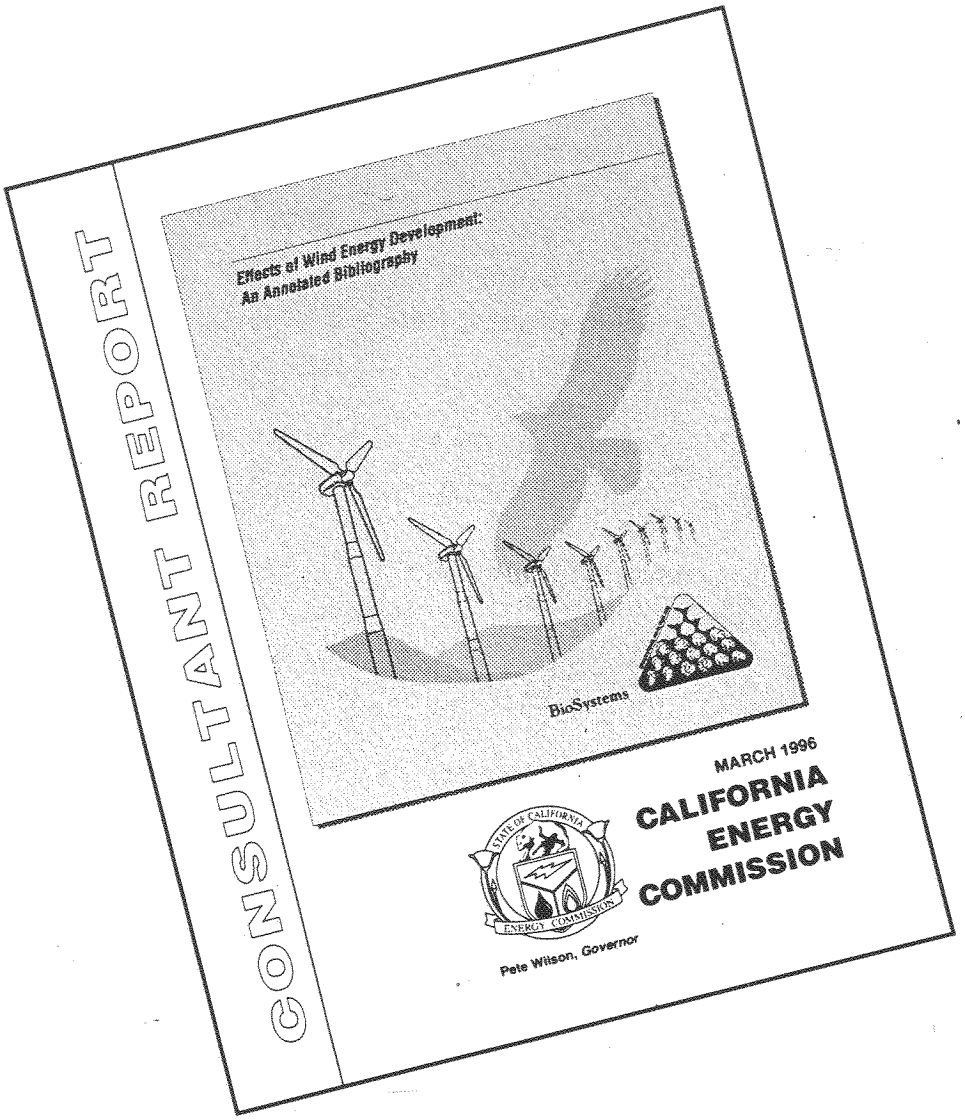

CALIFORNIA ENERGY COMMISSION

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Introduction

This bibliography was initiated in response to numerous requests for a summary of literature related to the effects of wind energy development, particularly effects on birds. Interest in the bird/wind energy issue in this country began in the mid 1970s with the development of large windfarms. In recent years, there has been growing interest and controversy over potential impacts to birds from wind energy development. Currently, wind energy developments have either been constructed or are in the planning stages in many states within the U.S. as well as in many other countries.

This bibliography contains entries that date from mid 1970 to 1995, from both the U.S. and abroad. Entries were taken from government documents, conference proceedings, journals or periodicals, utility company reports, books, and magazines. Some entries are taken from other bibliographies; these are identified in the citation. Articles not published in English were included when an English summary was available. Approximately 20 articles published in a foreign language had no English summary; these are on file at the California Energy Commission Sacramento office for future translation.

Although all effects of wind energy development were considered, special attention was given to the following aspects of each report: avian mortality and disturbance at wind turbines, habitat and structural features that could contribute to mortality, avian behaviors that may help explain mortality, suggested mitigation measures, study methodologies, and siting criteria. Citations are indexed by subject, taxonomic, and geographic categories at the end of this report.

Glossary of Acronyms

The following list provides the translation of acronyms used both in citations and in annotations.

BLM	Bureau of Land Management
BPA	Bonneville Power Administration
CEC	California Energy Commission
DEIS	draft environmental impact statement
EA	environmental assessment
EAR	environmental assessment report
EIA	environmental impact assessment
EIR	environmental impact report
EIS	environmental impact statement
EPRI	Electric Power Research Institute
FEIS	final environmental impact statement
FONSI	finding of no significant impact
IEEE	Institute of Electronics and Electrical Engineering
NEPA	National Environmental Policy Act
PG&E	Pacific Gas and Electric Company
RSPB	Royal Society for the Protection of Birds
USDOE or DOE	U.S. Department of Energy
USFWS	U.S. Fish and Wildlife Service
WECS	wind energy conversion systems
WED	wind energy development
WRA	wind resource area
WTG	wind turbine generator

Annotated Bibliography
Alphabetical Listing by Author

1. 3-C Energy Systems, Inc. (Casey-Courtney-Cotter). 1983. Unpublished letters and telephone records from raptor experts regarding the Bald Mountain Wind Park. 3-C Energy Systems, Inc., Westlake Village, California.

A number of experts provided their opinions, either through letters or through telephone conversations with 3-C personnel, on the potential for endangerment of California condors by installation of the Bald Mountain Wind Park. The general opinion was that there was little likelihood the windfarm would seriously affect condors. Transmission lines were stated to constitute a greater hazard than the turbines themselves. One expert suggested that all transmission lines associated with the project be placed underground. Most experts stated that little information existed upon which to base a firm opinion, either positive or negative.

2. Air Quality Research. 1992. Los Angeles Harbor Wind Power Plant, San Pedro Breakwater, San Pedro Bay. Research report—avifaunal impact. Prepared for Department of the Army, Corps of Engineers, Los Angeles District.

This report was prepared to provide federal, state, and local agencies with an identification of the potential avifaunal impacts associated with the proposed Los Angeles Harbor Wind Power Plant. Because the proposed project was the first significant coastal wind turbine installation in the U.S., no previous American studies existed to assess impacts posed to marine-associated species. The study was based on a review of European literature. Four potential areas of impact were identified: nesting, foraging, roosting/loafing, and collisions. Nesting impacts included loss of nesting habitat possibly associated with the constant disruption of light caused by rotating blades, which decreased suitability in a radius of up to 400 m around turbines in one study. Impacts to foraging and to roosting/loafing included wind turbines causing either a direct physical barrier or "frightening" birds away from foraging areas. An already-high loss of foraging habitat in L.A. Harbor made this a heightened concern. Avian collisions with human-made structures are well documented in the literature, but experience in Europe has shown that individual and single rows of turbines in unclustered areas with small bird populations provide the best landscape design for wind parks.

3. Air Quality Research. 1992. Los Angeles Harbor Wind Power Plant, San Pedro Breakwater, San Pedro Bay. Concept summary. Prepared for Department of the Army, Corps of Engineers, Los Angeles District.

This short document defines the need, the concept, and the precedent on which the proposed project was based. The *need* was based on the fact that Los Angeles is in nonattainment of federal and state air quality standards and must develop ways to reduce air pollution, especially at sources within its boundaries. The *concept* was to place 20 to 30 wind turbine generators along the existing San Pedro Breakwater to produce 600 million kWh of clean electricity over the next 20 years, which was expected to displace more than 1,400,000 barrels of fuel oil, 2,200,000 pounds of air pollutants, and 9,000,000 tons of greenhouse gases over a conventional power plant burning a mix of oil and natural gas. The *concept* was based on European experience, recognizing that, despite precedent set by many projects, the San Pedro Bay area would have unique structural and environmental issues: siting the

wind power plant in an already-busy industrial environment may be not only the least intrusive to neighboring land use and public perception of visual disturbance, it may also be the most valuable location for displacing air pollution related to or generated from the local industry.

4. Air Quality Research. 1992c. Los Angeles Harbor Wind Power Plant, San Pedro Breakwater, San Pedro Bay. General information document. Report no. AV-R-91/7015R4. Prepared for Department of the Army, Corps of Engineers, Los Angeles District.

This document provides general information on the proposed Los Angeles Harbor project, including background, breakwater selection criteria, technical specifications of the wind turbines to be used, engineering considerations, operational considerations, and environmental considerations. Environmental impact was not appraised; rather, areas of potential concern were described. These included air resources, utilities, land use, recreation, socioeconomics, cultural resources, aesthetics, noise, bird collisions and other disruptions, and water quality.

5. Anderson, R.A. and J.E. Estep. 1988. Wind energy development in California: impacts, mitigation, monitoring, and planning. California Energy Commission, Sacramento. Reference and summary taken or adapted from California Energy Commission 1995.

Of 147 documented avian collision and electrocution incidents at California wind energy facilities from 1985 to 1988, 101 were raptors. Of these, 34 were eagles and 58 were hawks. "In the Altamont Pass since 1985, an average of 11 eagle incidents and 17 hawk incidents have occurred annually. Ninety-one percent of all documented avian mortality incidents have resulted in mortality." Later the authors state, "Based on the collection of existing mortality information, monitoring studies, with the objective of better understanding and resolving biological effects of wind projects, are definitely needed and justified in California."

6. Association of Bay Area Governments. 1987. Small but powerful: a review guide to small alternative energy projects for California local decisions. Reference and summary taken or adapted from California Energy Commission 1995.

Bird collisions and electrocutions with wind turbines and associated wires are cited as wind energy development impacts. Lines near water have been found to be more hazardous than lines near other areas. "Although bird mortality rates are relatively low, even these rates may be significant for endangered raptors," notably the California condor, peregrine falcon, and bald eagle. Appropriate mitigation measures are discussed and techniques for protecting birds are given. Special attention is given to the California condor, whose survival is seen as a major conflict with windfarm development.

7. Bechtel Power Corporation. 1981. Kahuku Wind Energy Project EIS. Prepared for Windfarms, Ltd. Submitted to Department of Land and Natural Resources, Honolulu, Hawaii.

This EIS was undertaken to evaluate a proposed large-scale commercial wind energy project on the island of Oahu. To assess the environmental consequences of the project, all construction and operational activities and their resulting adverse environmental effects were identified. The ability to mitigate the effect, either partially or completely, was considered, and appropriate mitigation measures were developed. The EIS states it would be possible, by careful application of these measures, to minimize or completely eliminate the impact. The major potential adverse construction and operations impacts identified include erosion, siltation, topographic alteration, soil and vegetation

removal, liquid spill, fugitive dust, hydrologic, disturbance of endangered or special-interest species and/or habitat, employment, traffic, cultural resource, visual, noise, water quality, land use, communication systems interference, and safety. Mitigation measures are proposed for each. Mitigation measures suggested for impacts to special-status species or their habitats include avoidance of known special habitat, development of survey and monitoring efforts, revegetation with native plant species, and consultation with the appropriate state personnel.

8. Benner, J.H.B., J.C. Berkhuizen, R.J. de Graaff, and A.D. Postma. 1993. Impact of wind turbines on birdlife. Final report No. 9247. Consultants on Energy and the Environment, Rotterdam, The Netherlands.

This paper is the final status report on wind energy and its impact on bird life. The goals and preliminary results were presented in Berkhuizen and Postma (1991). The conclusions presented here are similar to those in the report on the preliminary results, but a more detailed analysis is presented. Studies from Europe and the U.S. are analyzed for legitimacy of assumptions and validity of conclusions. Most European studies deal with bird mortalities and disturbance in coastal areas. The number of victims per turbine per year in such areas appears to be acceptable. Although the effect of wind turbines on breeding birds appears to be negligible, disturbance to some species of resting and migrating birds has been noted in several studies. The authors consider the most important concern to be disturbance to resting birds. Consequently, when planning new developments, areas that are rich in resting birds, such as wetlands, should be avoided. The authors state that negative attitudes toward wind energy projects are not particularly due to avian considerations, but rather to the general objective to protect landscapes and habitats from disturbance. The report concludes that all new locations for wind energy projects should be weighted on the disturbance aspect, particularly disturbance to resting birds.

9. Berkhuizen, J.C. and A.D. Postma. 1991. Impact of windturbines on birdlife. Consultants on Energy and the Environment, Rotterdam, The Netherlands.

