue that such a blind spot not only does disservice to the sustainability efforts but also misses an important opportunity to consider how urban development strategies such as land use, transportation, and economic development are closely interlinked with energy production and distribution. Planners should be proactive in creating new institutional and infrastructure frameworks as new technologies become viable and old ones adapt to changing markets. In this article, we elaborate on interactions of land use and energy production and argue that planners should pay greater attention to the interdependencies.

In a pioneering work, Andrews (2008) uses the industrial ecology frameworks to identify the various ways in which planning should interact with emerging energy technologies. In particular, he identifies the nodes of conversion of energy and their implications for planners. In this particular article, we focus on the conversion from primary fuel to usable energy usually in the form of electricity and to a lesser extent in the form of liquid fuels. The siting of conversion facilities, transport and transmission infrastructure, and their spillover effects need to be considered separately. To structure the interactions between land use and energy, we classify the production technologies as centralized or distributed,[1] as they have different issues associated with them. Centralized production technologies require fuel and other resources to be delivered to the production facility, whereas distributed technologies may rely on either on-site fuel and/or use the energy locally, significantly reducing the need for transportation and transmission infrastructure. Therefore, the implications of these two types are different. Furthermore, planners are interested in promoting sustainable sources of energy, and, therefore, we differentiate between renewable and nonrenewable sources of energy (see Table 1). Renewable energy sources have low energy density and, therefore, the effects on land use are much larger though

[1] Department of City and Regional Planning, University of North Carolina at Chapel Hill, Chapel Hill, NC, USA

Corresponding Author:
Nikhil Kaza, Department of City and Regional Planning, University of North Carolina at Chapel Hill, Chapel Hill, NC 27599, USA.
Email: nkaza@unc.edu

Table 1. Classification of Energy Production Technologies.

	Centralized	Distributed
Renewable	~~For example, utility~~ scale solar, wind, and other sources	~~For example, roof~~ top solar, small-scale wind turbines, and geothermal
Conventional	~~For example, coal~~, nuclear-based power	~~For example, microturbines~~, small-scale nuclear

nonrenewable sources might have more intense local effects. This article does not discuss the merits and demerits of each technology (see e.g., Harvey 2010; Randolph and Masters 2008). Instead, it focuses on the specific interactions of these technologies with land use planning. We argue that planners should think of energy beyond just siting of generation facilities but consider the implications of the entire life cycle of different technologies and fuel use on land use planning.

Proactive land use planning considers the implications of the various energy production technologies and four specific stages of the production process: (1) extraction of primary fuels, (2) transportation of fuels to conversion facilities (generation), (3) transmission of usable energy, and (4) disposal of waste from conversion. Each of these stages has different land and water requirements and different environmental impacts that affect different groups (see Table 2 for a summary). In addition, concentrated and distributed modes of energy production will have different land use impacts. For example, while rooftop solar collects its primary fuel in a distributed fashion and converts it into usable energy on-site, biomass must be collected and transported to a centralized facility before it can be converted, thus incurring significant transportation costs.

In the rest of the article, the bidirectional interactions of land use and energy production[2] are viewed through this lens. This serves as a useful starting point for tracing the implications of local land use and environmental planning on energy. In this article, we systematically lay out the land use and environmental impacts of various kinds of energy production. At the same time, we argue that planners should be cognizant of the impact of their plans and decisions on the energy future of the community and the region. The extraction of fuel, the siting of production facilities, the production processes on neighboring uses, and the disposal of waste have land use and environmental impacts and should be carefully considered as planning issues. We bring together disparate literature and show the importance of thinking about energy in a traditional planning context.

Conventional Energy

The land use impacts of conventional energy production can be classified into multiple categories. Depending on the type of technology and the production processes, they present different challenges. In general, the impacts of thermoelectric (both coal and nuclear) plants are localized through the various stages of their life cycle, which has disparate impacts on their neighbors. This is due to the centralization of the production of electricity and the extraction of primary fuels.

Fuel extraction for conventional energy applications significantly alters the landscape and results in pollution and water consumption. Transporting coal and nuclear rods utilizes the existing infrastructure (e.g., rail, truck routes). Although natural gas can be delivered by truck, it is also delivered by pipeline, which does have significant siting implications. The primary consequences of electricity generation are the consumption of water from local supplies and the release of heated water back into the local ecosystem. The secondary consequences result in airborne pollutants due to the combustion process, which results in varying levels of pollution from each type of application. The transmission and distribution of electrical power is the same for all three applications (coal, nuclear, and natural gas). However, the waste stream of each fuel is quite different. Fly ash, the by-product of coal, can be repurposed. The combustion process for natural gas does not result in waste for disposal. Nuclear waste is toxic and must be stored. Thus, it is useful to consider their implications separately.

Coal

Consider the standard energy production technology using coal. Primary fuel extraction and processing, as well as the waste disposal of fly ash, have important land use and environmental implications. Coal mining practices significantly alter the landscape during the excavation process (Bureau of Land Management 2012). Wickham et al. (2007) argued that indirect forest losses in Appalachia are up to five times the direct land use transformation through mountain top removal. Even though Federal law requires mined areas to be returned to their approximate original contours, mountain top removal mining practices rarely accomplish this. The excess debris from this removal buries the streams. The US Environmental Protection Agency (US EPA), Region 3 (2005) estimates that since 1992, streams have been lost at a rate of 193 km/year in Appalachia alone. Though coal mining can create new natural wetlands, artificial wetlands are usually constructed to treat the acid mine drainage (Johnson and Hallberg 2005). However, these wetlands are of low quality (Bernhardt and Palmer 2011).

According to Fthenakis and Kim (2009), a coal-based power plant requires 6–18 square meters per gigawatt hour (m^2/GWh)[3] of land. This includes storage, walkways, and cooling towers. In addition, 2–11 m^2/GWh is required to store the ash and sludge that are by-products of the operation. Only 30 percent of the fly ash in the United States are put to use, while the rest are disposed of in landfills (US EPA 2012c). While laboratory tests have indicated contamination effects on groundwater, field studies have been sparse (Haynes 2009). Carlson and Adriano (1993) showed that aquatic systems that are adjacent to coal combustion plants are adversely affected through surface runoff and seepage into groundwater.

Table 2. Key Environmental and Land Use Issues of Energy Production (ERG and RDC 2011; US DOE 2006; Fthenakis and Kim 2009, 2010).

Fuel	Land (m^2/GWh)	Water (L/MWh)	Some Key Land Use Planning Issues: Extraction	Generation[a]	Transmission	Waste Disposal
Coal	8–29	1,100–2,300	Mining significantly changes the landscape. Large quantities of water needed for mining can result in runoff that can contaminate water resources with heavy metals, arsenic, and lead. Mining can result in a loss of streams. Mining can create low-quality wetlands	Over time sites can be contaminated with pollutants from coal. Large quantities of water are needed to create steam and cool turbines. The local ecology can be harmed when contaminated water is released into local lakes and streams at high temperatures	Continuous train loads of fuel are required to meet energy consumption needs. Utilizes the existing transmission and distribution infrastructure.	70 percent of fly ash is sent to landfills. The remaining 30 percent can be used in cement and building materials
Natural gas	6–18	380–1,400	Frac sand extraction alters the landscape and requires land for storage. Extraction infrastructure significantly alters the natural landscape. Large quantities of water needed for fracturing can contaminate water resources with fracturing chemicals. Fracturing can contaminate local water resources with methane	Large quantities of water are needed to cool turbines. Water discharge consequences are similar to that of coal plants	Pipelines require land over extensive distances. Siting of pipelines create new land use conflicts. Electricity generation occurs near areas of consumption and utilizes the existing transmission infrastructure	In the hydraulic fracturing process, wastes from extraction can be injected below groundwater deposits or encapsulated in underground injection well sections or abandoned well bores
Nuclearb	75–77	1,500–2,700	Mining significantly changes the landscape. Fossil fuel emissions from mining can be significant. Waste and rainwater runoff can contaminate water resources with heavy metals and radioactive uranium	Large quantities of water are needed to create steam and cooling turbines. Water discharge consequences are similar to that of coal plants	Truck and rail routes must be secured and planned to avoid high-density populations. Electricity generation occurs near areas of consumption utilizes the existing transmission infrastructure	Stored radioactive uranium fuel and power plant equipment can contaminate the land. Transporting wastes requires securing truck and rail routes that avoid high-density populations
Utility scale solar	164–552	2,900–3,500	N/A	Requires a large area dedicated to solar collection which can affect local ecosystems. Concentrating solar plants may use large quantities of water for recirculating cooling systemsc	Electricity generation occurs far from areas of consumption, which requires new transmission lines and may result in large transmission losses	N/A
Rooftop solar	N/A	N/A	N/A	Can cause solar access conflicts. Trigger aesthetic concerns	Power is consumed at the generation site and/or sold to the electric grid	N/A
Wind	1,030–3,230	Negligible	N/A	Land can simultaneously be used for other purposes (i.e., grazing, farming). Negligible water is needed to keep the turbine blades clean. Operation can trigger noise and aesthetic concerns. Conflicts with neighboring land uses (e.g., military bases, residential areas) are significant	Generation occurs far from areas of consumption, which requires new transmission lines and results in large transmission losses	N/A

(continued)

Table 2. (continued)

