8.3.1 Wind

Of the approximately 33,000 quads of wind resources available annually in the coterminous United States, only about 170 quads per year can be accessed with current technology, and only about 1/6 quad per year can currently be used cost-effectively to generate electricity (DOE/EIA-0561). Wind speeds of at least 21 km/h (13 miles/h) are considered necessary for generating electricity. As shown in Figure 8.1, regions with such speeds include the Great Plains, the West, coastal areas, and parts of the Appalachians (DOE/EIA-0561).

The average annual capacity factor (i.e., the proportion of actual generation to potential generation at 100 percent capacity utilization) is estimated at 21 percent in 1995 and 29 percent in 2010. This relatively low capacity, compared with current baseload technologies, results from the high degree of intermittency of wind energy in many locations (DOE/EIA-0561). Current energy storage technologies are too expensive to permit wind power plants to serve as large baseload plants. The inability to increase the capacity factors of wind power makes the technology an inappropriate choice for baseload power (Johansson et al. 1993)

In 1992, wind provided 1676 MW(e) of electric generating capacity, produced mostly in California by nonutility generators (Hamrin and Rader 1993). Windfarms in areas around the Altamont Pass, the Tehachapi Mountains, and the San Gorgino Pass have more than 15,000 wind turbines (Pace 1991). The U.S. Department of Energy's (DOE's) Energy Information Administration (EIA) projects that the contribution of wind power will rise to 3600 MW(e) in 2000 and 6300 MW(e) in 2010, all of which would be generated by nonutilities (DOE/EIA-0561).

A recent survey of utilities conducted by UDI/McGraw-Hill indicated that no utilities have announced plans to construct 25 MW(e) or larger wind power plants in the foreseeable future, although some utilities may have unpublished plans (Bergesen 1994). Wind technology can be advanced with many small improvements, as well as larger ones such as development of lighter, stronger blade materials; improved gearing to capture a greater portion of useful wind velocities; improved understanding of wind patterns and siting configurations for wind turbines at a site; and improved electrical storage capabilities (SERI/TP-260-3674).

Wind energy is expected to require the use of approximately 61,000 ha (150,000 acres) or 610 square km (about 235 square miles) of land to generate 1000 MW(e) of power (see Table 8.1 for construction impacts and references). This large land requirement, even in dispersed sites, would eliminate any possibility of co-locating a wind energy facility with a retired nuclear plant, thereby pointing to the need for greenfield siting (siting on undeveloped land). The relatively low capacity factor of wind power means that it would operate less frequently at full power than nuclear, but the impacts associated with land use would still occur. The earth-moving that might be required to clear such a large amount of land would destroy much of the natural environment in affected areas (e.g., coastal, mountainous, or plains), where wind velocities are highest. Erosion and sedimentation, while controllable, would still occur and would adversely affect land and water resources. The visual impact of such extended land clearing would be quite

Figure 8.1 U.S. wind energy resources (contiguous states, winds 13 miles per hour or greater).
Source: Adapted from DOE/EIA-0561.

noticeable and would be a negative aesthetic consequence. Short-term air quality impacts from fugitive dust and equipment exhaust would occur with such extensive activities, and considerable vegetation debris could require disposal. Disturbance of such a large amount of land likely would reveal cultural resources that would require protection. Each of these site impacts would be magnified because of the new transmission lines that are almost always required for greenfield sites. Agricultural land could also be committed to the siting of wind energy facilities in some areas. Adverse impacts could still occur where land is taken out of production, but the acreage lost would likely be less than with natural environments.

The projected impacts of operating wind energy facilities are less than those expected from construction (see Table 8.2 for operational impacts and references). The same amount of land would still be committed to wind generation, but the machines would occupy less than 10 percent of it, freeing up most of the remainder for agricultural or some other compatible use. The aesthetic impact of several thousand wind turbines over a large area likely would strike many

observers as obtrusive. The noise from such equipment likely would reinforce these negative opinions. Birds are likely to collide with the turbines, and wind energy developers should consider migration areas and nesting locations when sites for wind energy facilities are selected. In terms of positive environmental impacts, wind power plants would have little effect on water and air quality and would generate very little waste. Human health, except for a potential small number of occupational injuries, would not be affected by operations.