This is a preliminary status report on the impact of wind turbines on bird life in Europe and the United States. The paper includes an analysis of studies conducted to date, an analysis of the potential conflict between selecting a desired wind energy location and the risks for birds, an inventory of attitudes of the nature conservation organizations toward wind energy, and an estimation of the remaining gaps in knowledge. Results from several studies indicate that bird collisions and bird disturbance both occur. The magnitude of the impact varies according to location, with coastal areas having the greatest potential for impact. In most studies, the number of bird victims was not considered alarming. Disturbance to birds caused by wind parks has more uncertainties, with no results available yet on the magnitude of the impact. The biggest gaps in knowledge concern the impact to birds by disturbance and the collision of birds with turbines just off shore.

10. Berrini, M., F. Butera, L. Cobello, D. Franchini, M. Grondacci, L. Pagliano, G. Silvestrini, and S. Woess-Gallasch. 1992–93. Environmental and normative issues concerning the installation of offshore wind turbines. Italian Specifities [*sic*]. Extract from Wind and solar technologies in Italy: obstacles to an extensive use and possibilities for the diffusion of these technologies. Research Institute Ambiente Italia, Milan, Italy.

Abstract by authors: The aim of this project is to indicate the environmental and normative issues which can be expected regarding the installation of offshore wind turbines in Italy and to propose siting strategies and mitigation measures for guaranteeing a good start for the first Italian offshore

projects. As far as a relative information has been available, the research takes into account the experiences with realized offshore wind plants. Because of the lack of consolidated results on the environmental impacts of offshore wind turbines, they have been deduced to a large extend [*sic*] from the knowledge concerning on-land wind plants, by considering the different conditions between the two types of sites. The results — impacts, planning strategies and mitigation measures — have to be interpreted as hypotheses which have to be verified by concrete case studies. Also the specific Italian legal situation is demonstrated. This project of the Research Institute Ambiente Italia is part of a research project currently in elaboration for ENEL, the Italian national energy board.

11. Bonneville Power Administration. 1979. Environmental report—Goodnoe Hills wind turbine generation. U.S. Department of Energy, BPA, [location unknown].

This report is an updated version of the environmental report submitted with BPA's proposal to the USDOE to construct three MOD-2 (2,500 kW) turbines at Goodnoe Hills, in southern Washington State. The assessment of probable impacts included a discussion of the following topics: construction, noise, transportation, visual, communications interference, microclimate effects, recreation, safety, and bird collisions and wildlife. Visual impacts were judged to be potentially high. No adverse impacts on wildlife were anticipated, based on discussions with resource agencies, past studies of MOD turbines in Ohio, and the nature of the wildlife habitat at the site. Wildlife populations at Goodnoe Hills are sparse, says the report, and the site is of little importance as a pathway for migratory waterfowl or songbirds.

12. Bonneville Power Administration. 1987. Cape Blanco Wind Farm feasibility study. BPA, Portland, Oregon.

This feasibility study investigated the engineering, economic, environmental, and meteorological aspects of a proposed 80-MW wind energy project in southwest Oregon. Study sponsors evaluated the potential impacts of large (2,500 kW) MOD-2 and intermediate (170 kW) FloWind turbines. No unusual engineering aspects were discovered that would preclude development at Cape Blanco. State noise regulations reduced the number of useable sites in the study area. Still other sites were eliminated to mitigate visual impacts, but in some cases visual impacts would still be high. Vibrations were not expected to affect anadromous fish in nearby rivers. Television signal interference could be mitigated in several ways. Average wind speed at 50 ft above the ground was not considered high enough to be cost-effective for current wind turbine designs. Birds at greatest risk were believed to be nocturnal migrants because of limited visibility of structures at night. Moreover, guy wires on vertical-axis turbines pose a greater threat than rotating blades. Most birds killed by collisions with human-made structures are passerines (songbirds) that migrate singly, the study states. Given that only about 10 percent of migratory passerines travel at altitudes below 350 ft, and given that a conservative 95 percent avoidance rate is likely (i.e., at least 95 percent of birds are likely to see and successfully avoid turbines), it was projected that less than 0.1 percent of birds flying low enough to strike turbines would be injured or killed. Nevertheless, careful observation during phased-in construction was recommended.

13. Bosley, P. and K. Bosley. 1988. Public acceptability of California's wind energy developments: three studies. Wind Engineering 12(5):311–318.

Qualitative and quantitative research was conducted during 1988 to determine perceptions and attitudes regarding wind energy development as held by: government and regulatory officials involved with windfarm developments in the three major wind resource regions in California;

environmentalists and community activists in these regions; and members of the wind industry. Results indicate that development of large windfarm projects is being affected by local opposition that exists for several reasons: lack of knowledge about the technical maturity and economics of today's windpower, opposed interests between the developers and the local people, and development-created problems such as visual intrusion.

Results of interviews with local government and regulatory officials showed that opinions varied both between and within the three windfarm regions of California (Altamont Pass, Tehachapi, and San Gorgonio Pass), but the general trend was that industry credibility was "blown away" by the first surge of wind farmers. Interviews with community activists showed that risks were perceived to outweigh benefits within one's community. Respondents from the wind industry indicated that members were aware of their problems and were actively working to improve both performance and communications. Analysis of results and recommendations are presented in the paper, as are conclusions.

14. Bosley, P.B. and K.W. Bosley. 1992. Risks and benefits of wind generated electricity: facts and perceptions. Energy Sources 14:1-9.

The authors present current information regarding windpower technology, summarize their research on public acceptability of windpower technology, and offer recommendations to address certain issues identified as impeding the acceptance and usage of wind-generated electricity. Before tradeoffs can be effectively addressed, the benefits of wind-generated electricity must be recognized, which will not occur until perceptions regarding wind energy's attributes catch up with its technology. Perceptions and facts are not in accord.

Among the windpower facts presented are the number (16,000), location (Altamont Pass, Tehachapi, and San Gorgonio Pass), and aggregate power rating (1,500 MW) of California's wind turbines; projections for installations around the world; environmental and economic attributes of windpower; and reliability and risks of windpower. The authors' research suggests that perceptions, as well as behaviors, of four salient groups of people differ significantly from the reality of contemporary windpower facts. The four groups are local government officials, local environmentalists-activists, leaders of the National Coalition of Environmental Groups, and national and regional leaders of the Sierra Club. Participants in a survey were asked to respond to cost-effectiveness, environmental impact, advantages, and disadvantages. In the survey, cost-effectiveness and environmental impact were ranked on scales of least to most, while respondents were asked to list advantages and disadvantages.

Perceived advantages included that windpower was clean, renewable, or provided no advantage over other sources of energy. Perceived disadvantages included visual impacts, unreliability, other environmental problems, and cost-effectiveness. Those respondents who were most personally affected by a large windpower plant (those people belonging to the two local groups) believed that the overriding disadvantage was the environmental impact, primarily the visual impact. In contrast, respondents in the two national groups were most concerned with reliability and cost.

The authors say that developers must accept the inevitable fact that property values, quality of the environment, and operational nuisances are legitimate issues that should be identified and responded to. Author recommendations include several compensatory measures to attempt a balance between risks and benefits, and strong public participation in planning of windfarm developments.

15. Bureau of Land Management. 1982a. San Gorgonio wind resource site specific projects—draft environmental impact report no. 156. Prepared by Wagstaff and Brady for Riverside County, California, and BLM.

This draft EIR assesses the impacts of six applications for wind energy developments in the San Gorgonio WRA. The proposed projects would commit approximately 662 acres of land to wind development. The EIR addresses the environmental, social, and economic effects of the proposed development. It claims that long-term, cumulative effects of multiple-turbine wind developments on wildlife are not certain. At the time of the study, current data indicated little or no significant impacts on migratory birds and local raptors. It was thought that the number and size of turbines in some areas may increase collision hazards for birds. Suggested mitigation measures included participation in a monitoring program and proper turbine/transmission line design and location (e.g., siting in areas of previous disturbance). The monitoring program would define the impacts on migratory birds and local raptors to determine the needed levels of future mitigation (see McCrary et al. 1983, 1984, and McKernan et al. 1984). Visual mitigation measures included consideration of siting, color, and spacing of machines. With incorporation of these measures it was decided that the development would not significantly degrade the visual resource.

16. Bureau of Land Management. 1982b. Final environmental impact statement on the San Gorgonio Pass Wind Energy Project. Report ES 82 001-4211. BLM, Ridgecrest, California.

Five private developers, one utility, and a major city applied to the BLM for rights-of-way to use public lands for the development of large-scale wind energy systems. These systems would be constructed and operated by one public and six private groups on 12,780 acres surrounding the San Gorgonio Pass in Riverside County, California. Power generated by the windfarms would service customers in the Los Angeles metropolitan area. In accordance with NEPA, this document deals with the following issues: aesthetics, safety, noise, electromagnetic interference, ecology, land use, and wind access and equity. Three alternatives were considered: (1) development as proposed by the applicants; (2) development on lands except those with significant surface conflicts; and (3) the "no action" alternative. Under the first alternative, at least some level of impact was expected in the all areas except employment, housing, and tourism. Under the second alternative, mitigation would eliminate or reduce many impacts. The Bureau preferred the second alternative.

17. Bureau of Land Management. 1983. Decision record for wind energy development in the Tehachapi Pass area. BLM, Ridgecrest, California.

This Decision Record is primarily a collection of tables, exhibits, and public comments, with little narrative, relating to an EA analyzing the issuance of noncompetitive and competitive rights-of-way grants on approximately 1,300 acres of public land in the Tehachapi Pass Area of Kern County, California (the proposed action). Seven companies and two individuals applied to the BLM for rights-of-way to use thirteen parcels of public land for the development of large-scale wind energy systems, on which nine parcels would be competitively bid. Public comment on the proposed action involved concerns for scenic quality, wildlife, cultural resources, vegetation, recreation, mining, livestock grazing, social/economic values, safety, soil/water/air, and noise. None of these concerns was considered significant. Because it is the policy of the BLM to provide public lands for the exploration and development of new energy resources, the "no action" alternative (i.e., to not allow wind energy development) was not considered a reasonable alternative. Based on the EA, the BLM concluded that the decision to allow the proposed action, with mitigating measures in the form of operating

stipulations, did not constitute a major federal action significantly affecting the quality of the human environment, so no EIS was prepared for this project. It was agreed that a monitoring program would be conducted by resource specialists and Desert Rangers to ensure compliance with all terms and conditions of the grant and any additional stipulations added during review of the plans of operation.

18. Bureau of Land Management. 1984a. Draft suitability analysis and supplemental environmental assessment of certain additional lands in the western Mojave Desert, Tehachapi Pass region. BLM, Ridgecrest, California.

This report was prepared in part as a response to interest expressed by private developers to use lands within the Tehachapi-Mojave region of California for wind energy development. All lands identified in the report are located in the western Mojave Desert, north and south of Tehachapi Pass; they have existing access; and they are considered to be in areas of good or excellent wind energy resource (based on estimated average annual wind speed). The document was not intended to serve as a site-specific environmental analysis; it simply made recommendations about whether a parcel was suitable, not suitable, or suitable with modification. The document addresses the following resources: land use (recreation, geology and minerals, power transmission corridor, livestock grazing, and communications sites), wilderness, visual resources, biological resources (climate and soils, vegetation, and wildlife), archaeological resources, and Native American values. Each of the above resources was given a sensitivity rating of low, moderately low, moderate, moderately high, high, very high, or undetermined. Based on these sensitivity ratings, each parcel was given a suitability rating. Of ten parcels, two were ranked unsuitable and eight were ranked suitable with modification.

19. Bureau of Land Management. 1984b. Final environmental assessment for Table Mountain Study Area wind energy development. El Centro Resource Area, El Centro, California.

The purpose of this EA was to generically analyze impacts resulting from wind energy development in the Table Mountain area of San Diego County and to identify zones suitable for wind energy development. Major issues discussed include rare and threatened wildlife, wilderness, visual resources, archaeological resources, and Native American concerns. The level of general impacts was related to the location and degree of development occurring. Special management species, such as magic geckos, San Diego horned lizards, and golden eagles, could be impacted by habitat loss or disturbance, or could be killed or injured from construction or operation of the project. The document mentions the potential for loss of individual birds to collision, suggesting that primarily nonresident individuals would be affected, especially in poor weather conditions. It was not known whether the area is on a migration route, so the severity of loss of migrating birds was not predicted. Means of mitigating impacts resulting from development were presented, including avian mortality monitoring.

20. Bureau of Reclamation. 1979. Environmental assessment report for system verification units, wind energy project, Wyoming. Prepared by the Bureau of Reclamation, Lower Missouri Region, Denver, Colorado.

This EAR was written to assess impacts of installation of five 2.5-MW wind turbine generators in southeastern Wyoming; the number of units was later reduced from five to possibly two. These units would serve as system verification units to verify system performance, operation and maintenance requirements, design criteria, manufacturer's details, and the system integration concept for a

potential expanded wind-generator system. They would also be demonstration units to test public reaction and acceptance of wind turbine development in Wyoming, and they would serve as a means to measure and monitor possible changes in wildlife habitat and animal and bird behavior resulting from operation of the units. Impacts were considered to climate, air quality, and wind; topography, geology, and mineral resources; soils; land uses; vegetation; wildlife, including antelope, mule deer, raptors, prairie dogs/black-footed ferrets, sage grouse, and waterfowl; socioeconomics; aesthetic quality; recreation; cultural resources; safety; and communications interference. Anticipated unavoidable impacts included loss of vegetation at construction sites, disturbance to wildlife and to residents of the nearby town of Medicine Bow from noise and activity associated with construction, disturbance to wildlife associated with human visitation to turbine sites, possible bird kills from collision with towers and blades and from electrocution, and others.