Fuel	Land (m^2/GWh)	Water (L/MWh)	Some Key Land Use Planning Issues			
			Extraction	Generation[a]	Transmission	Waste Disposal
Biomass	266–716	1,100–1,800d	By-products of some industrial processes and municipal maintenance operations can be diverted from landfills and used as fuel. Logging for fuel may decimate forests. Biomass grown for fuel can deplete soil nutrients	Emissions include trace amounts of toxic pollutants. Generators are much smaller than fossil fuel power plants and generally use less water. Large quantities of water are needed to create steam and cooling turbines. Water discharge consequences are similar to that of coal plants	Pulp and other wood residues are used on-site. Whole log transport includes railways and ships. Power from pulp and wood residues are typically consumed on-site. Power derived from fuel crops is generated near areas of consumption and utilizes the existing transmission infrastructure	Nonhazardous ash is disposed in landfills or recycled
Direct waste to electricity	N/A Typically located on or near a landfill	1,100–1,800	Mitigates the need for additional landfill capacity. Reduces methane gas released in landfills	Generators are much smaller than fossil fuel power plants and generally use less water	WTE facilities located in cities reduce garbage truck traffic to landfills. Power is consumed at the generation site and/or sold to the electric grid	Nonhazardous ash is disposed of in landfills or used in roads, parking lots, or daily landfill covering. Hazardous ash must be safety contained
Landfill gas to electricity	N/A Typically located on or near landfill	1,100–1,800	Mitigates the need for additional landfill capacity. Reduces methane gas, landfill odors, and toxic compounds. Destroys most nonmethane organic compounds	Emissions include trace amounts of toxic pollutants. Reduces the methane gas that is released into the atmosphere. Reduces storm water runoff. Generators are much smaller than fossil fuel power plants and generally use less water	Land is required to place 16–32 km of pipeline from the landfill to the power plant. Power is consumed at the generation site and/or sold to the electric grid	N/A
Animal biogas	Varies	Negligible	Land is required for the anaerobic digester and effluent storage. Reduces methane emissions. Reduces eutrophication in surface waters and nitrates in groundwater	Variable emission levels can include H_2S and particulate matter. Generators are much smaller than fossil fuel power plants and generally use less water	On-site consumption results in lower transportation costs, less variability in feedstock quality, fewer biosecurity issues, and the mitigation of the size/scale effect on finished biomass	By-products can be used to create compost, fertilizer, livestock bedding, landscape products, and building materials
Human biosolids	49.9–290.2e	N/Af	Land is required for the anaerobic digester and effluent storage systems. Reduces the volume of volatile organic solids, removes pathogens from sewage. Facilitates water reclamation	Emissions levels include volatile organic compounds and can vary. Large quantities of water are needed to create steam and cooling turbines	Power is consumed at the generation site and/or sold to the electric grid	By-products can be reused in fertilizer, asphalt, concrete, and ceramic tile

Note: WTE = waste-to-energy.
[a]Greenhouse gas emissions were not included.
[b]This includes the area for spent fuel disposal and storage.
[c]Most of the water consumed is lost to evaporation.
[d]Value represents biomass water consumption for electrical generation only.
[e]Values are based on total daily system capacity and total land area of entire facility. Facilities in Los Angeles and San Antonio were excluded.
[f]The most common combined heat and power generators at wastewater treatment facilities are reciprocating engines and microturbines with a capacity of up to 234 kW (ERG and RDC 2011). These small systems typically use an integral coolant to maintain system temperatures.

The health impacts of coal-fired power production are largely due to airborne pollutants that are a product of the combustion process. However, the variability of the effects is based on proximity and weather conditions. In their study of approximately 400 coal-fired power plants, Levy, Baxter, and Schwartz (2009) used a reduced form chemical transport model to find significant variability in their monetized costs (US$0.02–US$1.57/kWh); most of which is related to fuel (bituminous vs. anthracite) and control technologies (i.e., scrubbers, etc.) as well as population densities at various distances.

Thermoelectric plants, most of which employ wet cooling technology, put a significant strain on the water resources of a community. It is estimated that 514.8 gigaliters (Gl) are withdrawn and of that, 12.5 Gl are consumed in the United States each day (US Department of Energy [DOE] 2006). For open loop cooling, 75.7–227.1 kl/MWh of water are withdrawn, and for closed loop cooling, 1.1–2.3 kl/MWh (up to 4.1 kl/MWh for nuclear) are withdrawn (US DOE 2006). Sovacool and Sovacool (2009) argued that by 2025, there will be at least one county in every state in the United States that is likely to face severe drought due to population increases. This will result in competition for potable water as well as water for electricity generation. Thus, urbanization will only exacerbate competing demands on water resources.

Nuclear Energy

Nuclear power generation[4] has been extensively examined in the existing literature and only specific topics relevant to the scope of this article will be briefly mentioned. The environmental consequences of residual radiation contamination in the soil, water, and decommissioned facilities are evaluated in Kennedy and Strenge (1992)'s model. Gagnon, Bélanger, and Uchiyama (2002)'s life cycle assessment showed that nuclear power emission factors are comparable to that of wind and reservoir-based hydropower. Nuclear power plants are generally located near large sources of water, such as rivers, lakes, or coastal regions, to economically meet substantial cooling requirements (World Nuclear Association 2011). However, due to the Fukushima disaster and the temporary shutdown at North Anna, Virginia, nuclear plants that are located in areas prone to earthquakes or vulnerable to tsunamis are now subject to increased scrutiny, resulting in the introduction of the Nuclear Power Safety Act of 2011 (H.R. 1242; Andrews and Folger 2012).

Nuclear fuel materials and waste are transported by dedicated rail and trucks using routes that avoid densely populated areas and are approved by the Nuclear Regulatory Commission. Gawande and Jenkins-Smith (2001) examined the effect of nuclear waste shipments on urban property values and found no effect in areas with significant experience in nuclear materials management but significant effect in populous urban areas. Comfort and experience of the local community with nuclear energy seem to be the recurring themes in the literature. Ewing and Hippel (2009) argued that the Yucca Mountain project was doomed by top-down decision making and management failures, contrary to Scandinavia, where local communities, experienced with nuclear plants, were involved in the process and finally volunteered to host nuclear waste repositories.

Natural Gas Extraction

The latest debate on energy self-sufficiency in the United States has focused attention on alternative extraction methods[5] of natural gas and their implications for local communities. According to the US Energy Information Administration (US EIA; 2011), the largest natural gas deposits are located in the Northeast (Marcellus, 54 percent) and Gulf Coast (Haynesville, 10 percent), Mid-Continent (Fayetteville, 4.2 percent), Southwest (Barnett. 5.7 percent), and Rocky Mountain (Mancos, 2.8 percent). Hydraulic fracturing or "fracking" consists of injecting a mix of water, sand, and chemicals into a deep well at high pressure. This causes fissures to form throughout the rock layer, which allows natural gas to flow up the well. Although the land requirements of these wells are small compared to coal mining or oil extraction, there are direct and indirect land use impacts of natural gas extraction technologies. Each well pad requires 28–36 m^2, which includes utility easements and roads, but this requirement can be amortized over multiple wells on a single pad (NYSDEC 2011; Smith and Ozer 2012; Ladlee and Jacquet 2011). While the popular concerns about water quality and induced seismic activity are well publicized, the indirect effects of the provision of infrastructure and the volatility of the natural gas industry have significant land use impacts that are relatively understudied.

Due to the relative novelty of operations, to date, very little peer-reviewed research has been published on the amount of water consumed and the effect on local water quality during extraction. Vertical wells may use 19–3,785 kl of water per well and a horizontal hydraulic facture operation may require 11–19 ml of water per well (Harper 2008). Nicot and Scanlon (2012)'s study on Texas shale gas production suggests that shale gas extraction has a water requirement of 300–380 ml/kWh and is comparable to other conventional energy resources. The main issue, however, is the volatility of the natural gas prices. Many of these shale wells are operational only when natural gas prices are above US$0.35/$m^3$, introducing significant volatility in the water supply. While the cumulative water use is relatively small in this industry (1 percent in Texas) compared to more traditional agricultural (56 percent) and residential uses (26 percent), the volatility and specific local impacts can be significant. In some counties, the water use for shale gas production reaches up to 30 percent (Nicot and Scanlon 2012).

The 2005 Energy Policy Act exempts all oil and gas companies from the Safe Drinking Water Act (Kosnik 2007). Osborn et al. (2011) demonstrated a link between hydraulic fracturing and methane contamination in local water supplies in Pennsylvania. According to the Society of Petroleum Engineers, approximately 10–30 percent of injected freshwater may return to the surface as flow back or wastewater (Rassenfoss 2011). In 2010, the EPA tested groundwater samples near extraction sites and determined that inorganic contaminants "associated with hydraulic fracturing have been released into the . . . drinking water aquifer . . . " (DiGiulio et al. 2011, 48).

Along with various proprietary chemicals that are used in the fracking process, another major ingredient is sand. Conventional vertical wells only require one fracturing stage, whereas horizontal wells can have up to fourteen, with each stage using about 136 tons of "frac sand" (Clark 2011). Being a bulk material, railroads are most suitable for long-haul transportation of sand, but the effect of transport of these industrial minerals on the freight system is not documented in the literature. On the other hand, the transportation of useful fuel post extraction received some attention in the planning literature (see e.g., Boudet and Ortolano 2010).

Induced seismic activity due to fracking is another popular claim and deals primarily with the wastewater disposal into the injection wells and not the extraction process. Waste related to oil and gas exploration and extraction is not regulated by the Resource Conservation and Recovery Act (Office of Solid Waste 2002) and can be recycled, stored, or injected into disposal wells. While the disposal of wastewater by injection into the subsurface does pose some risk for induced seismicity, only a small fraction of the wells have been correlated with increased seismic activity; in contrast, carbon capture and storage (CCS) systems pose much larger seismic risks (National Research Council [NRC] 2012).

The claims about economic impacts of fracking have created sharp debates about the accuracy, validity, and appropriateness of the methods used in those studies. However, in a critical review, Kinnaman (2011) argues that many of them have not been subject to peer review and therefore cannot be validated. By far the most comprehensive analysis of short-term and long-term economic impacts on communities is by Christopherson and Rightor (2012). They argue that the towns have to be cognizant of the boom and bust cycles of natural gas economies and the long- and short-term costs of provisioning housing, schools, and other amenities. The volatility of natural gas markets should remind us of the lessons from disruptive labor mobility caused by mining industry and subsequent ghost towns (Pritchett, Gaddy, and Johnson 2006).