Table 8.1 Environmental impacts of constructing 1000-MW(e)-equivalent electric power plants for non-nuclear alternative generating technologies

	Resource								
Alternative	Land use	Ecology	Aesthetics	Water quality	Air quality	Waste	Human health	Socioeconomic	Cultural
Wind	61,000 ha (150,000 acres) (Pimentel 1994)	Loss of thousands of acres of natural habitat (Pimentel 1994); some stream sedimentation; erosion	Substantial visual impact in any location (Pimentel 1994; SERI/TP-260-3674)	High potential for sedimentation/erosion damage	Considerable vehicle exhaust, dust from earth moving	Considerable amount of vegetation debris from land clearing	Some accident risks for workers (Grubb and Meyer 1993)	No known estimates but believed to be relatively small peak work force—little potential for adverse impacts	High potential for impacts because of large land area
Photovoltaic cells	14,000 ha (35,000 acres) (Pimentel 1994; Pace 1991)	Loss of 14,000 ha (35,000 acres) of natural habitat, some farm land (Pimentel 1994); some stream sedimentation; erosion is a particular threat to arid areas, fragile soil, and plant communities	Substantial visual impact in any location (Hamrin and Rader 1993)	High potential for sedimentation/erosion damage	Considerable vehicle exhaust, dust from earth moving (Pace 1991)	Considerable amount of vegetation debris from land clearing	Some accident risks for workers	No known estimates but believed to be moderate size peak work force—little potential for adverse impacts	High potential for impacts because of large land area

Table 8.1 (continued)

Alternative	Resource								
	Land use	Ecology	Aesthetics	Water quality	Air quality	Waste	Human health	Socioeconomic	Cultural
Solar thermal	5,700 ha (14,000 acres) (Pimentel 1994; Pace 1991)	Loss of 5,700 ha (14,000 acres) (Pimentel 1994); some stream sedimentation; erosion is a particular threat to arid areas, fragile soil, and plant communities (Pace 1991)	Substantial visual impact to 5,700 ha (14,000 acres) affected (Pimentel 1994; Pace 1991; Hamrin and Rader 1993)	High potential for sedimentation/erosion damage	Considerable vehicle exhaust, dust from earth moving (Pace 1991)	Considerable amount of vegetation debris from land clearing	Some accident risks for workers	No known estimates but believed to be moderate size peak work force—little potential for adverse impacts	High potential for impacts because of large land area
Hydroelectric	400,000 ha (1 million acres) (Pimentel 1994)	Loss of 400,000 ha (1 million acres) of natural habitat, farm land (Pimentel 1994); stream sedimentation, erosion	400,000 ha (1 million acres) visually impacted (Pimentel 1994; Hamrin and Rader 1993)	Considerable sedimentation/erosion	Considerable vehicle exhaust, dust from earth moving	Considerable amount of vegetation debris from land clearing	Some accident risks for workers; spread of diseases from reservoir filling (Moreira and Poole 1993)	Large work force, moderate potential for adverse community impacts; dislocation of residents (Hamrin and Rader 1993)	Almost unavoidable destruction of cultural sites, artifacts typically located on natural edges of water bodies
Geothermal	2800 ha (7000 acres) (DOE/EP-0093)	Loss of 2800 ha (7000 acres) of natural habitat (DOE-0093); some stream sedimentation, erosion	Visual impacts to 2800 ha (7000 acres) (DOE-0093)	High potential for sedimentation/erosion damage	Considerable vehicle exhaust, dust from earth moving	Considerable amount of vegetation, some construction debris	Some accident risks for workers	Moderate size work force; some potential adverse impacts	Moderate potential unless important site-specific resource affected by plant or transmission lines

Table 8.1 (continued)

Alternative	Resource								
	Land use	Ecology	Aesthetics	Water quality	Air quality	Waste	Human health	Socioeconomic	Cultural
Wood wastes	High variable and site specific, perhaps 160,000 to 320,000 ha (400,000 to 800,000 acres) for forest residue recovery. For plant, about 30 acres for each 20-MW facility	Considerable potential for loss of natural habitat and biodiversity; increased soil erosion and nutrient loss (ECO Northwest et al.)	Substantial visual impacts from land clearing. Localized visual impacts with plant construction	High potential for sedimentation/erosion damage. Small sedimentation/erosion damage at plant site (ECO Northwest et al.)	Considerable vehicle exhaust and fugitive dust impacts from earth moving	Considerable amount of vegetation debris and some construction debris	Some accident risks for workers	Source of income and employment in rural areas. Moderate size work force at plant site	High potential for impacts because of large land area
Municipal solid waste (MSW)	For plant, about 12 ha (30 acres) for each 20 MW facility	Small impact—few acres affected and in urban area. Potentially positive impacts if landfills displaced (ECO Northwest et al.)	Localized visual impacts with plant construction	Small sedimentation/erosion damage at plant site (ECO Northwest et al.)	Considerable vehicle exhaust and fugitive dust impacts from earth moving	Moderate amount of vegetation and construction debris	Some accident risks for workers	Moderate size work force at plant site	Relatively small unless important site-specific resource affected by plant or transmission lines