21. Bureau of Reclamation. 1981. Wind-hydroelectric energy project, Wyoming. Executive summary, feasibility report, and environmental assessment. Bureau of Reclamation, Wyoming.

This combined document is for a proposed development of a large wind turbine field near Medicine Bow, Wyoming. The executive summary is a brief résumé of the feasibility report and the environmental compliance documents. The feasibility report provides information on planning procedures, alternatives, economics, and regional economic and developmental effects. The EA and FONSI evaluate the environmental consequences associated with the proposed alternatives. The proposed development would consist of a wind turbine field with generation capacity of 100 MW. Three different plans were studied at two potential sites. These included wind field plans for 24 4-MW wind turbine units at Site A (Alternative 1), 25 4-MW units at Site C (Alternative 2), and 40 2.5-MW units at Site C (Alternative 3). Alternatives 1 and 3 are presented in this report. The lack of significant environmental impacts related to construction led to the conclusion that a FONSI was the appropriate NEPA-compliance document for this project.

22. Bureau of Reclamation. 1984. Status report on system verification units: wind-hydroelectric energy project, Wyoming. Bureau of Reclamation, Wyoming.

This paper presents the results of a five-year environmental monitoring program of two large wind turbines located near Medicine Bow, Wyoming. The analysis of environmental effects focused on wildlife, noise, aesthetics, and public reaction and acceptance. Specific wildlife concerns included impacts to sage grouse strutting grounds, waterfowl populations, raptor nesting and productivity, and pronghorns. Surveys for dead birds were also conducted. No permanent effects to wildlife reproduction or distribution were noted. A total of 25 dead birds comprising 12 species (mostly passerines) was recovered in a one-year period. Most mortalities were associated with guy wires attached to the meteorological tower. This number of mortalities was considered small relative to the number of birds resident to and passing through the study area.

23. Burke, B. 1975. Energy from the wind—annotated bibliography: basic volume, August 1975. Solar Energy Applications Laboratory, Colorado State University, Fort Collins, Colorado. Four supplements carrying the same title have since been published: April 1977, December 1979, April 1982, and June 1985.

The basis for this bibliography was a systematic search of the major abstracting and indexing tools from 1950 to 1974. This was augmented by references found in other bibliographies on windpower, publication lists of institutions known to be involved in windpower research, and input from

windpower professionals. This is a comprehensive bibliography that includes all references to wind energy regardless of scope or emphasis. Whenever possible, abstracts or annotations were included. The bibliography is organized by year and indexed by author and subject. Subject categories include environmental impact, aesthetics, public acceptance, safety, and noise. The bibliography has been updated through supplemental issues.

24. Buurma, L.S. and J. van Gasteren. 1989. Trekvogels en obstakels langs de zuidhollandse kust—radarwaarnemingen van vogeltrek en het aanvaringsrisico bij hoogspanningsleidingen en windturbines op de maasvlakte (Migratory birds and obstacles along the coast of the Dutch province Zuid Holland—radar observations from Hoek van Holland and victims of the electric power line over the maasvlakte compared, also in relation to the allocation of windturbines; English summary). Koninklijke Luchtmacht, Luchtmachstaf; Afdeling Luchtmacht Bedrijfsveiligheid, Sectie Ornithologie; Gravenhage, Province Zuid-Holland.

Migratory bird movements were studied in the vicinity of a power line along the coastal zone of Holland using tracking radar. Searches were also conducted for dead birds along the power line. Due to limited visibility at night, it was originally thought that birds may be at higher risk during nocturnal migration. Mortality was lower, however, than originally expected and constituted a small percentage of the birds that potentially could collide. This surprisingly low mortality was attributed to the finding that nocturnal migration was at higher altitudes and was spread out over a large area. Diurnal migration was, by comparison, more concentrated along the coast and lower in altitude. The strong diurnal coastal migration was the main stimulus for the concern among policy makers about erecting wind turbines in this coastal zone. Although no specific research on wind turbines was conducted for this study, the authors concur with other research to date that indicates that wind turbines are less dangerous than power lines to birds.

25. Byrne, S. 1983. Bird movements and collision mortality at a large horizontal axis wind turbine. Cal-Neva Wildl. Trans. 1983:76–83.

This study was conducted as part of PG&E's performance monitoring program for a Boeing MOD-2 wind turbine located on the western edge of Suisun Marsh in Solano County, California. Raptor and waterfowl movements were monitored prior to construction. Nocturnal migration over the site was monitored for 6 weeks using a portable ceilometer-image intensifier system. Searches for dead birds were conducted 5 days a week during this period and once weekly thereafter. Weather data were collected to determine the relationship between bird movements and weather conditions. Findings reported include low rates of waterfowl movement and nocturnal passerine migration over the site; moderate to high raptor use of the area; collisions occurring during all lighting and weather conditions; and insignificant collision mortality. Five dead birds were found between fall 1982 and January 1, 1983, including a warbler, a meadowlark, a starling, a coot, and an American kestrel. The paper includes an account of the authors watching an American kestrel interacting with an operating turbine, finally being struck by the rotor and killed. EPRI (1985) presents results of the completed study.

26. California Energy Commission. 1980a. Impact of large wind energy systems in California. Prepared by Solar Energy Conversion Systems Inc., Glendora, California.

The goal of paper was to evaluate the potential impact of large wind energy systems in California. Issues examined include environmental impacts, economic impacts, and institutional factors. This

report documents both environmental and economic benefits to developing large wind energy systems in the state. The environmental impacts addressed include health and safety, ecological effects, electromagnetic interference, noise, land use, and aesthetics. The consensus was that wind turbine generators imposed only minor effects on the environment. Conclusions regarding impacts to birds were primarily drawn from research by Rogers et al. (1976, 1977). Night-migrating birds were believed to face the highest risk but the danger was not expected to exceed the risk from encounters with structures or features already in existence, such as large trees, terrain features, or transmission lines. Authors stated that it may be desirable not to use sites near areas inhabited by endangered species. They suggested that a general EIS be prepared covering all large-scale wind energy conversion systems in California; otherwise the costly and lengthy permitting processes could have a major impact on developing wind energy in California.

27. California Energy Commission. 1980b. Wind energy assessment for the Palm Springs-Whitewater region. Prepared by AeroVironment Inc., Pasadena, California.

This report describes all field and related activities of a one-year study to investigate the wind energy potential of an area which extends from Beaumont, California, through the San Gorgonio Pass to the outskirts of Palm Springs. The report primarily deals with historical and measured wind data, energy assessment results, and wind energy conversion system performance estimates. An initial survey of the pertinent environmental factors is also presented, including microwave and aircraft interference, aesthetics (visual and noise), wildlife impacts, and land use and availability. No serious impediments to installation of wind turbines were identified at this level. A brief discussion of the potential for bird collisions is presented. Because many species of migratory birds use the San Gorgonio Pass as a major flyway, wind turbines could create a hazard for migratory birds. The authors predicted that the most susceptible species would be passerines (songbirds) that migrate at low altitudes during the night. The authors noted that the possibility of bird mortalities presents a legal problem only when a rare and endangered or otherwise regulated species is involved.

28. California Energy Commission. 1980c. Wind energy demonstration project in cooperation with the U.S. Fish and Wildlife Service: proposed wind energy conversion system at the San Francisco Bay National Wildlife Refuge Headquarters at Newark, Alameda County. California Energy Commission, Sacramento.

The CEC, in order to fulfill a legislative mandate, proposed to procure and test a medium-scale wind electric turbine. In cooperation with the USFWS, the Commission proposed to build a 25-kW turbine at the San Francisco Bay National Wildlife Refuge Headquarters in Newark, Alameda County. As part of the environmental evaluation process this revised initial study and associated negative declaration were prepared. Possible environmental effects were outlined and explained. The primary biological concern was the potential impact of the wind machine on birds. Concern was raised that because the refuge is on a major resting ground along the Pacific Flyway, the potential for bird impacts may be increased, particularly for nocturnal migrants. The preliminary assessment by USFWS staff indicated that the project would not have a significant impact on birds. However, they did recommend monitoring bird deaths to determine the actual impact of the project. The USFWS proposed several mitigation measures if impacts to nocturnal migrants proved to be significant, including shutting down during nighttime hours, use of high-visibility reflective paint, or possible removal of the turbine.

29. California Energy Commission. 1981. Final environmental impact report—California Energy Commission Solar Program and Wind Program. State Clearinghouse No. 78111406. California Energy Commission, Sacramento.

This EIR analyzes, among other things, the CEC Wind Program. Legislation passed in 1978 officially established a California Wind Program and directed CEC to locate and verify sites for windfarms in California, to develop and test wind systems, and to establish a wind information center. Potential sites for wind development are identified in the report. The EIR addresses the potential environmental, institutional, legal, and financial issues that may hamper wind power development in California. The discussion of the environmental effects is divided into siting, construction, and operation. Siting was considered the most crucial phase of development, as most environmental impacts can be avoided if windfarms are sited appropriately. Key factors they considered affecting siting included aesthetics, land use, and environmental considerations. A brief discussion of the potential for collision of birds with blades is included. It was concluded that most of the time the birds will fly right through the windfarm, but the probability of impact increases with the number of turbines per farm.

30. California Energy Commission. 1982. Wind energy assessment for northwestern California: three interim reports. Prepared by SRI International, Menlo Park, California.

This is a collection of three interim reports on the potential for wind energy development in northwestern California. The CEC Wind Program calls for selection of potential sites, verification of their suitability by field surveys, evaluation of wind-monitoring equipment, and conducting a long-term wind-measuring program. This collection of reports identifies and ranks candidate wind-monitoring sites based on wind energy potential, land use, and environmental constraints. Factors considered in the evaluation included aesthetic, biological, and physical constraints, land use, communication interference, transmission line availability, and road access. Regions in which windfarm development would be prohibited because of existing land use or other environmental factors were identified and mapped. Areas prohibited from development included wilderness areas, national parks, water bodies, critical habitats for endangered species, areas with poor access, and areas that lack existing transmission line facilities.

31. California Energy Commission. 1983. Wind energy assessment for northwestern California: Vol. 1. Final report. Prepared by SRI International, Menlo Park, California.

This document describes the results of a one-year assessment study of the wind resource potential in seven counties of northwestern California. The study consisted of three parts: (1) an assessment of the land use and environmental constraints related to the siting of windfarms, (2) selection of sites for monitoring, and (3) a one-year wind speed and direction program at 15 locations. This volume contains a discussion of the methods and analysis, including graphical summaries of the results.

32. California Energy Commission. 1986. California Energy Commission informational workshop on wind turbine effects on avian activity and habitat use. Workshop summary. California Energy Commission, Sacramento.

Based on the need for more information about the effects of wind turbine developments on bird populations, a study of avian activity and habitat use in Altamont Pass, California, was proposed. The study would evaluate environmental setting, habitat reduction, influx of scavengers or new predators, and other factors related to raptor mortality associated with wind turbine development,

and would include impact mitigation recommendations and a plan for a monitoring program. In this workshop summary, background information is provided, goals are developed, and data previously collected on avian injuries and death are presented. The workshop was attended by representatives of public utility companies, state and county agencies, windfarm developers, concerned citizens, environmental groups, and the scientific community in general.

33. California Energy Commission. 1989. Avian mortality at large wind energy facilities in California: identification of a problem. Staff report no. P700-89-001. California Energy Commission, Sacramento.

Mortality data on avian collision with or electrocution by wind energy-related structures were solicited and compiled in 1988 from many sources. All reported incidents occurred between 1984 and 1988. All documented incidents involved raptors and included 108 individuals of seven species. Ninety percent resulted in mortality. Seventy-two incidents involved collisions with turbines or associated powerlines. All collision incidents occurred at Altamont Pass and Tehachapi Pass WRAs. Golden eagles and red-tailed hawks were the most-frequently reported victims of collision. "Wing sheared off" was the most frequently reported injury. Of 33 collision incidents in which age class was reported, 18 involved adult birds and 15, immatures. Collisions occurred throughout the year but peaked in winter. Thirty-six incidents were electrocutions, all of which occurred at Altamont Pass WRA.

34. California Energy Commission. 1995. Avian collision and electrocution: an annotated bibliography. California Energy Commission, Sacramento. Prepared by E. Hebert, E. Reese, and L. Mark.

This bibliography annotates publications emphasizing bird losses at power lines, towers and other structures, and wind energy developments. The project was initiated in response to numerous inquiries regarding the problem of avian collision and electrocution mortalities at human-made structures.

35. Cauley, D.L., and L.L. Nelson. 1981. Environmental assessment of the Bureau of Reclamation's wind-hydroelectric project. Pages 205–216 in I.E. Vas, ed. Fifth biennial wind energy conference and workshop, Washington, D.C. Sponsored by the Solar Energy Research Institute, Golden, Colorado.