Renewable Energy

With the focus on the fluctuations in oil prices and the growing realization that climate change has detrimental impact on the economy, many countries have embarked on expansive renewable energy programs. Known for their virtually limitless fuel, these renewable energy programs have sought to significantly alter the energy as well as the natural landscape. In some cases, centralized generation of renewable energy is viable because of economies of scale. In other cases, small-scale distributed systems are used because the fuel is widely dispersed. The nature of energy production and the type of fuel that is harvested have different implications for planners.

For example, with the current technologies, wind energy is economical only in locations of medium to high wind speeds, and in the United States, these are in the Midwest or offshore. These locations are far from the population centers of the East, posing some concern about transmission losses. Siting of these wind farms on culturally and environmentally sensitive lands is a concern for planners. On the other hand, the intermittency of wind production, while a serious problem for adoption of the technology, has limited impact on planning.

~~On the other hand,~~ ~~biofuels~~ are much more intimately tied to land use planning. They are predominantly cultivated on industrial farms. Depending on the type of biofuels and the efficiency of the conversion processes, the land and water requirements of these crops can be quite high. Furthermore, because of the substitution effect, the land use impacts of agriculture to simultaneously provide fuel and food will have significant environmental impacts such as nutrient loadings. Nevertheless, many rural economic development strategies depend on repurposing cash crops, such as sugarcane, sugar beet, sorghum, corn, and wheat, to manufacture liquid biofuels. While the intermittency of wind energy is an issue that relates to widespread adoption of wind energy technologies in which planners have little say, the choice of particular rural economic development strategy is shaped by planners.

Perhaps the renewable energy debate that is most relevant to planners is the siting decisions of both centralized and decentralized production technologies.[6] What are the impacts on urban form and the suitability of current urban archetypes for distributed energy generation and fuel production? In the subsequent sections, the interactions of land use planning with the siting of renewable energy facilities are outlined.

Wind Energy

Wind turbines have become a popular mechanism to produce renewable energy. Wind energy in the United States has increased from 14.1 million MWh in 2004 to 55.3 million MWh in 2009, making it one of the fastest growing energy generation technologies[7] despite the rising capital costs within that same period.[8] Since 2009, capital costs have decreased from US$2,150/kW to US$1,600/kW in 2012 (Wiser et al. 2012). Maturing technologies have decreased the cost of electricity generation from US$0.30/kWh in 1980 to US$0.05/kWh in 2012 (American Wind Association 2011; Small Business Administration 2009)—an 80 percent decrease. Additionally, operations and maintenance costs have fallen from US$64/kW in 2002 to US US$57/kW in 2012. It is important to consider the environmental and planning issues that are the consequences of the rapid growth in this sector.

Two chief concerns for siting wind turbines are height and noise, both of which are under the purview of the local governments. Zoning ordinances in the United States not only dictate the type and intensity of land use but also set height restrictions. In fact, an early zoning ordinance promulgated in New York City was primarily meant to restrict the height of the high-rise buildings that cast long shadows on nearby buildings (Wilson 1997). Objections to wind energy based on aesthetics are primarily about height. Wind speeds are greater at higher elevations. Because embodied wind energy rises cubically with respect to the speed, cost-effective turbines are usually much taller (upward of 18.3 m) than what a typical zoning ordinance would allow in a single-family residential zone (10.7 m; Andriano 2009; Wolar 2008). Parcels that are zoned for industrial and commercial uses usually have greater allowances for height. However, these are not generally suitable locations for wind energy generation facilities because nearby taller buildings obstruct the wind. Thus, the land use that is most compatible with wind energy generation is agricultural use. Wind turbines do not necessarily impede agricultural production, livestock grazing, and other compatible land uses. In any case, most onshore wind turbine installations, specifically small-scale wind (<100 kW), require special use or conditional use permits as they are not considered regular uses (Green and Sagrillo 2005). These permits usually place the burden of proof on the petitioner to show that the negative impacts of the turbines are mitigated. Analogous cases are the controversy regarding siting cell phone towers.

Environmental protection statutes also work in conjunction with height restrictions (meant for other development) to impact wind energy generation. Wind is generally obstructed by topographical features such as hills and mountains, and some of the best sites to locate the turbines are on the windward side of an elevation. However, ridge laws, such as the 1983 North Carolina's Mountain Ridge Protection Act, are used to impede the construction of the turbines. In these kinds of statutes, exceptions are made for power and television transmission lines, and cell phone towers, which could be used as a template for wind projects.

Noise complaints[9] are routine in the case of wind farms. Local and state noise ordinances are guided by levels set by the EPA and must comply with levels set by the Occupational Health and Safety Administration (OSHA). Nighttime ambient noise-level recommendations issued by the International Standards Organization (ISO) vary from 25 to 40 decibel (dB), depending on land use category, with 10 dB higher for daytime. Wind turbines produce both aerodynamic and mechanical noise ranging from 96 to 108 dB depending on the type of turbine, power capacity, and wind speed. Few jurisdictions have noise ordinances that are targeted toward wind turbines (Bastasch et al. 2006). However, general noise restrictions preclude many sites that are otherwise suitable for wind power generation.

In addition to possible noise issues for neighbors, wind farms have conflicts with other nearby land uses. The Federal Aviation Administration (FAA) asserts jurisdiction over all navigable airspace. Therefore, FAA regulations impact the siting of wind turbines close to airports, especially on flight approach paths. Towers taller than 61 m are required to have aircraft safety lighting, which can also contribute to the flicker complaints of nearby residents. A recent report concluded that large wind turbine farms impact the ability of air defense radars to track areal objects (Office of the Director of Defense Research and Engineering 2006). This creates a conflict between military installations, airports, and wind turbine farms. Furthermore, the National Weather Service operates radars to monitor weather, which impacts the siting of wind turbines.

Construction and maintenance of wind turbines require infrastructure for access. Any such infrastructure that may impact the water quality and discharge is usually regulated by federal and state agencies. In February 2012, the US Army Corps of Engineers reissued the existing nationwide permits, fifty-one of the fifty-two pertaining to the effect of wind turbine construction and operations on nontidal and navigable US waters in compliance with sections 10 and 404 of the Clean Water Act (US Army Corps of Engineers 2012). Impacted wetlands from construction must be restored or relocated to avoid significant trauma to the existing ecosystem (Drewitt and Langston 2006).

There are other risks associated with the turbines that necessitate a separation of uses. In cold climates, ice throw from the turbine blades is a concern. Admittedly, the hazard risk depends greatly on the wind speed, turbine diameter, and operating conditions. Testing in cold weather conditions in Europe has demonstrated that a 250 m separation between turbines and inhabited land uses reduces the risk of impact (Cattin et al. 2007; Seifert, Westerhellweg, and Kröning 2003).

Solar Energy

Two types of solar energy production methods are prevalent for large-scale centralized systems: photovoltaic (PV) farms and concentrated solar power (CSP). Both require high solar insolation and large areas like the desert areas of the Southwest United States. However, these locations do present some environmental and land use concerns that should be accounted for.

The energy density of PV farms is relatively low compared to conventional sources (see Table 2). About 114–261 m^2 land per person is needed by the current PV technologies to meet the demand and depends very heavily on the local insolation characteristics (Denholm and Margolis 2008). However, there are significant advantages to centralized production, including grid connectivity, regulation, and institutional support.

On the other hand, the advantage of rooftop solar is that energy is usually consumed at the site. Rooftop solar has quickly become widely adopted because of increasing subsidies for renewable energy and increasing consciousness on part of homeowners and businesses. To avoid self-shading, Denholm and Margolis also find that flat collectors are twice as energy dense as two-axis tracking collectors. This suggests rooftop flat solar panels may utilize land more efficiently during energy generation and have near zero environmental impact after installation. Furthermore, some technologies in rooftop solar are established and therefore the technical skills to install and maintain them are available.

Solar water heating is one of the more mature renewable energy technologies. In the United States, the average daily per capita residential water consumption is 189–303 L, of which, over 50 percent is hot water.[10] Depending on the solar radiation and the incoming water temperature, the surface area of the solar collector can range from 0.01 to 0.03 m^2/L. Thus, solar water heaters are primarily suitable for single-family residences rather than multifamily buildings. Nonresidential buildings have different consumption profiles based on the use. Data from the US *Commercial Building Energy Consumption Survey* (US EIA 2003) suggests that the energy intensity of water heating within commercial buildings is 0.32–19.9 kWh/m^2; the upper end of the spectrum is dominated by uses such as food services and strip malls, much more so than office and medical buildings. Using only solar energy for water heating would require large surface areas on the building or on the site and can have significant impact on urban form, shape, and density. Generally solar water heaters are complements to, rather than substitutes for, conventional heaters and have not yet affected the urban form.

Solar energy generation, whether it is a solar water heating or rooftop PV, depends on access to solar radiation. Distributed systems pose some challenges for planners. Externalities such as shade by tall buildings have legitimized height restrictions and setback requirements in zoning ordinances using solar access as one of the justifications. Many states such as Wyoming and New Mexico have codified these access rights with Solar Rights Acts that provide property rights for solar radiation by establishing or encouraging solar easement through grants by way of litigation, covenant, or mutual agreement. These solar access rights thus prevent current and future obstruction of access through adjacent buildings or structures. Preserving access rights is important not only for active energy generation technologies such as PV but also for passive technologies such as Trombe walls (Stromberg 2010). Usually, these are state laws that prevent covenants, local regulations, and other restrictions on access to claimed solar rights.