Table 8.1 (continued)

Alternative	Resource								
	Land use	Ecology	Aesthetics	Water quality	Air quality	Waste	Human health	Socioeconomic	Cultural
Energy crops	About 400,000 ha (1 million) acres for crop production. For plant, about 12 ha (30 acres) for each 20 MW facility	Impacts depend on prior land use; if conversion of cropland, then more environmentally benign and would improve biodiversity (OTA; Ranney and Mann)	Minor visual impacts with energy crop establishment. Localized visual impacts with plant construction	Energy crops lower sedimentation, soil erosion, and chemical use relative to agriculture (Ranney and Mann). Small sedimentation and erosion damage at plant site	Moderate vehicle exhaust and fugitive dust impacts from earth moving at plant site	Considerable amount of vegetation debris and some construction debris at plant site	Some accident risks for workers	Source of income and employment in rural areas. Moderate size work force at plant site	Relatively small impacts if cropland and pasture converted to energy crops
Coal	700 ha (1,700 acres) for plant site (DOE/EP-0093)	Loss of 700 ha (1,700 acres) habitat; some erosion, stream sedimentation	Localized visual impacts from land clearing	Potential sedimentation/ erosion damage	Moderate vehicle exhaust, dust from earth moving	Considerable construction debris	Accident risk for workers	1,200–2,500 peak work force (UDI-021-89)	Relatively small unless important site-specific resource affected by plant or transmission lines
Natural gas	45 ha (110 acres) for plant site (DOE/EP-0093)	Loss of 45 ha (110 acres) varied habitat; some erosion, stream sedimentation	Localized visual impacts from land clearing	Potential sedimentation/ erosion damage	Some vehicle exhaust, substantial dust from earth moving	Considerable construction debris	Accident risk for workers	1,200 peak work force (UDI-021-89)	Relatively small unless important site-specific resource affected by plant or transmission lines
Oil	50 ha (120 acres) for plant site (DOE/EP-0093)	Loss of 50 ha (120 acres) varied habitat; some erosion, stream sedimentation	Localized visual impacts from land clearing	Potential sedimentation/ erosion damage	Some vehicle exhaust, substantial dust from earth moving	Considerable construction debris	Accident risk for workers	1,700 peak work force (UDI-021-89)	Relatively small unless important site-specific resource affected by plant or transmission lines

Table 8.1 (continued)

Alternative	Resource								
	Land use	Ecology	Aesthetics	Water quality	Air quality	Waste	Human health	Socioeconomic	Cultural
Advanced light-water reactor	200–400 ha (500–1,000 acres) for plant site plus exclusion area	Loss of 200–400 ha (500–1,000 acres) of habitat; some erosion, stream sedimentation	Localized visual impacts from land clearing	Potential sedimentation/ erosion damage	Moderate vehicle exhaust, dust from earth moving	Considerable construction debris	Accident risk for workers	2,000–5,500 peak work force (UDI-021-89)	Relatively small unless important site-specific resource affected by plant or transmission lines
Conservation	Unquantified land lost to resource extraction for conservation technologies	Adverse impacts from resource extraction	Minimal for resource recovery and processing	Minimal for resource recovery and processing	Minimal for resource recovery and processing	Minimal for resource recovery, processing	Some risks from resource recovery	Minor employment, tax revenues from conservation industry	Minimal
Imported power	If excess Canadian capacity is insufficient, impacts will be similar to U.S. coal or hydro plants	If excess Canadian capacity is insufficient, impacts will be similar to U.S. coal or hydro plants	If excess Canadian capacity is insufficient, impacts will be similar to U.S. coal or hydro plants	If excess Canadian capacity is insufficient, impacts will be similar to U.S. coal or hydro plants	If excess Canadian capacity is insufficient, impacts will be similar to U.S. coal or hydro plants	If excess Canadian capacity is insufficient, impacts will be similar to U.S. coal or hydro plants	If excess Canadian capacity is insufficient, impacts will be similar to U.S. coal or hydro plants	If excess Canadian capacity is insufficient, impacts will be similar to U.S. coal or hydro plants	Same impacts as U.S. except northern Canada, where social conflict between tribes and government is substantial
Delayed retirement	Very few acres affected (DOE/EIS-0146)	Very few acres affected—no impact (DOE/EIS-0146)	Minimal changes	Incidental use	Small exhaust, fugitive dust (DOE/EIS-0146)	Moderate construction debris	Potential accidents to workers	Estimated one-half of normal construction work force	Minimal impact