This paper summarizes an EA and analysis of potential impacts associated with the construction of a large wind generator project in Wyoming. Environmental studies included a population and nesting survey for birds of prey. Data were also collected on pronghorns, sage grouse, passerine birds, waterfowl, small mammals, and endangered species. The lack of significant environmental impacts related to the project led to the conclusion that a FONSI would be the appropriate NEPA-compliance document. The report states that turbines, transmission lines, and other facilities are being designed to restrict and protect wildlife. The wind park will be monitored to evaluate operational impacts of the project on wildlife. The authors state that it is possible for raptors to collide with the rotating blades or use the wind turbines as a hunting/resting perch. (See Bureau of Reclamation 1984 for results of the monitoring studies).

36. Chris Blandford Associates. 1994. Wind turbine power station construction monitoring study. Prepared by Chris Blandford Associates in association with University of Wales, Bangor. A report commissioned by the Countryside Council for Wales.

The purpose of this report was to identify and analyze the impacts of three specific wind turbine stations consisting of 20 to 103 turbines. Specific research goals were to appraise the visibility and impact on the landscape, assess the ecological impact, and undertake a social survey of public attitudes of the three sites. The overall conclusion from the study suggests that in landscape terms the acceptability of medium and large wind turbines should be determined by their degree of visibility and their fit into both the local and wider landscape. This will be greatly influenced by the size of the development, distance to other similar developments, and landscape character. The impact on the nature conservation value of the three sites was considered low, but further research that incorporates both avian and turbine characteristics was considered necessary.

37. Clarke, A. 1989. Wind farm location and environmental impact. Int. J. Ambient Energy 10(3):129–144.

.Synopsis: "Though wind power is now cheap enough to be economic, and its technical feasibility has been demonstrated to produce the equivalent energy generation capacity of a power station, [it] still requires hundreds of very large machines or even thousands of smaller ones. One remaining uncertainty concerns the environmental impact of this and the resulting public attitudes. Large machines, which could be up to 125 meters in height, can be visible for miles, and must be spread out. Relatively large land areas are required. In addition, the machines emit noise and safety considerations preclude siting them in built up areas. Shadow effects might intrude upon habitations, and there could be effects on birdlife. Wind energy will therefore be highly conspicuous and the final constraint on the amount of wind power installed will be the reaction of the public. This paper reviews some of the relevant factors which make up the environmental impact and then addresses the question of windfarm siting to cause the least impact in the U.K."

38. Colson and Associates. 1995. Avian interactions with wind energy facilities: a summary. Prepared for the American Wind Energy Association, Washington, D.C.

This report summarizes worldwide research on the interactions of birds with wind energy developments, considering both positive and negative impacts. The authors present a comparison between European and U.S. studies regarding mortality rates, species affected, and issues of concern. The environmental (e.g., weather), engineering (e.g., turbine type, turbine placement), and biological (e.g., species, habitat use, behavior) characteristics that may increase the potential for bird collisions are summarized. To date, the authors state, most researchers report that mortalities are not biologically significant to local, regional, or migratory populations. The probability of adverse bird interactions appears to be both site-specific and species-specific. Mitigation ideas from past and ongoing studies are presented. The authors state that "the most important step that can be taken to avoid future adverse bird interactions is to locate facilities based on careful siting studies and away from critical habitat." They remind us that the apparent negative issues associated with avian interactions with wind energy developments must be carefully weighed against the negative issues of other forms of energy development. A summary of various current, future, and suggested research plans is also presented.

39. Cooper, B.A., and R.J. Ritchie. 1993. Wind power and birds: radar techniques for environmental assessment. Prepared by ABR, Inc., Fairbanks, Alaska. ABR address P.O. Box 81934, Fairbanks, 99708.

This 4-page paper briefly describes the use and advantages of mobile marine radar labs, which consist of two marine radars, night-vision equipment, and video recording equipment in cab-over campers, for monitoring or assessing bird use of windfarm developments. The system is powered by batteries and moved via 4-wheel-drive truck. Equipment can be disassembled for movement to remote locations such as inaccessible ridges or shorelines. Marine radar can detect individual songbirds up to 1 km, individual hawks up to 3 km, and waterfowl or cranes up to 10 km away. Radar provides information on number, altitude, direction, speed, behavior, and location of birds, while night-vision equipment improves capability for species identification, monitoring bird behavior near structures, and helps to evaluate bird movements. Radar can also be used during the day to help visual observers locate easily-missed birds and to measure bird altitudes.

40. Crockford, N.J. 1992. A review of the possible impacts of windfarms on birds and other wildlife. Joint Nature Conservation Committee, JNCC report no. 27, Peterborough, United Kingdom.

This report provides a comprehensive review and summary to date of the literature on the impacts on windfarms on wildlife. The purpose of this review was to facilitate a wise conservation response to windfarm proposals. Although emphasis was placed on birds, other wildlife species are included in the discussion. Topics reviewed and discussed include collision mortality, breeding success in wind parks, disturbance factors, species-specific and seasonal differences in mortality and disturbance, and flight characteristics. Recommendations are offered for planning developments to ameliorate adverse effects on wildlife, further research studies, and scoping of environmental impact assessments. Most studies in Europe seem to reach the same conclusion: the chance of bird collisions in daylight with good visibility is low. The author considers the California situation perhaps an exception to this conclusion but does not consider the circumstance comparable to that in Britain. The author concludes that impacts are not likely to be significant if wind turbines are located in areas of little wildlife importance, with low bird density, and without significant populations of susceptible species of high conservation importance.

41. Darwin Myers Associates. 1986. Draft environmental impact report, Howden Wind Parks Incorporated, Sections 25 and 31, Vasco Road area, Contra Costa County, LUP No. 2025-85. Prepared for Contra Costa County Planning Department, Martinez, California.

This EIR was required of Howden Wind Parks, Inc., for development of 107 wind turbines and associated transformer pads, transmission and collection lines, and service roads. The primary areas of concern were the sensitivity of biotic, archaeologic, and geologic constraints, and the cumulative impacts of wind turbines on wildlife, especially raptors. Appendix D of this report is the Larry Seeman and Associates 1986 report (see below); it presents a detailed analysis of the cumulative impacts on raptors. Of secondary concern were the relationship of a nearby proposed reservoir to the wind park, the visual impact of wind turbines, and the compatibility of the project with ordinances regulating wind turbines. Potential impacts are described and mitigation measures are recommended for each impact. Two alternatives are discussed, one of which is the no action alternative.

42. De Renzo, D.J., ed. 1979. Wind power—recent developments. Noyes Data Corp., Park Ridge, New Jersey.

This book presents the important developments that occurred in wind power technology in the U.S. during the 1970s. The chapter relevant to this bibliography includes a discussion of legal, social, and environmental issues. Social and environmental materials in this chapter were based on two papers (Ferber 1975 and Rogers 1975) presented at the second workshop on wind energy conversion systems in 1975.

43. Earth Metrics Incorporated. 1988. Draft environmental impact report for the Montezuma Hills Wind Park. Prepared for Solano County Department of Environmental Management, Fairfield, California.

This report investigates potential impacts and alternatives of a proposal to install 338 wind turbine generators and associated meteorological towers, transmission lines, service roads, a substation, and other facilities in the Montezuma Hills, Solano County, California. Potential impacts include incompatibility of windfarms and agricultural preserves, higher property taxes for landowners, public attraction along a scenic highway, increased wear to local roads, safety hazards at roadway intersections during construction, alteration of open space visual character of surrounding hills associated with turbines and roads to ancillary facilities, overhead transmission lines adding to those already existing, loss of vegetation and wildlife habitat, decreased water quality from soil erosion, electrocution hazards to birds, collision hazards to birds, loss or damage of subsurface cultural resource deposits, and disruption or modification of broadcast frequency patterns caused by steel lattice towers. Recommended mitigation measures are expected to reduce to insignificant levels all potential impacts except degradation of visual quality and alteration of the predominantly rural, open-space character to a more-developed industrial character. Cumulative impacts identified were increased daily traffic volumes on local and regional roads, increased air pollution associated higher daily traffic, loss of wildlife habitat, visual impacts, and potential loss of subsurface archaeological resources.

44. Electric Power Research Institute. 1984a. Early utility experience with wind power generation. Vol. 2: PG&E, Solano County project. Report no. AP-3233. Prepared by JBF Scientific Corporation, Wilmington, Massachusetts.

The purpose of EPRI Research Project 1590-1 was to monitor, evaluate, and document, from project inception to first rotation of the machine, the experience of two utilities with megawatt-scale wind turbine installations. This was to develop an improved understanding of the process a utility must undergo to initiate and carry out a wind turbine project. Volume 2, one of three volumes written, deals with the Solano wind turbine project. (Volume 1 is a summary of Volumes 2 and 3 and so is not annotated here; Volume 3 is annotated below). One turbine was installed in the Benicia Hills, an upwind, two-bladed, horizontal-axis machine designed to generate 2.5 MW of electric output in a hub-height wind speed of 12.3 m/s (27.5 mph). Based on difficulties encountered, the report recommends use of a multi-disciplinary team to install any significant wind turbine development and recommends consideration of the following screening criteria: wind resource, availability, environmental impacts, and regulatory requirements. Uncertainties in wind resource data increase uncertainty in estimates of power output. Moreover, in addition to normal problems encountered during any construction project, two problems encountered should be considered in selecting turbine sites: (1) because of variations in site topography and the size of some wind turbine components,

large trucks navigating the steep, winding access roads sometimes became stuck and required other equipment to extricate them, and (2) these same loads required special routing between the source of the equipment (Seattle, in this case) and the site, resulting in schedule delays.

45. Electric Power Research Institute. 1984b. Early utility experience with wind power generation. Vol. 3: BPA, Goodnoe Hills project. Report no. AP-3233. Prepared by JBF Scientific Corporation, Wilmington, Massachusetts.

Volume 3 of EPRI Research Project 1590-1 deals with experiences of BPA's Goodnoe Hills project in south-central Washington near the Columbia River. Three MOD-2 wind turbines were installed (see EPRI 1984a). BPA experimented with a number of approaches in its wind assessment. BPA successfully used observations of vegetation deformation as a wind evaluation tool and demonstrated the kite anemometer to be a useful tool in wind turbine site assessment. Use of CKX or Rayleigh distributions to characterize wind speed frequency distributions was found to be inaccurate. A comprehensive data acquisition system was installed to evaluate these wind turbines because of their experimental nature. Early component problems required corrective action and created delays. The limited size and favorable location of this project contributed to reducing permit and approval requirements. The report recommends early contacts with local planning and engineering officials to discuss ordinances that might be barriers to orderly installation. It also stresses the importance of keeping the community informed of developments and plans so as to avoid misconceptions.

46. Electric Power Research Institute. 1984c. Solano County MOD-2 wind turbine field experience. Report no. AP-3896. Prepared by PG&E, San Ramon, California.

This interim report covers results from the first year of data collection on the Solano County MOD-2 wind turbine experience, from September 1982 through August 1983. Objectives were to monitor, evaluate, and document Pacific Gas & Electric's experiences while testing, operating, and maintaining a megawatt-scale wind turbine, as well as general and site-specific performance and the impact of a turbine connected to an electrical network. Among factors discussed are wind speed correlation, wind speed characteristics, pitch control system, aerodynamic improvement, yaw position performance, wake effects, turbine operation and maintenance, turbine power and energy output, turbine availability, and environmental impact. See EPRI 1985 for summary of final results.

47. Electric Power Research Institute. 1985. MOD-2 wind turbine field experience in Solano County, California. Report no. AP-4239. Prepared by PG&E, San Ramon, California.

This report publishes findings of a two-year (September 1982 through August 1984) study testing, operating, and maintaining a 2.5-MW wind turbine in Solano County, California. Test plans, data collection methods, evaluation processes, and results of this study are included. During a six-month period in 1984, average measured wind direction at the turbine was found to be 10 degrees greater than that measured at its associated meteorological tower. Wind speeds were greatest from April through September. Peak winds occurred in late afternoon or early evening; wind speed was often highest at ground level, decreasing with height above the terrain.

Impacts to the environment relative to acoustic levels, television interference, and bird populations were also studied. Acoustic levels were at or below predictions; there were some weak low-frequency components but no measured infrasonic sound. The closest residence should be at least 1,000 m from the turbine. Maximum measured television interference was lower than predicted. Interference level was very sensitive to changes in turbine yaw angle. Bird studies showed low rates of waterfowl movement and nocturnal passerine migration over the turbine site. Bird collision

mortality was monitored for one year from 1 September 1982 to 31 August 1983. Three passerines, a waterbird, and a raptor were found under the wind turbine, and two passerines were found under the meteorological tower (which had guy wires). While a substantial number of birds did pass through the area during the migration season, collisions were negligible, possibly due to the presence of a strobe light (strobe lights appear to repel birds better than stationary lights), good visibility of the structure at night, infrequency of operation during the study period, and generally-mild weather typical of the area during migration periods. Collisions occurred during all lighting and weather conditions but the mortality rate was insignificant.

48. Electric Power Research Institute. 1986. The Solano MOD-2 wind turbine: operating experience, September 1984–August 1985. Report no. AP-4638. Prepared by PG&E, San Ramon, California.