Solar easement issues are closely related to those of solar rights. Easements protect the access of the right by the right holder even if other rights to the property are not held (e.g., utility easements). Because the height of vegetation and adjacent structures can hinder access to useful solar energy, setback requirements that are based on height in particular residential districts, should be tailored to preserve solar access. Tree ordinances are other potential irritants in the adoption of solar distributed energy. In general, wealthy communities want to protect the neighborhood character of their residential districts by limiting the kinds of trees that can be cut down or land that can be disturbed on private lots (Dickerson, Groninger, and Mangun 2001). These are restrictions imposed on homeowners who are willing to exercise their solar rights at the expense of vegetation cover (Anders, Day, and Kuduk 2010).

Shading requirements for parking lots are used in many cities across the country to control the urban heat island effect (McPherson 2001). The siting of parking lots with respect to more productive uses of the site is dependent on many factors, but energy production is rarely considered. With the advent of plug-in electric vehicles (PEVs) and "solar trees,"[11] urban designers, architects, and planners may need to rethink the relationships between parking, shading for parking, and provisions for charging stations and other infrastructure (Urban Land Institute and National Parking Association 2010; Morrow, Karner, and Francfort 2008). Because this is a relatively new phenomenon, very little research has been published in this regard.[12]

The operational parameters of solar and wind technologies generally do not require fuel or large amounts of water for cooling. They do not emit airborne pollutants or generate waste. Therefore, there are no direct consequences associated with fuel extraction, fuel transportation, or waste disposal due to energy generation. However, there are legal land use implications for locating wind and solar equipment near populated areas. The most direct conflicts can occur when large-scale renewable energy farms are located in or near sensitive ecosystems or migratory paths (e.g., offshore wind transmission corridors). More significantly, because the energy density of renewable fuels is low, large areas are required for centralized production. Large renewable energy projects are usually located in sensitive ecosystems such as deserts (McDonald 2009).

Biofuels, Biomass, and Forest Residues

The impacts of biofuels on land and water use have been extensively studied in the literature. Chemically transformed biomass (biofuels) used in the transportation sector, such as ethanol and biodiesel, have significant production and land transformation impacts (Nonhebel 2005). The food versus fuel debate has renewed attention with rising food prices. There are different types of biofuels, and it is difficult to generalize the effects of each of the production technology. The land and water requirements are very sensitive to the fertility of land, agricultural practices, and climate and conversion technology (Fthenakis and Kim 2010; Gerbens-Leenes, Hoekstra, and Meer 2009; Groom, Gray, and Townsend 2008).

While the direct land and water consumption of biofuel feedstock is relevant to the planners, it is their indirect effects that have contributed to the debate in the policy literature (Searchinger et al. 2008). The direct effects of growing primary crops for liquid biofuels are the same as those of agriculture. Therefore, all of the environmental effects of agriculture, including runoff into streams, should be considered for biofuels. The conversion of the harvested biomass requires similar infrastructure as agricultural products (such as storage, transportation, etc.). Because land use planners are quite aware of these issues (e.g., decrease in biodiversity and surface water pollution), they do not bear repetition in the context of liquid biofuels.

The indirect effect of land transformation is an issue of the scale and location of the transformation. If biofuels become substitutes for conventional fuels (especially for transportation), they dramatically increase the land use conflicts because of the high land and water requirements. In fact, Lapola et al. (2010) suggested that the carbon savings from biofuels are offset by direct and indirect land transformations such as the conversion of Amazonian forests to rangelands. However, innovative use of unproductive land can help mitigate some of these issues. In Europe, pilot projects, such as Rejuvenate, explore phytoremediation, the use of biofuel crops as a strategy to remediate contaminated land, as opposed to excavating contaminated soil (Suer and Andersson-Sköld 2011). The Freeways to Fuel program (F2F) has explored using otherwise unproductive government land holdings (e.g., rights of way, military bases, etc.) for production of fuel. The North Carolina Department of Transportation's (DOT's) pilot program to plant and harvest biofuel crops is the most promising of all the state DOT programs (US DOT 2012).

The transmission of liquid biofuel also poses a concern because it cannot be easily integrated into the existing oil pipeline network due to the presence of water. Creating a new and exclusive transportation system for biofuels will require two conditions: (1) relative consolidations of the conversion facilities and (2) rapid increase in the demand for biofuels. Planning for new pipelines is subject to the same controversies of locally unwanted land uses (LULUs). Although this is rarely discussed in peer-reviewed literature, it is the subject of many trade journal accounts.

The other pathway that biomass is converted to useful energy is through conversion into electricity. The mechanism and process for releasing stored energy in biomass is very similar to that of conventional and centralized fossil fuel power plants. According to the US DOE existing coal-fired power plants that are retrofitted to burn biomass fuel stocks are able to reach 33–37 percent energy conversion efficiencies, which are comparable to fossil fuel generation. In contrast, new biomass gasification power plants can reach up to 60 percent efficiency (US DOE 2011). Unlike other renewable energy technologies that require new hectares of land for production and transmissions lines, solid biomass is a fuel substitute for coal or natural gas and may utilize the existing power generation infrastructure already in place. The land use impact of biomass primarily occurs in the production and harvesting of the feedstock and the transportation of the fuel to the generation plant but not in the electricity generation and transmission process.

The biomass industry has a transformational effect on landscapes due to harvesting activities and preservation efforts to sequester carbon. Unlike conventional coal mining, effective biomass energy production requires significant long-term planning to consider alternative land uses (e.g., food and materials production), resource competition (e.g., soil and water), biodiversity reduction, and soil disturbance (Curran and Howes 2011). The total impact of energy crops on land use depends on the scale of production, crop yield per unit area, land occupation, and the time required for ecosystem restoration (Berndes, Hoogwijk, and Broek 2003). For example, high-pressure gasification utilizing willow feedstock requires a year-long land occupation of 104 m^2/GJ (Fthenakis and Kim 2009).

In addition to harvesting whole trees to generate wood pellets for fuel, wood residues diverted from the waste stream are used as fuel stock. Out of the 3 million km^2 of forestland in the United States (US EPA Office of Compliance 2012), 290 million tons of primary residues (Perlack, Stokes, and US Department of Energy 2011) are removed by conventional harvest operations such as forest management and annual land clearing. Secondary residues used for electrical generation include mill wastes (29 million tons) and pulping liquors (41 million tons; US EPA 2011b). Tertiary residues include urban waste (e.g., discarded furniture, landscaping wood wastes, and wood used in the construction, remodeling, and demolition of buildings). In 2007, approximately 54 percent of total municipal solid waste (MSW) generated in the United States, or 124 million tons, was discarded in landfills with the balance diverted to compost or energy recovery (US EPA 2011b).

Deriving Energy from Waste

Local governments including sanitary districts are usually in charge of waste disposal and this provides an opportunity for planners to influence energy production from waste directly. Because landfills and effluents cause serious environmental issues, the siting and discharge locations are very contentious. Since local governments are intimately involved in waste management, it is useful to consider the implications of generating energy from waste. Even though the energy density is fairly low, waste-to-energy (WTE) systems have potential co-benefits that might be considered.

Deriving energy from solid waste. Annually, over a quarter billion tons of MSW is generated in the United States (US EPA 2011b). Any transformation of the waste to usable energy has direct relevance for local land use planners. Electricity from MSW can be generated by direct WTE incineration and landfill gas (LFG; e.g., methane gas) collection. About 12 percent of the MSW is converted to energy through combustion.

Due to the diverse nature of the fuel stock, emissions from WTE electricity plants are subject to the EPA's Clean Air Act and the Best Available Control Technology standards, which are enforced by local and state authorities. WTE plants can release toxic emissions (dioxins and furans) and volatile metals (cadmium and mercury; Hasselriis and Licata 1996). Current technologies release less than 14 g of dioxin from all US WTE plants combined (US EPA 2012a). Despite these emissions, WTE plants are common in Europe with approximately 433 power plants (Fahey 2010) currently in operation. In contrast, there are only ninety-two operational plants in the United States.

The effect of methane on global climate change is more than twenty-one times stronger than CO_2 (US EPA 2012b). MSW landfills are the largest source of human-caused methane emissions in the United States (US EPA 2011a). Landfills will emit methane within six months for twenty years with peak methane production occurring five to seven years after waste deposition (ATSDR 2001). A landfill-gas-to-energy (LFGE) project can capture 60–90 percent of the methane emitted from MSW.

Nearly 1 million tons of MSW can yield about 8.5 kl per minute of recoverable LFG. According to the EPA, this is approximately 7 million kWh per year and can supply enough energy to 700 single-family homes (US EPA 2002). ~~For~~

~~comparison, 0.3 m³ of natural gas and 1 ton of coal is equivalent to 0.3 kWh and 7 MWh, respectively. In other words, approximately 660 m³ of natural gas have the same energy as 1 ton of coal.~~

Collecting LFG to produce electricity improves the air quality of the surrounding community by reducing landfill odors and destroying most nonmethane organic compounds that are present at low concentrations in uncontrolled LFG. Admittedly, the combustion process in LFGE plants for electricity generation does produce nitrogen oxides, organic compounds, and trace amounts of toxic materials such as mercury and dioxins.

Issues related to location of the landfills have generated a lengthy trail of environmental justice literature (see e.g., Bullard 1993). Since the conversion facilities are usually located on/near the landfills/transfer stations, the siting concerns of these facilities are the same as the location of landfills. However, economies of scale dictate that only large-scale facilities are amenable for WTE or LFG production. Potential LFGE power plants should contain at least 1 million tons of waste, have an average depth of at least 15.2 m, and have been operational within the last five years (US EPA 2008). At higher scales of production, transporting LFG to power plants becomes worthwhile. US EPA (2008) estimates that economical piping distance from landfill to the end user is between 16 and 32 km. These large landfill sites are disproportionately located in poor and minority neighborhoods, which bear the brunt of the externalities imposed by landfills. While LFGE conversion facilities might mitigate the externalities arising from the landfill, they may impose a new set of externalities associated with energy transmission infrastructure.