Table 8.2 Environmental impacts of operating 1000-MW(e)-equivalent electric power plants for non-nuclear alternative generating technologies

	Resource								
Alternative	Land use	Ecology	Aesthetics	Water quality	Air quality	Waste	Human health	Socioeconomic	Cultural
Wind	61,000 ha (150,000 acres) of which 3,000 acres occupied by turbines, rest available for agriculture (Pimentel 1994)	Bird collisions, loss of much of thousands of acres of habitat (Pimentel 1994); interference with animal migration routes (Pace 1991)	Substantial visual and some noise impact in any location (Pace 1991; SERI/TP-260-3674; Rader 1989)	Negligible (Pace 1991)	Negligible (Pace 1991)	Very minor amounts from maintenance of equipment, vegetation	Very minor risks from accidents, noise	Relatively low work force, assessed plant value—fewer potential long-term community benefits than large baseload plants	Relatively small unless important site-specific resource affected by plant or transmission lines
Photovoltaic cells	14,000 ha (35,000 acres); no other compatible uses (Pimentel 1994; Pace 1991)	Loss of 14,000 ha (35,000 acres) of natural habitat and some agricultural land (Pimentel 1994)	Substantial visual impact in any location (Hamrin and Rader 1993)	Small runoff from panels could cause sedimentation	Negligible	Very minor amounts from maintenance of equipment, vegetation; some toxics	Some risk to maintenance workers	Relatively small work force, assessed plant value—fewer long-term community benefits than large baseload plants	Relatively small unless important site-specific resource affected by plant or transmission lines
Solar thermal	5,700 ha (14,000 acres); no other uses (Pimentel 1994; Pace 1991)	5,700 ha (14,000 acres) of natural habitat lost and some agricultural land (Pimentel 1994)	Substantial visual impact; reflected sunlight (Pimentel 1994; Pace 1991; Hamrin and Rader 1993)	Minor amounts used except where water is cooling agent (Rader 1989); possible contamination from cleaning agents (Rader 1989); some runoff potential	Minor emissions of pollutants during normal operations, greater risks with accidents (Pimentel 1994)	Very minor amounts from maintenance of equipment, vegetation	Possible eye damage from reflected sunlight; occupational hazards from exposure to heat transfer fluids (Pace 1991); some risk to maintenance workers	Relatively small work force, assessed plant value—fewer long-term community benefits than large baseload plants	Relatively small unless important site-specific resource affected by plant or transmission lines

Table 8.2 (continued)

Alternative	Resource								
	Land use	Ecology	Aesthetics	Water quality	Air quality	Waste	Human health	Socioeconomic	Cultural
Hydroelectric	400,000 ha (1 million acres); no other uses (Pimentel 1994)	400,000 ha (1 million acres) of natural habitat and agricultural lands lost; disruption of spawning, migration routes (Rader 1989); killing of fish thru eutro-phication, passage through dam, water temperature change (Moreira and Poole 1993); altered flora, fauna populations	1 million acres visually impacted (Pimentel 1994; Hamrin and Rader 1993)	Increased sedimentation (Moreira and Poole 1993); temperature changes, competition for water and arid regions (Rader 1989)	Negligible	Minor amounts from equipment replacement, reservoir clearing	Some risks for recreational boating, swimming deaths; risk of dam failure; some risk to maintenance workers	Small work force, high assessed value—some potential long-term economic/ community impacts, changes in recreation (free-flowing stream to lake)	Relatively small unless important site-specific resource affected by plant or transmission lines