This report is similar to other reports summarizing experiences with the operation and maintenance of the Solano County MOD-2 wind turbine. Topics discussed include wind resources, turbine power output and energy capture, turbine control system performance, vortex generators, turbine capacity factor and utilization factor, turbine availability, and turbine operation and maintenance.

49. Energy and Environmental Analysis, Inc. 1979. Programmatic EA, Wind Energy Conversion Systems (WEC) Program. Issues identification report, revised draft. Prepared for U.S. Department of Energy, San Francisco Operations Office, Environment and Safety, Oakland, California, by Energy and Environmental Analysis, Inc., Arlington, Virginia.

This report briefly describes environmental issues that may be associated with development of WECS. A system of classifying and ranking environmental issues is described. Environmental issues were derived from a literature survey. WECS characteristics were compared with potential environmental impacts (air and water quality, land use, solid waste, health and safety, aesthetics, and social/institutional effects). Where a potential WECS characteristic could adversely affect an environmental aspect, an environmental issue was considered to exist. The issues list was then subjected to two evaluative criteria: (1) potential adverse effects (physical/environmental, climatic, health and safety, resource demands and availability, and scope and content of existing and future environmental regulations), and (2) potential for public controversy and/or social institutional adjustments (public, industry, and governmental reaction and necessary socio-institutional adjustments). Once this was done, impacts were considered either primary or secondary.

Primary impacts were grouped into (1) physical/environmental (microclimatic effects, bird collisions, offshore ecosystem effects, solid waste during decommissioning stage); (2) health and safety (equipment safety, aircraft interference); (3) resources (land supply, material supply); and (4) social/institutional (electromagnetic radiation interference, electric utility interface, wind rights, noise, visual impact, other issues such as zoning). Each of these primary impact subcategories was ranked low, medium, or high for significance within both large and small systems. All are discussed.

50. Energy Research and Development Administration. 1977. Solar assessment: environmental factors, wind energy conversion. Energy Research and Development Administration (ERDA 77-47/6), Division of Solar Energy, Environmental and Resource Assessment Branch, Washington, D.C.

The purpose of this report was to present and prioritize the major environmental issues associated with the further development of WECS. The potential effects of this new technology on the full range of environmental concerns (air and water quality, biological systems, safety, aesthetics, and

social/institutional structures) are discussed in terms of their relative significance and possible solutions. The possibility of machines being potential obstacles for migrating birds is discussed. The authors state that the most important variable affecting collision probability is the siting of wind machines. The authors state that machines placed out of the migratory path of lower-flying songbirds should present only minor hazards. They also state that wind machines with blade tip extension of 300 ft above the ground should present little hazard to higher-flying waterfowl except under infrequent conditions such as bad weather. An environmental work plan is presented, listing research and development proposals that might help to clarify and/or alleviate specific environmental problems.

51. Engström, S. and B. Pershagen, eds. 1980. Aesthetic factors and visual effects of large-scale WECS. Final report of Task A5. International Energy Agency Programme of Research and Development on Wind Energy Systems. Published by National Swedish Board for Energy Source Development. Also available from the Solar Energy Research Institute Technical Library, Golden, Colorado.

The visual effects of WECS units and groups were studied by means of perception theory, field observations, visualization of model WECS in real landscapes, and case studies. Perception is discussed from functional, social, and aesthetic aspects. The visual impression of WECS is analyzed in terms of properties of the eye, landscape types, and design of WECS. A case study is analyzed: a WECS group sited in an agricultural area in southern Sweden was studied for grouping and effects of unit size (50 and 100 m diameter turbines) on the visibility and character of the landscape. Use of vegetation to diminish visual interference is discussed, and visual effects are illustrated in artist's sketches.

Among the conclusions: (1) In open, flat landscape, the zone where the WECS is perceived as visually intrusive is limited by a radius of about three times the height. The WECS dominates a sector of the field of vision to a radius of about ten times the height. The theoretical distance of visibility is about 40 km for a 100 m unit. In practice, visibility is limited by topography, vegetation, and weather. (2) Units in a group should be arranged in rows or subdivided in small groups with free zones in between, following natural boundaries of the landscape. From the aspect of visual effects, a small number of large units is likely to be preferred to a large number of smaller units. Vegetation can be used to lessen visual interference both at large and small distances. (3) Visual effects of a WECS unit or group can be shown quite realistically by pictures and films of model WECS in natural landscapes.

52. Environmental Management Consultants. 1984. A draft EIR for the Casas Del Sol Wind Farm project. Prepared for Monterey County, California.

This EIR was prepared for a proposed 100-turbine windfarm development near King City, California. The report describes both positive and negative impacts of the proposed project, and offers suggestions for mitigating adverse impacts. Environmental issues addressed include wildlife, visual quality, noise, air quality, electromagnetic interference, and soils and erosion. Under wildlife issues, the major concern was the potential impact on resident and migrating birds. The authors state that although it was difficult to assess the potential for bird collisions, the potential impacts did not appear to be significant. This was based primarily on past research (Rogers et al. 1976, 1977; BLM 1982a, 1982b), and the fact that this area was not considered to be a significant migration route.

Mitigation measures suggested include a one-year monitoring program for bird collisions. The only environmental effect that could not be mitigated to insignificant levels, according to the authors, was the visual one.

53. Ferber, R. 1975. A pilot study on public reactions to wind energy devices. Pages 380–384 in F.R. Eldridge, ed. Proceedings of the second workshop on wind energy conversion systems, Washington, D.C. Prepared for the National Science Foundation.

This paper presents a research plan and objectives for a pilot study to explore reactions of the general public to the construction and operation of wind turbines. The study would be carried out at locations of high wind power potential in different parts of the country. The study was intended to provide information on the extent to which wind turbines were likely to be accepted by different groups of the population and the extent to which particular types of turbines were likely to meet public opposition. In addition, the study would explore different approaches to obtaining this information and evaluating the validity and efficiency of these different approaches for more intensive work at a later time.

54. Ferber, R. 1978. Public reactions to wind energy and windmill designs. Pages 413–418 in Proceedings of the third wind energy workshop, vol. 1, [workshop location unknown]. Coordinated for U.S. Department of Energy, Washington, D.C.

This study was undertaken to explore the reactions of the general public toward different types of wind energy devices. The specific objectives were to provide substantive information on public acceptance of different types of wind energy devices in different settings and to furnish a methodological base for more intensive studies of public acceptance of such devices. Results indicated that people basically favored the use of wind and solar sources for electric energy production, and that Americans seemed to be willing to pay more for energy if it were pollution free. Of six windmill designs, the order of people's preference was the old dutch motif windmill as the overwhelming favorite followed by the horizontal axis on an old dutch tower, horizontal axis on a columnar tower, a toss-up between the horizontal-axis machine on a lattice tower and the vertical-axis machine, and lastly, the gyromill. Many people objected to placing windmills along shorelines.

55. Gauthreaux, S. 1994. Standardized assessment and monitoring protocols. Pages 53–59 in Proceedings of the national avian-wind power planning meeting, Denver, Colorado, 20–21 July 1994. Proceedings prepared by LGL Ltd., environmental research associates, King City, Ontario, Canada. Author's address: Department of Biological Science, Clemson University, South Carolina.

This is a summary of a presentation given on the techniques that can be employed to study avian-wind turbine interactions. Emphasis was placed on appropriate methods to monitor bird movements during the day and at night, and to assess bird injury and mortality during pre- and post-construction studies. The need for development of observation and monitoring protocols was stressed. Several recommendations were included, such as conducting searches for dead and injured birds before and after construction, expressing collision rates in terms of the percentage of birds passing through the envelope of risk, and using standardized methods so that data can be compared.

56. Gauthreaux, S. 1994. The history of wind-related avian research in the U.S.A. Pages 33–35 in Proceedings of the national avian-wind power planning meeting, Denver, Colorado, 20–21 July 1994. Proceedings prepared by LGL Ltd., environmental research associates, King City, Ontario, Canada. Author's address: Department of Biological Science, Clemson University, South Carolina.

This is a summary of a presentation given on studies that have been conducted on avian-wind turbine interactions. The summary covers the findings of four major studies conducted in the U.S. since the mid 1970s, including the NASA MOD-2 investigations in Ohio (Rogers et al. 1977); Pacific, Gas and Electric Company's study on a MOD-2 turbine in Solano County, California (EPRI 1985); and two CEC studies (Estep 1989, Orloff and Flannery 1992). Several studies to assess the potential impact of windfarm development on bird injury and mortality that are either planned or currently underway are also summarized.

57. Greene, G.C. 1981. Measured and calculated characteristics of wind turbine noise. Pages 355–362 in R.W. Thresher, ed. Wind turbine dynamics. Proceedings of a workshop sponsored by the U.S. Department of Energy, Division of Wind Energy Systems, and the NASA Lewis Research Center, in Cleveland, Ohio. NASA Conference Publication 2185, DOE Publication CONF-810226.

This paper presents results of an analytical and experimental investigation of wind turbine noise. Noise measurements are presented for solid and truss-type tower models with both upwind and downwind rotors. When the rotor is downwind of the support tower, the primary source of noise is the rapid change in rotor loading that occurs as the rotor passes through the tower wake. Upwind rotor configurations are significantly quieter than downwind configurations. This investigation was undertaken as a result of complaints from community members about noise associated with a MOD-1 wind turbine, a comparatively large turbine for its time, in North Carolina. Calculations and model tests indicate that placing the rotor upwind of the support tower minimizes the noise risk. The author states that it is difficult to extrapolate model results for the downwind configuration to full scale since all the parameters that affect wake affect generated noise. The inherent unsteadiness of wake flows may produce noise that is louder than would be expected from averaged measurements or calculations based on averaged wake characteristics.

58. Gruenhagen, N.M. and S. Byrne. 1981. Raptor observations at two Solano wind turbine generator sites—fall 1980. Report no. 411-81.201. Pacific Gas & Electric, Department of Engineering Research, San Ramon, California.

This was an early study to assess the potential for raptor collisions with wind turbines by documenting raptor use and activity near two future wind turbine generator sites. Nine raptor species were observed; red-tailed hawks were most common, followed by northern harriers, unidentified buteos, turkey vultures, and golden eagles. The minimum number of raptors observed daily ranged from 8 to 12. The number of raptor observations was greatest between 15 and 100 m above the ground; most activity (79% of observations) was within 100 m above or below meteorological tower bases. The authors concluded that there was a potential for raptor collisions with wind turbines and recommended further study to assess the magnitude of the potential. They also suggested ways to improve the data collected as well as data collection techniques.

59. Hall, S.S. 1987. Talking to the cows: landscape transformation in Altamont Pass. Unpublished report. Berkeley, California.

In this report, the author discusses the history of urban development in the Greater San Francisco Bay Area and in Altamont Pass, as well as the history of WED, both in general and in Altamont Pass. She describes the structure of WEDs, i.e., the participants (developer, landowner, county planning department, and utility) and the sequence of development events. The environmental impact is discussed, including land use, environmental concerns, and aesthetic impacts, as is the operation of WEDs, their productivity, and refinement of WED technology. Finally, she discusses the future of WEDs, including such topics as challenges to WEDs, industry direction, and other considerations.

60. Hanson, A.C. and D.L. Martin. 1981. Measurement and assessment of the noise produced by small wind energy systems. Pages 189–203 in I.E. Vas, ed. Fifth biennial wind energy conference and workshop, Washington, D.C. Sponsored by the Solar Energy Research Institute, Golden Colorado.

This paper describes a preliminary study to measure and assess the impact of wind machine noise. Noise levels measured at the bases of four towers are presented. A method for systematically assessing probable response to wind turbine noise is proposed. The method assesses noise by using a synthesis of noise annoyance predictors to estimate the percentage of the population that would be highly annoyed by the noise. This method indicates that noise emissions from the four turbines measured would highly annoy 0 to 20 percent of the population.

61. Hartwig, E. 1994. Naturschutz und windenergienutzung—ein konflikt? (Nature conservation and the use of wind energy—conflict?; English summary). Aus dem Institut für Naturschutz-und Umweltschutzforschung des Verein Josdsand, Hamburg. Seevögel 15/1:5–10.

In Germany, 1,436 wind turbines, with an energy capacity of ~233 MW, are presently installed. Although environmental organizations have favored a further expansion because of the green house effect, they also have criticized wind energy development because European studies have shown that wind turbines can cause distinct disturbance to bird life. Potential solutions are described including determining suitable areas where wind turbines can be installed.

62. Haussler, R.B. 1988. Avian mortality at wind turbine facilities in California. Pages 349–355 in Proceedings of WindPower 1988, Hawaii. Sponsored by American Wind Energy Association, Arlington, Virginia. Reference and summary taken or adapted from California Energy Commission 1995.

Data obtained by the CEC indicates that bird collisions and electrocutions are occurring at wind turbine facilities in California. Most documented incidents are due to collision and the majority of birds killed are hawks and eagles. Incidents documented to date are mostly from the Altamont Pass area, Alameda County. The author states that "Because there is concern over stability of raptor populations, ways to avoid and reduce losses must be incorporated into man's development activities." The paper suggests that each WRA should be considered specifically to determine (1) the significance of ongoing effects, (2) the potential for adverse effects due to future development, and (3) the potential to mitigate and/or avoid adverse effects upon avian populations in the future.