Energy from liquid waste. Bacteria are used to digest biodegradable feedstock in a process called anaerobic digestion. A by-product of this process is methane gas, which can be used as fuel for electric generation in landfills and farms (Santoianni et al. 2008). More recently, biogas derived from sanitation wastewater is being used as fuel source. According to the American Biogas Council, only 250 out of 1,500 wastewater treatment plants in the United States generate energy. Diverting manure and wastewater for electrical generation can reduce point source contamination into the US waters and alleviate the stress to comply with federally regulated total daily maximum loads. It also produces by-products that can be used to create compost and fertilizer.

Concentrated animal feeding operations (CAFOs) increase meat output and reduce land use (grazing, housing, etc.) by increasing the animal density on land. CAFOs result in large volumes of animal fecal matter that can negatively impact the environment and public health unless properly managed (Osterberg and Wallinga 2004; Mirabelli et al. 2005). California, Iowa, Maryland, North Carolina, Pennsylvania, and Texas are CAFO centers that produce the most animal waste (Santoianni et al. 2008) and are the most susceptible for runoff pollution due to flooding, hurricanes, or tropical storms. Untreated animal waste can cause eutrophication in surface and ground water, when nitrates leech into the supply.

Alternatively, manure can be diverted to on-site energy generation (Table 2). This would involve building new containment facilities that prevent runoff pollution. Unfortunately, the energy density inherent in this feedstock is not high (0.67–8.2 kWh/head/day; Barker 2001). Although converting animal waste to electricity on-site may result in the reduction of hazardous spillovers, there is little economic incentive for the farmers to invest in these facilities. For example, even though North Carolina's Renewable Energy Portfolio Standards (REPS) has an explicit quota for energy derived from swine waste, none of the participants who were enrolled in the pilot program have a full operational system (Royster 2011). One of the major challenges is that the up-front costs of heated tank digesters can be significantly higher than those of the standard lagoons and surface applications that are in practice today.

Like manure, human wastewater can negatively impact the environment and public health and is strictly regulated. However, when managed properly the resultant recycled water can be used for irrigation, industrial processes, and in limited cases, household use. Biosolids can be used in soil conditioning or compost production. Gases captured can then be used to produce heat or electricity. Human wastewater has a chemical energy content ranging from 6.3 to 7.6 kJ/L (Heidrich, Curtis, and Dolfing 2011; Shizas and Bagley 2004) and can be diverted from the waste stream to produce electric generation fuel. Many large sewage districts such as Chicago and Washington, DC produce about 757 L of wastewater per capita daily (City of Los Angeles 2012; Detroit Water and Sewerage Department 2012; Fujita 2009; Mukahirn 2010; Massachusetts Water Resources Authority[MWRA] 2009; Metropolitan Water Reclamation District [MWRD] 2012; National Association of Energy Service Companies 2011; Red Oak Consulting 2011; LA Sewers 2011; DC WASA 2007; DC Water 2012; Wong 2011). Much of this wastewater is already treated for effluents, and planning for energy recovery requires coordination between sanitary districts, land use planners, and power generators.

WTE applications can reduce negative land use impacts by redirecting MSW, animal feces, and human biosolids from the waste stream to energy fuel production. Capturing the methane produced in landfills reduces harmful emissions. Redirecting animal feces and human biosolids into storage can reduce non-point source water contamination. WTE systems are often small in scale, thus rendering the transportation of fuel as cost prohibitive. For this reason, energy is typically generated and consumed at the site of fuel production. However, as the scale of fuel production increases, it is possible to ship the fuel (e.g., methane gas) via pipeline to the generation facility. The planning issues associated with pipeline infrastructure are similar to that of natural gas. Although the WTE process does create by-products, those by-products can be used as compost or bedding. The primary land use implication for WTE applications are mitigation of negative externalities associated with the conventional treatment of waste. While this mode of energy production is cost-prohibitive in some cases, it has the potential to provide energy in communities that may not be served by traditional energy infrastructure.

Conclusions

The literature discussed in this article suggests that while there are strong connections between energy and land use, little work has been done in the land use planning realm. However, even in the cases of centralized production, there are significant land use issues that are rarely considered in the environmental impact statements that usually accompany these projects. As distributed energy production systems become increasingly common, the conflicts and the opportunities for traditional planners will only multiply. Innovations in energy production (e.g., discovery of new fuels, fuel extraction, and conversion into useful energy) may pose problems in regard to adapting the existing institutional structures, rules, and regulations. By closely monitoring the rapid change in these technologies and by understanding the different ways in which these technologies might intersect with traditional land use and environmental planning, planners can use the time lag inherent to large-scale adoption to gracefully build new infrastructure, retire and reuse old ones, adapt old institutions and proactively create new institutions.

In some cases, however, traditional institutional structures have been responsible for delaying the rapid adoption of alternative energy sources. For example, very few municipalities have a zoning category that covers solar farms, and in many cases it is unclear as to whether PV farms are regulated as industrial use or other use. Wind turbines have been blocked by local opposition using noise and height regulations. Because some power distribution and generation is done by rural cooperatives and municipal-owned utilities, planners could have greater influence in the composition of the energy sources used to produce electricity and liquid biofuels and in the creation of institutional incentives for their adoption. While large privately owned utilities have little incentive to invest in emerging technologies, smaller publicly owned cooperatives may be more amenable to such investments. However, these investments are largely relegated to centralized systems due to maintenance and quality control capabilities. As a recent controversy in a small town in Maine suggests, cooperatives resist distributed production technologies by disallowing their members to produce electricity on the site of consumption (Brophy 2011). As the technologies that utilize alternative fuels mature and become cost-effective, these institutional structures are slowly adapting to accommodate them.

Another avenue where planners can have significant impact is in the emerging carbon markets, which have significantly expanded since 2006. Land may be used to sequester carbon in forests to earn tradable offsets in the growing carbon market. Small forest owners may choose to maintain their forests, thereby altering the incentives for different land uses. Active energy efficiency and renewable energy measures by local governments could be used to trade offsets.

In addition to the rightly placed emphasis on reduction of energy use through more efficient urban form as well as promoting conservation efforts, land use planners have a strong role to play in the emerging distributed energy production phase. They also need to be assertive in the planning for centralized systems as the economic and environmental impacts also need to be weighed in with the social impacts. Local land use regulations, plans, and programs should account for energy production as a key element.

Declaration of Conflicting Interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article. AQ3

Funding

The author(s) received no financial support for the research, authorship, and/or publication of this article. AQ4

Notes

1. "Distributed" refers to decentralized or localized energy generation. Energy "distribution" refers to energy transmission to the end user.
2. While energy transmission intersects with land use issues including takings (e.g., Rossi 2009; Osland 2013) and are likely to become more important with different distributed production (Andrews et al. 2011), we review them only cursorily in this article for want of space and focus.
3. In the interest of consistency, we follow International System of Units (SI) in the rest of the article, even when the original authors use other units.
4. This section specifically addresses nuclear power plants fueled by uranium ore, which is the prevalent nuclear power generation technology in use.
5. Conventional oil and natural gas extraction also have significant planning implications but are omitted in this review for want of space (see e.g., O'Rourke and Connolly 2003; Brody et al. 2006).
6. On the other end of the spectrum, changes in transportation fuels will have significant impact on the parking regulations and design in dense urban areas where off-street parking is not the norm. This is not the focus of this article.
7. *Source*: Table 1.11 (US EPA 2010).
8. The declining US dollar and increases in raw material commodity prices and energy prices were factors influencing capital costs over this time period (Lantz, Wiser, and Hand 2012).
9. In addition to complaints about audible noise, local opponents to wind energy cite impacts of subaudible noise to include "rapid heartbeat, nausea and blurred vision caused by the ultra-low frequency sound and vibrations ..." (Zeller 2010).
10. This section refers to domestic hot water, which is hot water that is used for purposes other than space heating.
11. Solar trees are carports located in surface parking lots and are equipped with roof-mounted solar panels.
12. Not directly related to land use impacts, the increasing number of PEVs not only require charging infrastructure but also could serve as a grid regulator when they are parked, in Vehicle2Grid systems and could become potential solution for the intermittency of renewable energy production (Tomic and Kempton 2007).

References

American Planning Association. 2004. "Policy Guide on Energy." Accessed September 30, 2011. http://www.planning.org/policy/guides/adopted/energy.htm.

American Wind Association. 2011. "Press Release." News. *Press Release*. Accessed July 5, 2012. http://www.awea.org/newsroom/pressreleases/release_01-24-11.cfm.

Anders, S., T. Day, and C. A. Kuduk. 2010. "'Hey, Your Tree Is Shading My Solar Panels': California's Solar Shade Control Act." *The Journal of Sustainable Real Estate* 2 (1): 361–81.

Andrews, Clinton J. 2008. "Energy Conversion Goes Local: Implications for Planners." *Journal of the American Planning Association* 74 (2): 231–54. doi:10.1080/01944360801993531.

Andrews, C. J., L. Dewey-Mattia, J. Schectman, and Mathias Mayr. 2011. "Alternative Energy Sources and Land Use." In *Climate Change and Land Policies*, edited by G. K. Ingram and Yu-Hung Hong, 91–116. Cambridge, MA: Lincoln Institute of Land Policy. Accessed June 16, 2013. https://www.lincolninst.edu/pubs/dl/2036_1358_LP2010-ch05-Alternative-Enegry-Sources-and-Land-Use.pdf.