63. Hayes, M.D. 1992. Noise impact assessment of wind farms. Wind Engineering 16(3):141-157.

In the absence of specific U.K. legislation relating to windfarms, the assessment of wind turbine noise has led to a variety of approaches being adopted by local authorities. Development of noise criteria acceptable to both local authorities and the developer is crucial to site planning. This is important for reaching approval of the project at the planning stage and also in terms of constraints on the layout and number of turbines that may be placed on the site while still meeting noise standards. This paper reviews related U.K. noise standards and planning policy guidance notes and their applicability to windfarms, and discusses corresponding European legislation. Criteria are suggested in light of these reviews and of the author's previous experience in the field.

64. Henderson, A.C.B. 1986. Richborough wind turbine. Report on preconstruction bird survey 1984-1985. Royal Society for the Protection of Birds (RSPB), Sandy, Bedfordshire.

This report presents the results of a pre-construction study on birds at the Richborough wind turbine site in Kent, England. Four aspects of avian resources were reported: breeding bird populations, nonbreeding bird populations, movements of birds flying over the site, and the occurrence of dead birds in the area. The study provided baseline data against which to judge any effects on birds from wind turbine construction. Of special concern was the breeding bird community, particularly wetland species. Counts of bird movements over the site indicated that more than 100,000 birds may pass through the areas of influence of the proposed turbine site during one year. Few dead birds were found in the absence of the turbine, but the effect of predators on corpse removal was not studied. The study recommended that, following construction, a study with similar format should be conducted to assess any effects on birds from the wind turbine development.

65. Higgins, K.F., C.D. Dieter, and R.E. Usgaard. 1995. Monitoring of seasonal bird activity and mortality on Unit 2 at the Buffalo Ridge Windplant, Minnesota. Preliminary progress report for the research period May 1-December 31, 1994. Prepared by the South Dakota Cooperative Fish and Wildlife Research Unit, National Biological Service, South Dakota State University.

This report summarizes results of an avian monitoring program associated with the near completion of the first phase (25 MW) of the Kenetech Windpower 100-MW Buffalo Ridge Windplant in Minnesota. The purpose of the research was to conduct a systematic avian monitoring program to measure seasonal movements, relative abundance, temporal flight patterns, and incidence of nesting and bird mortality associated with Unit 2 of the Buffalo Ridge site, the unit encompassing the Buffalo Ridge Windplant (Units 1 and 3 comprised lands under easement for potential future wind turbine sites). Unit 2 had 73 wind turbines located in 10 turbine strings varying in length from 3 to 20 turbines per string. During roadside, site specific, and raptor surveys, 66 bird species were observed. Bird numbers were higher during spring and fall migrations than during summer. No threatened or endangered birds were seen. Eighty-four percent of birds seen during site-specific surveys flew at heights above or below the height range of wind turbine blades (70-170 ft). Three dead birds and five dead bats were found during mortality searches in wind turbine plots. No bird deaths were attributed to collision with turbines, but all bats were presumed to have died as a result of collision with turbines.

66. Howell, J.A. 1990. Summary of site differences between Montezuma Hills and Altamont Pass. Prepared for U.S. Windpower, Inc., Livermore, California. U.S. Windpower, Inc., is now known as Kenetech Windpower, Inc.

This short report focuses on the three main differences between the existing windfarm in the Altamont Pass and the location of a new windfarm development in the Montezuma Hills in Solano County, California. Those differences are topography, land use practices, and relative abundance of raptors. Montezuma Hills has lower topographic relief, is characterized by almost exclusive wheat production (versus cattle grazing in Altamont Pass), and supports raptor species in different numbers than Altamont Pass.

67. Howell, J.A. 1995. Avian mortality at rotor swept area equivalents, Altamont Pass and Montezuma Hills, California. Prepared for Kenetech Windpower [formerly U.S. Windpower Inc.], San Francisco, California.

This study was designed to test the hypothesis that the newer KVS-33 turbines with a large blade diameter (33 m) would potentially kill more birds than the older KCS-56 (18.5 m blade diameter) turbines because the blades sweep more area. The ratio of the rotor swept area (RSA) of the KVS-33 to that of the KCS-56 is 3.46:1. Based on this hypothesis, it was predicted that a KVS-33 turbine would be three times as likely to cause an avian collision as a KCS-56. The study was designed so that within study sites the combined RSAs were equal between KVS-33 and KCS-56 sample turbines: in the Altamont Pass sample there were 36 of the larger KVS-33 turbines and 130 of the smaller KCS-56 turbines, and in the Montezuma Hills sample there were 17 of the larger and 59 of the smaller turbines. The number of sample turbines in each group at each site approximated the 3.46:1 RSA ratio. Bird deaths between the small and large turbine types were compared within study sites. A total of 70 bird deaths, 45 of which were raptors, were identified during the 13-month sampling period in Altamont Pass. In Montezuma Hills, surveyors found 13 dead birds, 12 of which were raptors, in five months of sampling. In Altamont Pass, avian mortality *per turbine* was roughly the same at both small and large turbines; the turbines appeared to present an obstacle to birds regardless of RSA. The evidence from Altamont Pass, the author states, does not support the hypothesis that the larger RSA of the KVS-33 turbines contributes to higher mortality. In the Montezuma Hills, however, avian mortality *per turbine* at the larger KVS-33 turbines was three times higher than at the smaller KCS-56 turbines, but the author states that this may be due to the smaller sample size and short duration of the Montezuma study.

68. Howell, J.A. and J.E. DiDonato. 1988a. Crepuscular avian use monitoring related to wind turbine siting, Montezuma Hills, Solano County, California, spring, 1988. Prepared for Solano County Department of Environmental Management, Fairfield, California.

This is the second of three reports (see Howell et al. 1988 and Howell and DiDonato 1988b) examining crepuscular (dawn and dusk) avian activity in the Montezuma Hills. Eleven morning (from two hours before sunrise) and 10 evening (to two hours after sunset) time periods were sampled in late February to early March using a night vision scope. Four raptor species (black-shouldered kite [now called white-tailed kite], great horned owl, short-eared owl, and common barn owl) and five waterfowl species (Canada goose, white-fronted goose, American widgeon, mallard, and pintail) were recorded during these hours. Morning and evening raptor abundance was low. Morning and evening goose abundance was higher than in a nearby area near Suisun Marsh. A distinct pattern of

daily movement was observed among waterfowl. Average flight altitudes were higher than the blade height of proposed turbines. Geese were counted more frequently on rainy days than would be expected from a random distribution.

69. Howell, J.A. and J.E. DiDonato. 1988b. Raptor nesting survey related to wind turbine siting, Montezuma Hills, Solano County, California, spring, 1988. Prepared for Solano County Department of Environmental Management, Fairfield, California.

In this third of three reports (see Howell et al. 1988 and Howell and DiDonato 1988a), results are presented on surveys of raptor nesting activity conducted between late March and mid May in the Montezuma Hills as part of pre-construction surveys for a proposed windfarm development. Areas as far as 0.5 mi from the proposed development were searched. Habitat consisted mainly of tilled dry-land wheat fields that were heavily grazed by sheep after harvest, although riparian vegetation associated with the Sacramento River was nearby. There were a few stands of eucalyptus, all of which were used by more than one species. Eleven nests of eight species were discovered, only one of which, an inactive black-shouldered [now the white-tailed] kite nest, was within the proposed development. Five nests produced young.

70. Howell, J.A. and J.E. DiDonato. 1989. Project expansion, avian use monitoring related to wind turbine siting, Montezuma Hills, Solano County, California, fall, 1987 to spring, 1989. Prepared for Solano County Department of Environmental Management, Fairfield, California.

This report relates avian use data collected during previous years in the Montezuma Hills to a proposed additional development in the same area, and examines the applicability of those data to the expansion properties. Expansion properties were found to be similar. The authors made recommendations to increase the area of nest surveys and banding, increase monitoring on the expansion properties that are not near existing observation sites, and include the properties in the post-construction mortality monitoring program.

71. Howell, J.A. and J.E. DiDonato. 1991. Assessment of avian use and mortality related to wind turbine operations, Altamont Pass, Alameda and Contra Costa counties, California, September 1988 through August 1989. Final report. Prepared for U.S. Windpower, Inc., Livermore, California. U.S. Windpower, Inc., is now known as Kenetech Windpower, Inc.

The authors monitored avian activity and behavior for 12 months at two wind turbine sites comprising roughly 10 mi^2 in the Altamont Pass of California. Mortality surveys were conducted at 359 turbines (10% of total U.S. Windpower turbines in the area). Scavenging rates were estimated to examine biases affecting timing and frequency of mortality surveys. Raptor nest surveys were also conducted. Bird activity among raptor species was highest for turkey vultures, red-tailed hawks, and golden eagles; among nonraptor species, bird activity was highest for common ravens, rock doves, and passerine flocks. Ten raptor species were identified during the year-long study.

Forty-two dead birds and one dead bat were recovered during mortality surveys; all were considered probable strikes with turbines. Species included red-tailed hawks, golden eagles, an unknown buteo, owls, and some nonraptors. Results of pooling data from this study with other local data suggested (but did not conclude) that golden eagles tended to be more vulnerable to turbine strikes than red-tailed hawks. Most carcasses were found downwind of turbines, and multiple strikes occurred in swales or at shoulders of hills. These observations led the authors to conclude that the

majority of strikes occurred among birds in transit, birds that were moving with the wind or sheering across the wind at an angle acute to the rotation of the turbine blades.

Results were compared to a similar area in nearby Solano County called Montezuma Hills. There were differences in species composition, activity rates, and relative abundance. Specifically, golden eagles were approximately three times more active in Altamont Pass than in Montezuma Hills, probably owing to the greater amount of suitable habitat for this species in Altamont Pass. Golden eagle collision mortality, the authors suggest, coupled with natural and other human-caused mortality and loss of historical nesting and foraging habitat, could affect local golden eagle recruitment.

72. Howell, J.A., J.J. Keane, and J.E. DiDonato. 1988. Avian use monitoring related to wind turbine siting, Montezuma Hills, Solano County, California, fall, 1987 to spring, 1988. Prepared for Solano County Department of Environmental Management, Fairfield, California.

This is the first in a series of three reports (see Howell and DiDonato 1988a, 1988b). Avian activity was monitored in the Montezuma Hills for 4½ months; emphasis was placed on raptors and waterfowl because of the proximity of the habitat to Suisun Marsh and Grizzly Island Refuge. Fourteen raptor species were recorded; 90 percent of observations were of red-tailed hawks, turkey vultures, American kestrels, and northern harriers. Seven waterfowl species were recorded. Eleven dead birds were located along 4 km of a 230-kV transmission line; most were songbirds. A significant difference existed between the frequency of birds observed on clear days and that of birds observed on days of inclement weather: raptors were more active on clear days and waterfowl were more active during inclement weather. Other variables measured and tested include daily and monthly variation, flight direction, distance from observer, angle above horizon, and sample site variation. Data were also compared to those collected during studies at other locations.

73. Howell, J.A. and J. Noone. 1992. Examination of avian use and mortality at a U.S. Windpower wind energy development site, Montezuma Hills, Solano County, California. Final report. Prepared for Solano County Department of Environmental Management, Fairfield, California.

This report summarizes data on avian movements (especially raptors and waterfowl) collected over a period of four years in the Montezuma Hills: two years of pre-windfarm construction and two years of post-windfarm construction. A total of 17 raptor species was recorded; 90 percent comprised red-tailed hawks, turkey vultures, American kestrels, and northern harriers. Six waterfowl species were recorded. Overall raptor activity decreased significantly each year, as did the number of goose and duck flocks. Post-construction mortality surveys were conducted at 39.5 percent (237) of turbines; 22 dead birds were recovered. Thirteen were raptors. No waterfowl mortalities were discovered during the study, but windfarm personnel found one dead mallard outside the study area. Windfarm personnel also discovered six raptors outside the study area. Researchers extrapolated the estimated per-turbine mortality to the entire windfarm facility and estimated that 11 raptor mortalities occurred in the first study year and 29 raptor mortalities occurred in the second study year. Results of four years of raptor nesting surveys were also presented. Data were compared to those collected during other studies. Mortalities were not found to be higher at end-of-row turbines than at within-row turbines. Avian mortality rates per turbine were compared among four studies conducted in similar areas in California and were not found to be significantly different.

74. Howell, J.A. and J. Noone. 1994. Examination of avian use at the Sacramento Municipal Utility District, proposed wind energy development site Montezuma Hills, Solano County, California: 1992–94 preconstruction report. Prepared for Kenetech Windpower [formerly U.S. Windpower, Inc.], Department of Permits and Environmental Affairs, San Francisco, California.

The authors conducted bi-weekly surveys of avian (particularly raptors and waterfowl) movements and flight patterns through the Montezuma Hills, Solano County, California, between August 1992 and July 1994. The purpose was to assess pre-construction bird activity and the potential for collisions with the post-construction wind turbine development. On average, approximately 3.005 raptors of 15 species were recorded per 10-minute scan period. Ninety-one percent of all raptor observations were of red-tailed hawks, turkey vultures, American kestrels, and northern harriers. Comparison with 1987–1992 data showed increased activity in 1992–1994 among the most abundant raptors. Of waterfowl species, Canada geese and mallards were observed in the study area. During the day, over the two-year period, goose flocks averaged 0.057 per hour and duck flocks averaged 0.076 per hour. During 1993 nest studies, 13 diurnal raptor nests, 16 nocturnal raptor nests, and 5 mallard nests were located during 11 days from April to May. In 1994, 15 diurnal raptor nests, 9 nocturnal raptor nests, and 3 mallard nests were found during August. The authors conclude that given the numbers of raptors and the recruitment rates of young into their populations, the proposed facility will not likely have a biologically significant impact on raptor populations of the region or the state.

75. Howell, J.A., J. Noone, and C. Wardner. 1991a. Avian use and mortality study, U.S. Windpower, wind energy site development, Montezuma Hills, Solano County, California, post construction, spring, 1990 to spring, 1991. Prepared for Solano County Department of Environmental Management, Fairfield, California.

Post-construction observations of avian movement focused on raptors and waterfowl for 12 months in the Montezuma Hills. Twelve raptor species were identified, but 90 percent of observations were of red-tailed hawks, turkey vultures, American kestrels, and northern harriers. Data were compared to two pre-construction studies in the same area. Reductions in the proportion of birds observed over a three-year period were significant for five raptor species. Reduced activity was attributed to drought because decreases were evident prior to turbine installation. Activity rates of two species, golden eagles and prairie falcons, increased. The increase was statistically significant for golden eagles. Waterfowl activity (as reflected by the number of goose and duck flocks) also declined significantly over the three years. Five dead birds were recovered during mortality surveys at 230 (38% of total turbines) wind turbines. No waterfowl deaths were detected. Flight characteristics were also recorded.

76. Howell, J.A., J. Noone, and C. Wardner. 1991b. Visual experiment to reduce avian mortality related to wind turbine operations, Altamont Pass, Alameda and Contra Costa counties, California, April 1990 through March 1991. Final report. Prepared for U.S. Windpower, Inc., Livermore, California. U.S. Windpower, Inc., is now known as Kenetech Windpower, Inc.

Three hypotheses about avian-turbine collisions were tested: (1) birds cannot see the high-velocity, neutral-colored turbine blades under specific conditions, (2) bird collisions tend to occur at turbines located at swales or hill shoulders, and (3) bird collisions tend to occur at turbines at the ends of turbine rows. To test the first hypothesis, turbine blades were painted a pattern of red and white. To

test the other two, mortality was monitored at sites of known higher mortality, comparing turbines either in swales or on shoulders, or at ends of rows, with adjacent turbines not fitting these characteristics. Mortality surveys were conducted weekly (because of high scavenging rates) for 12 months. Ten dead birds were recovered, one of which was a raptor. Results were inconclusive (not statistically significant) but the authors suggested that painting turbine blades may reduce the number of bird collisions, and that end turbines did not contribute disproportionately to collision mortality. Because of their small sample sizes, they recommended additional trials using more sample plots, and trying different painting patterns and colors.

77. Hubbard, H.H., F.W. Grosveld, and K.P. Shepherd. 1983. Noise characteristics of large wind turbine generators. Noise Control Engineering J. 21(1):21–29. Reference and summary taken from Hubbard and Shepherd 1988b.

The noise characteristics of three representative large wind turbine generators are summarized. The main noise sources are identified. Loading noise components are a characteristic of downwind machines and are usually confined to frequencies below 100 Hz. Broad band components extend throughout the audible frequency range and were observed for both upwind and downwind machines.

78. Hubbard, H.H. and K.P. Shepherd. 1982. Noise measurements for single and multiple operation of 50-kW wind turbine generators. National Aeronautic and Space Administration, CR 166052. Reference and summary taken from Hubbard and Shepherd 1988b.

The noise characteristics of the U.S. Windpower 50-kW wind turbine generator were measured at various distances from 30 m to 1,100 m and for a range of output power. Generator noise is affected by the aerodynamic wakes of the tower legs at frequencies below about 120 Hz and the blade trailing edge thickness at frequencies of about 2 kHz. Rope strakes and airfoil fairings on the legs did not result in substantial noise reductions. Sharpening the blade trailing edges near the tip was effective in reducing broad band noise near 2 kHz. For multiple machines, the sound fields are superimposed. A three-fold increase in the number of machines (from 1 to 3) results in a predicted increase in the sound pressure level of about 5 dB. The detection threshold for 14 machines operating in a 13-20 mph wind is observed to be at approximately 1160 m in the downwind direction.

79. Hubbard, H.H. and K.P. Shepherd. 1988a. Wind turbine noise. Chapter 6 of ASME/DOE Wind Turbine Technology Book. Reference and summary taken from Hubbard and Shepherd 1988b.

This chapter includes discussions of the physical characteristics of wind turbine noise, prediction methodology for noise from single and multiple machines, atmospheric propagation, and evaluation of both indoor and outdoor receiver responses, and provides a summary of measurement technology including wind screens.

80. Hubbard, H.H. and K.P. Shepherd. 1988b. Wind turbine acoustics research bibliography with selected annotation. National Aeronautic and Space Administration, Langley Research Center, Hampton, Virginia.

This bibliography includes references and annotations of documents that represent the following acoustic subject areas: prediction of wind turbine noise, acoustic measurements for wind turbines,

effects of wind turbine noise on building structures, people and communities, atmospheric propagation, and measurement technology including wind screens.

81. Hunt, G. 1994. A pilot golden eagle population project in the Altamont Pass Wind Resource Area, California. Prepared by The Predatory Bird Research Group, University of California, Santa Cruz, for The National Renewable Energy Laboratory, Golden, Colorado. 212 pp.

The primary purpose of this pilot study was to lay the groundwork for determining whether or not wind energy development in the Altamont Pass WRA may affect golden eagles on a population basis. To determine whether the golden eagle population in the Altamont Pass is sufficient to absorb losses caused by turbine-related deaths, the study needed to: (1) identify the population at risk, (2) quantify the reproductive rate (natality), and (3) estimate the annual survivorship of each population segment. Golden eagles were radio-tagged and regularly censused to establish resident population levels and determine the rate of survival. Nesting surveys were conducted to estimate the productivity of the breeding population in the region. Data from 31 radio-tagged eagles suggested that at least 75 percent of the eagles present in the Altamont Pass in the winter are resident to the region surrounding the WRA. Nesting productivity and success in this region were higher than normal for golden eagles; nesting density in portions of the study area was among the highest reported for the species. At this time, however, data are insufficient to predict a population effect.

In addition to gathering population data, observation surveys were conducted to identify factors and behaviors that might increase the risk of mortality to eagles and other raptors. Data indicated that lattice turbines had the highest "perchability" of any turbine type. End turbines were used for perching more than non-end turbines, which may explain the higher mortality rate found at end turbines in a previous study (Orloff and Flannery 1992). The author suggested mitigation measures, including reducing the raptor food availability in the WRA, avoiding constructing more lattice-type turbine towers, and improving nesting habitat potential outside the WRA.

82. Ingram, D.J. 1984. Unpublished letter to U.S. Fish and Wildlife Service, Sacramento, California, regarding the effects of the Bald Mountain Windfarm Project and windfarms in general on the California condor.

The first part of this letter constitutes an "Official Complaint" submitted to the U.S. Fish and Wildlife Service in July 1994. It outlines Mr. Ingram's reasons for filing an official complaint as well as his opinions on the potential for the Bald Mountain Project to affect California condors. His opinion is that there is no reason for the U.S. Fish and Wildlife Service to oppose the Bald Mountain Windfarm Project because of potential condor conflicts. The second part of this letter is a three-page paper by Mr. Ingram entitled *Where Have All Our Condors Gone*. In this paper, Mr. Ingram first outlines the number of condor adults and eggs lost between 1966 and 1976, and second, summarizes activities related to the capture of adults and removal of eggs for the captive breeding program over the years. He finishes by providing his personal comments on these activities.

83. Jacobs, M.B. 1994. Avian mortality and windpower in the northeast. Pages 91–99 in Proceedings of the American Wind Energy Association's Windpower '94 conference, Minneapolis, Minnesota.

This paper identifies the lack of a pattern of avian mortality at California windpower sites, and argues that, despite similar bird species and windpower equipment at California WRAs and northeastern U.S. sites, there is no basis for applying Altamont Pass WRA avian mortality rates to

other sites. The range of site-specific information available instead suggests that important relevant factors such as raptor abundance and site-specific behavior have not been adequately explored at northeast windpower development sites to allow predictions of raptor mortality. The paper combines a number of methodologies (surveys, observations, and analysis of existing information) to understand the limited information currently available about specific windpower sites in the Northeast.

84. Johnson, B.S. and E. Cheslak. 1985. Raptor abundance and distribution in relation to a large wind turbine generator. Prepared for Pacific Gas & Electric, San Ramon, California, by BioSystems Analysis, Inc., Tiburon, California.

In 1984, BioSystems Analysis investigated the effects of a newly-erected MOD-2 wind energy generator on abundance and distribution of diurnal raptors. Differences in pre- and post-construction data were compared between the MOD-2 site and a control site, providing both spatial and temporal controls. No effect of the turbine on number of birds seen or on species composition was detected. Data did suggest, however, that the spatial control may not have been a true control because of topographic differences between sites. There were also differences at the control site between pre- and post-construction conditions that may have obscured turbine-related effects. The authors recommend additional, more long-term, more extensive investigations.

85. Jones & Stokes Associates, Inc. 1985a. Draft environmental impact report, Potrero Hills Wind Park, SCH #84112001. Prepared for Solano County Department of Environmental Management, Fairfield, California.

This proposed wind energy development would be sited within the secondary management area of Suisun Marsh in the Potrero Hills of California. The DEIR addresses potential adverse effects associated with placement of 195 wind energy generators and related facilities along a ridgeline overlooking the marsh. Potentially significant impacts include conversion of grazing land to wind energy production, interference with operations of two local businesses, conflicts with existing land use plans, soil slumping and increased soil erosion following grading and excavation, damage to proposed facilities by severe ground shaking or slope failure, increased turbidity in a nearby slough from soil erosion, collisions between birds and wind turbines, reduced raptor use of ridgeline and adjacent trees, electrocution hazard to large birds, increased bird/aircraft collision risk associated with disruption of bird flight paths in and out of Suisun Marsh, generation of low frequency impulse sound under certain wind conditions, alteration of views of Potrero Hills (visual effect), increased fire hazards during construction and maintenance, and reduced obstruction clearance for aircraft using nearby Travis Air Force Base. Planned and recommended mitigation measures are discussed for each potential impact. Five alternatives are considered.

86. Jones & Stokes Associates, Inc. 1985b. Final environmental impact report, Potrero Hills Wind Park, SCH #84112001. Prepared for Solano County Department of Environmental Management, Fairfield, California.

Potential environmental effects of the proposed installation of 195 wind energy generators in the Potrero Hills of California are summarized, as are planned and recommended mitigation measures. All written and oral comments on the DEIR are published and addressed in this FEIR. This report is an attachment to the DEIR; with the exception of the summary table, it does not duplicate information contained in the draft (see Jones and Stokes Associates, Inc. 1985a).

87. Jones & Stokes Associates, Inc. 1987. Bird abundance and movements at the Potrero Hills wind turbine site, Solano County, California. Prepared for Solano County Department of Environmental Management, Fairfield, California.

A proposed wind turbine site (195 turbines and associated facilities) in the Potrero Hills of Solano County, California, was studied to determine baseline bird use and evaluate potential project-related impacts on birds pursuant to recommendations in an EIR prepared for the project. Two sites were monitored, one for use as an experimental site during post-construction surveys and the other as a control site. Eight raptor and nine waterfowl species were recorded; relative raptor abundances indicated the area was an important concentration area. Waterfowl (primarily geese) tended to make more flights in overcast weather than on clear days. Data showed that thousands of waterbirds crossed the Potrero Hills annually during the fall-to-spring period. In clear weather, most waterfowl flew above the 30 m height of proposed turbines. Waterfowl and gulls should easily see and avoid turbines, electrical collection lines and other facilities in clear weather. Guy wires would be less visible. A greater potential exists for collisions at night and on foggy days. Some birds flew within fog at low elevations, suggesting that turbine collisions may be expected.

Habitat loss and consequent prey reduction could cause local declines in wintering raptor populations. Data suggested that all raptor species mainly used the airspace that would be occupied by turbines (< 30 m). Because of their excellent eyesight, raptors were not expected to collide frequently with turbines and other facilities under good visibility conditions. Again, collisions were expected to be most likely with guy wires. Habitat use patterns for raptors could be affected in several ways, including (1) increased suitability associated with increasing perch sites, (2) obstruction of foraging activities and general movements, (3) downwind air turbulence caused by turning turbine blades, which may decrease habitat suitability, and (4) placement of turbines along ridgelines supplanting raptors. Electrocution hazards are also possible, but could be avoided with careful design of utility lines.