Andrews, Anthony, and Peter Folger. 2012. *Nuclear Power Plant Design and Seismic Safety Considerations*. Congressional Research Service. Accessed August 12, 2012. http://digital.library.unt.edu./ark:/67531/metadc87179/m1/1/high_res_d/R41805_2012Jan12.pdf.

Andriano, Jennifer R. 2009. "The Power of Wind: Current Legal Issues in Siting for Wind Power." *Planning & Environmental Law* 61 (5): 3–13. doi:10.1080/15480750902963328.

ATSDR (Agency for Toxic Substances and Disease Registry). 2001. "Landfill Gas Primer—Chapter 2: Landfill Gas Basics." Government. *Agency for Toxic Substances and Disease Registry*. Accessed June 10, 2012. http://www.atsdr.cdc.gov/hac/landfill/html/ch2.html.

Barker, J. C. 2001. "Methane Fuel Gas from Livestock Wastes—A Summary." *North Carolina Cooperative Extension Service Publication Number EBAE* (March 14): 071–90. Accessed June 10, 2012. http://www.bae.ncsu.edu/extension/ext-publications/waste/animal/ebae-071-80-methane-gas-barker.pdf.

Bastasch, M., J. van Dam, B. Sondergaard, and A. Rogers. 2006. "Wind Turbine Noise—an Overview." *Canadian Acoustics* 34 (2): 7.

Berndes, G., M. Hoogwijk, and R. van den Broek. 2003. "The Contribution of Biomass in the Future Global Energy Supply: A Review of 17 Studies." *Biomass and Bioenergy* 25 (1): 1–28.

Bernhardt, E. S, and M. A. Palmer. 2011. "The Environmental Costs of Mountaintop Mining Valley Fill Operations for Aquatic Ecosystems of the Central Appalachians." *Annals of the New York Academy of Sciences* 1223 (1): 39–57.

Boudet, Hilary Schaffer, and Leonard Ortolano. 2010. "A Tale of Two Sitings: Contentious Politics in Liquefied Natural Gas Facility Siting in California." *Journal of Planning Education and Research*, 30 (July 8): 5–21. doi:10.1177/0739456X10373079.

Brody, Samuel D., Himanshu Grover, Sarah Bernhardt, Zhenghong Tang, Bianca Whitaker, and Colin Spence. 2006. "Identifying Potential Conflict Associated with Oil and Gas Exploration in Texas State Coastal Waters: A Multicriteria Spatial Analysis." *Environmental Management* 38 (4): 597–617. doi:10.1007/s00267-005-0265-4.

Brophy, Jessica. 2011. "Solar Panel Installation Sparks Controversy." Online Newspaper, *Island Ad-Vantages*. Accessed June 25, 2011. http://islandadvantages.com/news/2011/apr/22/solar-panel-installation-sparks-controversy/.

Bullard, R. D. 1993. "Race and Environmental Justice in the United States." *Yale J. Int'l L.* 18 (1):319–36.

Bureau of Land Management. 2012. *BLM Coal Resources*. Uncompahgre Field Office. Accessed July 6, 2012. http://www.blm.gov/pgdata/etc/medialib/blm/co/field_offices/uncompahgre_field/documents/lands___minerals.Par.35163.File.dat/2012-0301%20BLM%20Coal%20Overview%20North%20Fork.pdf.

Carlson, C. L., and D. C. Adriano. 1993. "Environmental Impacts of Coal Combustion Residues." *Journal of Environmental Quality* 22 (2): 227–47.

Cattin, R., S. Kunz, A. Heimo, G. Russi, M. Russi, and M. Tiefgraber. 2007. "Wind Turbine Ice Throw Studies in the Swiss Alps." In *European Wind Energy Conference Milan*. Accessed October 31, 2011. http://www.meteotest.ch/cost727/media/paper_ewec2007_cattin_final.pdf.

Christopherson, S., and N. Rightor. 2012. "How Shale Gas Extraction Affects Drilling Localities: Lessons for Regional and City Policy Makers." *Journal of Town and City Management* 2 (4): 350–368.

City of Los Angeles. 2012. "Hyperion Sewage Treatment Plant." Government. *City of Los Angeles Stormwater Program*. Accessed July 5, 2012. http://www.lacitysan.org/wpd/siteorg/general/hypern1.htm.

Clark, Bobbie. 2011. "US Shale Boom Fuels Growth in Propopants Market." Marketing News, *ICIS.com*. Accessed June 25, 2012. http://www.icis.com/Articles/2011/08/15/9485305/us-shale-boom-fuels-growth-in-proppants-market.html.

Curran, M. P., and S. W. Howes. 2011. "Soil Disturbance Concerns Regarding the Use of Forest Biomass as a Source of Energy: Examples from Pacific Northwestern North America." *Biomass and Bioenergy*. Accessed July 7, 2012. http://www.sciencedirect.com./science/article/pii/S0961953411004831.

DC WASA. 2007. *Blue Plains Total Nitrogen Removal/Wet Weather Plan*. District of Columbia Water and Sewer Authority. Accessed July 5, 2012. http://www.dcwater.com/news/publications/Draft%20NTWW%20plan.pdf.

DC Water. 2012. "Areas Served by DC Water." *District of Columbia Water and Sewer Authority*. Accessed July 5, 2012. http://www.dcwater.com/about/areas_served.cfm.

Denholm, Paul, and Robert M. Margolis. 2008. "Land-use Requirements and the Per-capita Solar Footprint for Photovoltaic Generation in the United States." *Energy Policy* 36 (9) (September): 3531–43. doi:10.1016/j.enpol.2008.05.035.

Detroit Water and Sewerage Department. 2012. "Wastewater Treatment Plant." *Facilities*. Accessed July 5, 2012. http://www.dwsd.org/pages_n/facilities_wastewater.html.

Dickerson, S. D., J. W. Groninger, and J. C. Mangun. 2001. "Influences of Community Characteristics on Municipal Tree Ordinances in Illinois, US." *Journal of Arboriculture* 27 (6): 318–25.

DiGiulio, D. C., R. T. Wilkin, C. Miller, and G. Oberley. 2011. *Investigation of Groundwater Contamination near Pavillion, Wyoming. US Env. Protection Agency draft report*. US EPA. Accessed June

5, 2012. http://www2.epa.gov/sites/production/files/documents/EPA_ReportOnPavillion_Dec-8-2011.pdf.

Drewitt, Allan L., and Rowena H. W. Langston. 2006. "Assessing the Impacts of Wind Farms on Birds." *Ibis* 148 (S1):29–42. doi:10.1111/j.1474-919X.2006.00516.x.

ERG and RDC. 2011. *Opportunities for Combined Heat and Power at Wastewater Treatment Facilities: Market Analysis and Lessons from the Field*. EPA-430R11018. Accessed August 25, 2012. http://epa.gov/chp/documents/wwtf_opportunities.pdf.

Ewing, Rodney C., and Frank N. von Hippel. 2009. "Nuclear Waste Management in the United States—Starting Over." *Science* 325 (5937) (July 10): 151–52. doi:10.1126/science.1174594.

Fahey, Jonathan. 2010. "How To Burn Trash For Power—Forbes." *Forbes*. Accessed July 7, 2012. http://www.forbes.com/sites/energysource/2010/06/09/how-to-burn-trash-for-power/.

Fthenakis, Vasilis, and Hyung Chul Kim. 2009. "Land Use and Electricity Generation: A Life-cycle Analysis." *Renewable and Sustainable Energy Reviews* 13 (6–7) (September): 1465–74. doi:10.1016/j.rser.2008.09.017.

Fthenakis, Vasilis, and Hyung Chul Kim. 2010. "Life-cycle Uses of Water in U.S. Electricity Generation." *Renewable and Sustainable Energy Reviews* 14 (7) (September): 2039–48. doi:10.1016/j.rser.2010.03.008.

Fujita, Gary. 2009. *Indicator: Phosphorus Discharges From Detroit Wastewater Treatment Plant*. US EPA. Accessed July 12, 2012. http://www.epa.gov/med/grosseile_site/indicators/sos/dwwtp.pdf.

Gagnon, Luc, Camille Bélanger, and Yohji Uchiyama. 2002. "Life-cycle Assessment of Electricity Generation Options: The Status of Research in Year 2001." *Energy Policy* 30 (14) (November): 1267–78. doi:10.1016/S0301-4215(02)00088-5.

Gawande, Kishore, and Hank Jenkins-Smith. 2001. "Nuclear Waste Transport and Residential Property Values: Estimating the Effects of Perceived Risks." *Journal of Environmental Economics and Management* 42 (2) (September): 207–33. doi:10.1006/jeem.2000.1155.

Gerbens-Leenes, Winnie, Arjen Y. Hoekstra, and Theo H. van der Meer. 2009. "The Water Footprint of Bioenergy." *Proceedings of the National Academy of Sciences* 106 (25) (June 23): 10219–23. doi:10.1073/pnas.0812619106.

Green, J., and M. Sagrillo. 2005. "Zoning for Distributed Wind Power–Breaking Down Barriers." Accessed July 7, 2012. http://istec.colostate.edu./ALP/Zoning_for_Distributed%20Wind.pdf.

Groom, Martha J., Elizabeth M. Gray, and Patricia A. Townsend. 2008. "Biofuels and Biodiversity: Principles for Creating Better Policies for Biofuel Production." *Conservation Biology* 22 (3): 602–9. doi:10.1111/j.1523-1739.2007.00879.x.

Harper, J. A. 2008. "The Marcellus Shale—An Old 'New' Gas Reservoir in Pennsylvania." *Pennsylvania Geology* 38 (1): 2–13.

Harvey, L. D. Danny. 2010. *Energy and the New Reality 2—Carbon-free Energy Supply*. London, UK: EarthScan.

Hasselriis, Floyd, and Anthony Licata. 1996. "Analysis of Heavy Metal Emission Data from Municipal Waste Combustion." *Journal of Hazardous Materials* 47 (1–3) (May): 77–102. doi:10.1016/0304-3894(95)00107-7.

Haynes, R. J. 2009. "Reclamation and Revegetation of Fly Ash Disposal Sites—Challenges and Research Needs." *Journal of Environmental Management* 90 (1): 43–53.

Heidrich, E. S., T. P. Curtis, and J. Dolfing. 2011. "Determination of the Internal Chemical Energy of Wastewater." *Environmental Science & Technology*. Accessed May 30, 2012. http://pubs.acs.org./doi/abs/10.1021/es103058w.

Johnson, D. B., and K. B. Hallberg. 2005. "Acid Mine Drainage Remediation Options: A Review." *Science of the Total Environment* 338 (1): 3–14.

Kennedy, W. E., and D. L. Strenge. 1992. "Residual radioactive contamination from decommissioning." *Pacific Northwest Laboratory, NUREG/CR-5512, PNL-79941*.

Kinnaman, Thomas C. 2011. "The Economic Impact of Shale Gas Extraction: A Review of Existing Studies." *Ecological Economics* 70 (7) (May 15): 1243–49. doi:10.1016/j.ecolecon.2011.02.005.

Kosnik, Renee Lewis. 2007. *The Oil and Gas Industry's Exclusions and Exemptions to Major Environmental Statutes*. Durango, CO: Earthworks. Accessed July 2, 2012. http://www.earthworksaction.org/files/publications/PetroleumExemptions1c.pdf?pubs/PetroleumExemptions1c.pdf.

Ladlee, Jim, and Jeffrey Jacquet. 2011. "The Implications of Multi-well Pads in the Marcellus Shale." *Research & Policy Brief Series* 43 (September). Accessed June 24, 2012. http://devsoc.cals.cornell.edu/cals/devsoc/outreach/cardi/publications/loader.cfm?csModule=security/getfile&PageID=1016988.

Lantz, Eric, Ryan Wiser, and Maureen Hand. 2012. *The Past and Future Cost of Wind Energy*. Golden, CO: National Renewable Energy Lab. Accessed July 5, 2012. http://www.nrel.gov/docs/fy12osti/53510.pdf.

Lapola, David M., Ruediger Schaldach, Joseph Alcamo, Alberte Bondeau, Jennifer Koch, Christina Koelking, and Joerg A. Priess. 2010. "Indirect Land-use Changes Can Overcome Carbon Savings from Biofuels in Brazil." *Proceedings of the National Academy of Sciences* 107 (8) (February 23): 3388–93. doi:10.1073/pnas.0907318107.

LA Sewers. 2011. "Gas to Energy—Piped to Scattergood." *Hyperion Treatment Plant Tour*. Accessed July 5, 2012. http://www.lasewers.org/treatment_plants/hyperion/index.htm.

Levy, J. I., L. K. Baxter, and J. Schwartz. 2009. "Uncertainty and Variability in Health-related Damages from Coal-fired Power Plants in the United States." *Risk Analysis* 29 (7): 1000–1014.

Lindseth, G. 2004. "The Cities for Climate Protection Campaign (CCPC) and the Framing of Local Climate Policy." *Local Environment* 9 (4): 325–61.

McDonald, R. I., J. Fargione, J. Kiesecker, W. M. Miller, and J. Powell. 2009. "Energy Sprawl or Energy Efficiency: Climate Policy Impacts on Natural Habitat for the United States of America." *PLoS ONE* 4 (8): e6802.

McPherson, E. G. 2001. "Sacramento's Parking Lot Shading Ordinance: Environmental and Economic Costs of Compliance." *Landscape and Urban Planning* 57 (2): 105–23.

Mirabelli, Maria C., Steve Wing, Stephen W. Marshall, and Timothy C. Wilcosky. 2005. "Race, Poverty, and Potential Exposure of Middle-school Students to Air Emissions from Confined Swine Feeding Operations." *Environmental Health Perspectives* 114 (4) (November 10): 591–96. doi:10.1289/ehp.8586.

Morrow, K., D. Karner, and J. Francfort. 2008. "Plug-in Hybrid Electric Vehicle Charging Infrastructure Review." *US Departent of*

Energy-Vehicle Technologies Program. Accessed June 13, 2012. http://avt.inl.gov/pdf/phev/phevInfrastructureReport08.pdf.

Mukahirn, Laura. 2010. "Notice of Public Hearing for NPDES Permit." Illinois Environmental Protection Agency. Accessed July 5, 2012. http://www.epa.state.il.us/public-notices/2010/mwrdgc-stickney-calumet-northside/hearing-transcript-pm.pdf.

MWRA (Massachusetts Water Resources Authority). 2009. "The Deer Island Sewage Treatment Plant." *Massachusetts Water Resources Authority Online*. Accessed July 5, 2012. http://www.mwra.state.ma.us/03sewer/html/sewditp.htm.

MWRD (Metropolitan Water Reclamation District). 2012. "Stickney WRP." *Metropolitan Water Reclamation District of Greater Chicago*. Accessed July 5, 2012. http://www.mwrd.org/irj/portal/anonymous/stickney.

National Association of Energy Service Companies. 2011. "National Association of Energy Service Companies." Accessed May 29, 2012. http://www.naesco.org/resources/casestudies/documents/CS_SAWS.pdf.

Nicot, Jean-Philippe, and Bridget R. Scanlon. 2012. "Water Use for Shale-gas Production in Texas, U.S." *Environmental Science & Technology* 46 (6): 3580–86. doi:10.1021/es204602t.

Nonhebel, S. 2005. "Renewable Energy and Food Supply: Will There Be Enough Land?" *Renewable and Sustainable Energy Reviews* 9 (2): 191–201.

NRC (National Research Council). 2012. *Induced Seismicity Potential in Energy Technologies*. Washington, DC: National Research Council of the National Academies. Accessed June 22, 2012. http://i2.cdn.turner.com/cnn/2012/images/06/15/induced.seismicity.prepublication.pdf.

NYSDEC (New York State Department of Environmental Conservation). 2011. *Revised Draft Supplemental Generic Environmental Impact Statement*. New York State Department of Environmental Conservation. Accessed June 19, 2012. http://www.dec.ny.gov/docs/materials_minerals_pdf/rdsgeisch50911.pdf.

Office of the Director of Defense Research and Engineering. 2006. *The Effect of Windmill Farms On Military Readiness*. Accessed July 24, 2011. http://www.defense.gov/pubs/pdfs/windfarmreport.pdf.

Office of Solid Waste. 2002. *Exemption of Oil and Gas Exploration and Production Wastes from Federal Hazardous Waste Regulations*. Washington, DC: US EPA. Accessed June 22, 2012. http://epa.gov/osw/nonhaz/industrial/special/oil/oil-gas.pdf.

O'Rourke, Dara, and Sarah Connolly. 2003. "Just Oil? The Distribution of Environmental and Social Impacts of Oil Production and Consumption." *Annual Review of Environment and Resources* 28 (1): 587–617. doi:10.1146/annurev.energy.28.050302.105617.

Osborn, S. G., A. Vengosh, N. R. Warner, and R. B. Jackson. 2011. "Methane Contamination of Drinking Water Accompanying Gas-well Drilling and Hydraulic Fracturing." *Proceedings of the National Academy of Sciences* 108 (20): 8172.

Osland, Anna C. 2013. "Using Land-use Planning Tools to Mitigate Hazards Hazardous Liquid and Natural Gas Transmission Pipelines." *Journal of Planning Education and Research* 33 (2) (June 1): 141–59. doi:10.1177/0739456X12472372.

Osterberg, D., and D. Wallinga. 2004. "Addressing Externalities From Swine Production to Reduce Public Health and Environmental Impacts." *Am J Public Health* 94 (10): 1703–8.

Perlack, R. D., and B. J. Stokes. (Leads), and US Department of Energy. 2011. *U.S. Billion-Ton Update: Biomass Supply for a Bioenergy and Bioproducts Industry*, 227. ORNL/TM-2011/224. Oak Ridge, TN: Oak Ridge National Laboratory. AQ5

Pritchett, Lant, Clifford G. Gaddy, and Simon Johnson. 2006. "Boom Towns and Ghost Countries: Geography, Agglomeration, and Population Mobility [with Comments and Discussion]." *Brookings Trade Forum* (January 1): 1–56. http://www.jstor.org/stable/25063204. AQ6

Randolph, J., and G. M. Masters. 2008. *Energy for Sustainability: Technology, Planning, Policy*. Washington, DC: Island Press.

Rassenfoss, S. 2011. "From Flowback to Fracturing: Water Recycling Grows in the Marcellus Shale." *Journal of Petroleum Technology* 63 (7):48–51.

Red Oak Consulting. 2011. *Water and Wastewater Facilities Land Use Assumptions Plan, Capital Improvements Plan, and Maximum Impact Fees*. San Antonio, TX. Accessed July 4, 2012. http://www.saws.org/business_center/developer/impactfees/docs/FinalReport-COSAOrdinance-5-11.pdf.

Rossi, Jim. 2009. "Trojan Horse of Electric Power Transmission Line Siting Authority." *Lewis & Clark Law School Environmental Law* 39 (4):1015–48.

Royster, Betty. 2011. *The Evolution and Impediments of North Carolina's Methane Capture Pilot Program*. Honors Thesis. Chapel Hill, NC: University of North Carolina at Chapel Hill.

Santoianni, D. A., M. F. Bingham, D. M. Woodard, and J. C. Kinnell. 2008. "Power from Animal Waste–economic, Technical and Regulatory Landscape in the United States." *Journal of Electric Utilities Environmental Conference* 2:1–37.

Searchinger, Timothy, Ralph Heimlich, R. A. Houghton, Fengxia Dong, Amani Elobeid, Jacinto Fabiosa, Simla Tokgoz, Dermot Hayes, and Tun-Hsiang Yu. 2008. "Use of U.S. Croplands for Biofuels Increases Greenhouse Gases Through Emissions from Land-use Change." *Science* 319 (5867) (February 29): 1238–40. doi:10.1126/science.1151861.

Seifert, H., A. Westerhellweg, and J. Kröning. 2003. "Risk Analysis of Ice Throw from Wind Turbines." *BOREAS* 6 (9). Accessed July 7, 2012. http://www.nhsec.nh.gov./2006-01/documents/24_risk_analysis.pdf.

Shizas, Ioannis, and David M. Bagley. 2004. "Experimental Determination of Energy Content of Unknown Organics in Municipal Wastewater Streams." *Journal of Energy Engineering* 130 (2): 45.

Small Business Administration. 2009. "The EPRI/DOE Utility Wind Turbine Performance Verification Program." Government. *Green Government Opportunities for Small Businesses*. Accessed July 7, 2012. http://green.sba.gov/epridoe-utility-wind-turbine-performance-verification-program.

Smith, Robin, and Trina Ozer. 2012. *North Carolina Oil and Gas Study under Session Law 2011276*. Raleigh, NC: NC Department of Environment and Natural Resources. Accessed June 19, 2012. http://portal.ncdenr.org/c/document_library/get_file?uuid=9a3b1cc1-484f-4265-877e-4ae12af0f765&groupId=14.

Sovacool, Benjamin K., and Kelly E. Sovacool. 2009. "Identifying Future Electricity–water Tradeoffs in the United States." *Energy Policy* 37 (7) (July): 2763–73. doi:10.1016/j.enpol.2009.03.012.

Stromberg, S. F. 2010. “Has the Sun Set on Solar Rights? Examining the Practicality of the Solar Rights Acts.” *Journal of Natural Resources* 50 (1):211–54.

Suer, Pascal, and Yvonne Andersson-Sköld. 2011. “Biofuel or Excavation?—Life Cycle Assessment (LCA) of Soil Remediation Options.” *Biomass and Bioenergy* 35 (2): 969–81.

Tomic, J., and W. Kempton. 2007. “Using Fleets of Electric-drive Vehicles for Grid Support.” *Journal of Power Sources* 168 (2): 459–68.

Urban Land Institute and National Parking Association. 2010. *The Dimensions of Parking*. 5th ed. Washington, DC: Urban Land Institute.

US Army Corps of Engineers. 2012. “Nationwide Permit Program.” Military. *Regulatory Permitting*. Accessed July 5, 2012. http://www.spn.usace.army.mil/regulatory/nwp.html.

US DOE (United States Department of Energy). 2006. *Energy Demands on Water Resources: Report to the Congress on Interdependency of Energy and Water*. Albuquerque, NM: Sandia National Laboratories. Accessed January 15, 2010. http://www.sandia.gov/energy-water/docs/121-RptToCongress-EWwEIA-comments-FINAL.pdf.

US DOE (United States Department of Energy). 2011. “Biopower Basics”. Government. *Biomass Program*. Accessed March 5, 2011. http://www1.eere.energy.gov/biomass/biopower_basics.html.

US DOT (Unites States Department of Transportation). 2012. *Alternative Uses of Highway Right-of-way: Accommodating Renewable Energy Technologies and Alternative Fuel Facilities*. Cambridge, MA: U.S. Department of Transportation Office of Planning, Environment, and Realty, Federal Highway Administration.

US EIA (United States Energy Information Administration). 2003. “Commercial Buildings Energy Consumption Survey (CBECS).” *Consumption & Efficiency*. Accessed September 30, 2011, http://www.eia.gov/consumption/commercial/data/2003/index.cfm?view=consumption#e1.

US EIA. 2011. “Review of Emerging Resources: U.S. Shale Gas and Shale Oil Plays.” Government. *US Energy Information Administration*. Accessed June 20, 2012. http://205.254.135.7/analysis/studies/usshalegas/.

US EPA (United States Environmental Protection Agency). 2002. “Potential Benefits Gained By Landfill Owners/Operators From Landfill Gas Energy.” EPA430-F-02-011:1-2. http://nepis.epa.gov/Exe/ZyNET.exe/P10050G0.TXT?ZyActionD=ZyDocument&Client=EPA&Index=2000+Thru+2005&Docs=&Query=&Time=&EndTime=&SearchMethod=1&TocRestrict=n&Toc=&TocEntry=&QField=&QFieldYear=&QFieldMonth=&QFieldDay=&IntQFieldOp=0&ExtQFieldOp=0&XmlQuery=&File=D%3A\zyfiles\Index%20Data\00thru05\Txt\00000021\P10050G0.txt&User=ANONYMOUS&Password=anonymous&SortMethod=h|-&MaximumDocuments=1&FuzzyDegree=0& ImageQuali ty=r75g8/r75g8/x150y150g16/i425&Display=p|f&DefSeekPage=x&SearchBack=ZyActionL&Back=ZyActionS&BackDesc=Results%20page&MaximumPages=1&ZyEntry=1&SeekPage=x&ZyPURL#.

AQ7

US EPA (United States Environmental Protection Agency). 2008. “7. 4 Landfill Methane Utilization.” *Clean Energy Strategies for Local Governments* (December 10): 1–34.

US EPA (United States Environmental Protection Agency). 2010. “Electricity Net Generation From Renewable Energy by Energy Use Sector and Energy Source, 2004–2008.” Accessed October 26, 2011. http://www.eia.gov/cneaf/solar.renewables/page/trends/table1_11.pdf.

US EPA (United States Environmental Protection Agency). 2011a. “Sources and Emissions.” Government. *Methane*. Accessed June 8, 2012. http://epa.gov/methane/sources.html.

US EPA (United States Environmental Protection Agency). 2011b. “Municipal Solid Waste Generation, Recycling, and Disposal in the United States: Facts and Figures for 2010.” US EPA. Accessed April 16, 2012. http://www.epa.gov/osw/nonhaz/municipal/pubs/msw_2010_rev_factsheet.pdf.

US EPA (United States Environmental Protection Agency). 2012a. “Air Emissions from MSW Combustion Facilities.” Government. *Wastes—Non-Hazardous Waste—Municipal Solid Waste*. Accessed July 6, 2012. http://www.epa.gov/osw/nonhaz/municipal/wte/airem.htm#3.

US EPA (United States Environmental Protection Agency). 2012b. “Basic Information.” Government. *Landfill Methane Outreach Program*. Accessed April 29, 2012. http://www.epa.gov/lmop/basic-info/index.html.

US EPA (United States Environmental Protection Agency). 2012c. “Coal Ash.” Government. *Radiation Protection*. Accessed June 20, 2013. http://www.epa.gov/radiation/tenorm/coalandcoalash.html.

US EPA (United States Environmental Protection Agency) Office of Compliance. 2012. “Forestry.” Government. *Agriculture*. Accessed July 5, 2012. http://www.epa.gov/oecaagct/forestry.html#FactsandFigures.

US EPA (United States Environmental Protection Agency), Region 3. 2005. *Final Programmatic Environmental Impact Statement on Mountaintop Mining/Valley Fills in Appalachia*. Accessed March 19, 2012. http://www.epa.gov/region03/mtntop/eis2005.htm.

Wickham, J., K. Riitters, T. Wade, M. Coan, and C. Homer. 2007. “The Effect of Appalachian Mountaintop Mining on Interior Forest.” *Landscape Ecology* 22 (2): 179–87. Accessed July 7, 2012. doi:http://dx.doi.org/10.1007/s10980-006-9040-z.

Wilson, W. H. 1997. “Moles and Skylarks.” In *Introduction to Planning History in the United States*, edited by D. Krueckeberg, , 88–121. New Brunswick, NJ: Rutgers University Press.

Wiser, Ryan, Mark Bollinger, Eric Lantz, and Maureen Hand. 2012. “Recent Developments in the Levelized Cost of Energy from U. S. Wind Power Projects.” Accessed July 7, 2012. http://eetd.lbl.gov/ea/ems/reports/wind-energy-costs-2-2012.pdf.

Wolar, John. 2008. *Meteoroogical Towers and Wind Power Analysis: General Primer*. Eastpointe, MI: Alternate Energy Solutions, Inc. Accessed July 6, 2012. http://www.imea.org/EnergyInformation/AESI_MetTowerPrimer.pdf.

Wong, Shutsu Chai. 2011. “Tapping the Energy Potential of Municipal Wastewater Treatment: Anaerobic Digestion and Combined Heat and Power in Massachusetts.” Massachusetts Department of Environmental Protection. Accessed July 5, 2012. http://www.mass.gov/dep/water/priorities/chp_11.pdf.

World Nuclear Association. 2011. “Direct or Once-through Wet Cooling.” *Cooling Power Plants*. Accessed August 12, 2012. http://www.world-nuclear.org/info/cooling_power_plants_inf121.html.

Zeller, Jr., Tom. 2010. “Noisy Wind Turbines Attract Complaints.” *The New York Times*, October 5, sec. Business/Energy &

Environment. Accessed October 27, 2011. http://www.nytimes.com/2010/10/06/business/energy-environment/06noise.html.

Author Biographies

Marie Curtis graduated from UCLA with a BS in electrical engineering and has more than ten years of design and policy experience. She is a dual degree graduate student in City and Regional Planning and Environmental Science at UNC Chapel Hill.

Nikhil Kaza is an assistant professor of City and Regional Planning at UNC Chapel Hill and an adjunct assistant professor in the Curriculum of Environment and Ecology. His research interests are at the intersection of land use, transportation, energy and environment. AQ8