88. Jones & Stokes Associates, Inc. 1994. Klickitat County avian study plan. Revised draft. April 25. Technical report JSA 93-303. Bellevue, Washington. Prepared for R.W. Beck and Associates, Seattle, Washington.

This study plan describes goals, objectives, study parameters, methods, data analysis, and use of pre-existing data to be used to evaluate avian use within an area proposed for wind power generation. The site comprises approximately 5,300 ha in the Columbia Hills above the Columbia River in Klickitat County, Washington. Three wind power generation projects, including the eventual placement of up to 450 wind turbines, were being considered. Questions to be answered related to general avian use, use during migration, and potential presence of threatened or endangered species. Bird species of primary concern were bald eagle, golden eagle, four falcon species, turkey vulture, three *Accipiter* species, four *Buteo* species, burrowing owl, long-billed curlew, loggerhead shrike, black tern, western sage grouse, waterfowl, and migrating passerines. No results are presented.

89. Jones & Stokes Associates, Inc. 1995. Avian use of proposed Kenetech and CARES wind farm sites in Klickitat County, Washington. Technical report JSA 93-303. Bellevue, Washington. Prepared for R.W. Beck and Associates, Seattle.

An area above the Columbia River in Klickitat County, in southcentral Washington, is being considered for development of two wind power generation projects that could include as many as 436 wind turbines. Due to the concern regarding the potential for avian impacts, this study was initiated to assess the likelihood of adverse impacts on special-status birds. There were four elements to the

study: (1) a winter raptor and waterfowl study, (2) spring and fall bird migration studies, (3) a summer resident bird study, and (4) a raptor breeding study. Eight special-status species were determined to be present in sufficient numbers or to have sufficient protection to be evaluated in detail, including the peregrine falcon, bald eagle, golden eagle, Swainson's hawk, and prairie falcon. Of the potential impacts evaluated, collision with wind turbines was determined to have the most potential for significant impact on raptors and other birds. Based solely on avian mortality experienced at California windfarms, mortality resulting from development of both Washington wind sites could range from 8 to 26 raptor deaths per year. However, since the overall levels of raptor use at both sites is lower than that of California windfarms, the potential for raptor mortality is expected to be lower. The authors conclude that mortality for some special-status raptor species could affect local populations. Mitigation measures proposed include the use of tubular towers to reduce the potential for perching which may be a contributing factor in mortality.

90. Karlsson, J. 1983. Fåglar och vindkraft (Interactions between birds and aerogenerators; English summary). Resultatrapport 1977–1982. Ekologihuset, Lund University, Sweden.

This study was designed to determine the effect of two large wind turbines on the local breeding bird fauna in Sweden. Surveys were conducted for three years (1979–1982) both before and after installation. The results obtained did not indicate any effect on species diversity or abundance when comparing the situation before and after erection of the turbines. Reactions of migrating birds when passing close to the turbines will be evaluated in future studies. Results indicated that collision frequency would not normally exceed five birds per night during nights with normal traffic of migratory birds. However, on particular occasions of concentrated migration the figures may be as high as 50 birds per night.

91. Kelley, N.D. 1981. Noise generation by large wind turbines. Pages 169–180 in Proceedings of wind energy technology conference, March 1981, Kansas City, Missouri. Solar Energy Research Institute, Golden, Colorado.

This paper presents the results of a series of measurements on acoustic emissions from several large wind turbines. Both vertical- and horizontal-axis turbines were tested. Evidence is presented to support the hypothesis that annoying impulsive sounds associated with the operation of some turbines are the direct result of the interaction of the blades and unstable vortex flows in the wakes of the support-tower legs. The maximum acoustic energy is concentrated in the low-frequency audible and subaudible ranges, often less than 100 Hz.

92. Kelley, N.D. 1981. A methodology for assessment of wind turbine noise generation. Pages 175–188 in I.E. Vas, ed. Fifth biennial wind energy conference, Washington, D.C. Sponsored by the Solar Energy Research Institute, Golden, Colorado.

This paper describes a turbine noise evaluation technique that measures the degree of coherence in the acoustic radiation being emitted from a given turbine. It also compares the acoustic performance of and estimates the annoyance potential of several large wind turbine designs. It presents evidence to support the hypothesis that one of the major causal agents responsible for the turbine-caused annoyance of nearby residents is related to the degree of coherent impulsiveness present and the subsequent harmonic coupling of acoustic energy to residential structures.

93. Kelley, N.D. 1981c. Acoustic noise generation by the DOE/NASA MOD-1 wind turbine. Pages 375–387 in R.W. Thresher, ed. Wind turbine dynamics. Proceedings of a workshop sponsored by U.S. Department of Energy, Division of Wind Energy Systems, and NASA Lewis Research Center, held in Cleveland, Ohio. NASA Conference Publication 2185, DOE Publication CONF-810226.

A series of measurements was taken over the previous year of the acoustic emissions from the DOE/NASA MOD-1 wind turbine. The measurements showed that the maximum acoustic energy was concentrated in the low frequency range, often below 100 Hz. Temporal and frequency characteristics of the turbine sounds have been shown to be important, since the MOD-1 is capable of radiating both coherent and incoherent noise. Coherent sounds were usually impulsive and were manifested in an averaged frequency domain plot as large numbers of discrete energy bands extending from the blade passage frequency to beyond 50 Hz on occasion. These impulsive sounds were identified as the principal source of annoyance to people within 3 km of the MOD-1 turbine. The source of the coherent noise appeared to be the rapid, unsteady blade loads encountered as the blade passed through the wake of the tower structure. Annoying levels were occasionally reached at nearby homes due to the interaction of the low-frequency, high-energy peaks in the acoustic impulses and the structural modes of homes, as well as by direct radiation. The peak levels of these impulses might be enhanced or subdued through complex propagation. This paper documents methods, results, and details of the tests and measurements undertaken as well as preliminary conclusions about what needs to be done to correct the problem.

94. Kelley, N.D., R.R. Hemphill, and H.E. McKenna. 1982. A methodology for assessment of wind turbine noise generation. J. Solar Energy Engineering 104:112–120.

Abstract by authors: The detailed analysis of a series of acoustic measurements taken near several large wind turbines (100 kW and above) has identified the maximum acoustic energy as being concentrated in the low-frequency audible and subaudible ranges, usually less than 100 Hz. These measurements have also shown that any reported community annoyance associated with turbine operations has often been related to the degree of coherent impulsiveness present and the subsequent harmonic coupling of acoustic energy to residential structures. Thus, one technique to assess the annoyance potential of a given wind turbine design is to develop a method that quantifies this degree of impulsiveness or coherency in the radiated acoustic energy spectrum under a wide range of operating conditions. Experience has also shown that the presence of annoying conditions is highly time dependent and nonstationary, and, therefore, any attempts to quantify or at least classify wind turbine designs in terms of their noise annoyance potential must be handled within the proper probabilistic framework. A technique is described that employs multidimensional, joint probability analysis to establish the expected coincidence of acoustic energy levels in a contiguous sequence of octave frequency bands that have been chosen because of their relationship to common structural resonant frequencies in residential buildings.

The paper presents evidence to support the hypothesis that one of the major causal agents responsible for the annoyance of nearby residents by wind turbine noise is the excitation of highly resonant structural and air volume modes by the coherent, low frequency sound radiated by large wind turbines. Further, there is evidence that the strong resonances found in the acoustic pressure field within rooms actually measured indicates a coupling of subaudible energy to human body resonances at 5, 12, and 17–25 Hz, resulting in a sensation of whole-body vibration.

95. Kelley, N.D., H.E. McKenna, R.R. Hemphill, C.L. Etter, R.L. Garrelts, and N.C. Linn. 1985. Acoustic noise associated with the MOD-1 wind turbine: its source, impact and control. Solar Energy Research Institute, U.S. Department of Energy. SERI/TR-635-1166. Reference and summary taken from Hubbard and Shepherd 1988b.

A summary is presented of the extensive research conducted by Solar Energy Research Institute to establish the origin and possible amelioration of acoustic disturbances associated with the operation of the MOD-1 wind turbine installed in 1979 near Boone, North Carolina. Results have shown that the source of this acoustic annoyance was the transient, unsteady aerodynamic lift imparted to the turbine blades as they passed through the lee wakes of the large, cylindrical tower supports. Nearby residents were annoyed by the low-frequency acoustic impulses propagated into their homes. Several techniques for reducing the noise were researched and are discussed.

96. Kelley, N.D., H.E. McKenna, E.W. Jacobs, R.R. Hemphill, and N.R. Birkenheur. 1987. The MOD-2 wind turbine. Volume I, aeroacoustical noise sources, emissions and potential impact. U.S. Department of Energy, Solar Energy Research Institute. SERI/TR-217-3036. Reference and summary taken from Hubbard and Shepherd 1988b.

This paper gives a description of an extensive series of acoustic measurements at the MOD-2 wind turbine site at Goldendale, Washington. Sound pressure level and spectral data are presented for frequencies from the subaudible range for single and multiple machines. The resultant noise is shown to be related to atmospheric parameters such as wind speed and stability.

97. Kenetech Windpower, Inc. 1994. Avian research program update. San Francisco, California. 22 pp.

This pamphlet describes the goals and research efforts of Kenetech Windpower, Inc. [formerly U.S. Windpower Inc.], to provide effective, long-term measures to reduce turbine-related impacts to birds. In 1992, Kenetech established an Avian Research Task Force composed of nationally known research biologists to develop and oversee a multiphase research program focusing on the interaction of birds and turbines at Kenetech turbines in the Altamont Pass WRA. The goals of the research program are to develop and implement appropriate siting procedures to identify and resolve potential conflicts, to develop mitigation to offset avian losses, and to develop research-based modifications to wind turbines. Specific research programs currently underway include: (1) examining the sensory capacities of raptors common to the Altamont Pass to determine what visual stimuli are most effective in improving their recognition of a wind turbine as an obstacle to be avoided, (2) monitoring and evaluating controlled flights of trained birds using a 3-D video tracking system to study their evasive actions around turbines, (3) initiating a telemetry study to ascertain the dynamics of the golden eagle population in the Altamont Pass WRA and vicinity, (4) developing anti-perching devices to deter avian use of turbines as hunting and roosting sites, and (5) operating a remote video camera monitoring system to try to record bird deaths, located where multiple bird collisions have occurred.

98. Kern County Planning Department. 1985. Draft master EA for wind energy development in eastern Kern County, California. Kern County Planning Department, Bakersfield, California.

The purpose of this assessment was to provide an information base for reference on future wind energy parks and a base from which to periodically review existing parks. The paper identifies

environmental characteristics and constraints of the identified WRAs (in the Tehachapi area and portions of the Mojave Desert). This information is to be used to influence the design and location of individual projects. It also provides a summary of environmental effects of and mitigation for existing wind parks. Impact and mitigation areas addressed include hydrology, geology, air quality, biotic resources, and noise. Impacts to wildlife include loss of habitat and potential loss in wildlife populations. Mitigation measures recommended by the California Department of Fish and Game include protection of wetlands, revegetating disturbed areas, installing wildlife guzzlers (guzzlers provide water for wildlife), and acquiring open space easements along drainage channels. An ecological assessment and a noise study are included in the appendix.

99. Kirtland, K. 1985. Wind implementation monitoring program: a study of collisions of migrating birds with wind machines. Prepared for Riverside County Planning Department by Tierra Madre Consultants.

This study was prompted by concern for wind park-related deaths of migratory bird species. Three wind parks in or near San Gorgonio Pass, California, were chosen for study plots. San Gorgonio Pass acts as a natural travel corridor for migratory birds. Plots were walked for dead birds, and tests of scavenging rates and observer ability were performed. No dead migratory birds were observed during surveys, but feathers of nonmigratory species were collected. Scavenger removal was significant, with 60 percent of test chicks removed within three days. Observer ability was 86 percent. The author identifies six possible reasons dead birds were not found: scavenger removal, observer ability, timing (frequency) of surveys throughout the survey period, sample location, sample size/sampling time, and the possibility that there were no collisions between birds and towers. Because a concurrent Southern California Edison study found collision-killed migratory birds at a number of wind parks, the author notes that the results of the San Gorgonio study cannot be extrapolated to other wind parks. She recommended: further, more-extensive study; increased level of effort; surveying only sites with high collision potential and in the most sensitive areas; studies during fall migration season as well as spring; and efforts to design studies to make them more comparable to studies conducted elsewhere or by other people. She also recommended using WIMP (Wind Implementation Monitoring Program) fees, paid by wind park developers, be used to fund further studies.

100. Lago, C., A. Prades, E. Soria, and A. Diaz. 1993. Study of environmental aspects of the wind parks in Spain. European community wind energy conference, proceedings of an international conference at Lubeck-Travemunde, Germany, 8–12 March 1993. Published by H.S. Stephens and Associates, [location unknown].

Abstract by authors: The environmental aspects of Cabo Villano and Tarifa windfarms have been studied in this paper together with a study on public opinion of the affected populations. The nuisance on birds, the visual impact and the noise have been evaluated before the installation of the windfarms. The favourable response of the people regarding the installation of these windfarms has been one of the most relevant findings of this study. Now, we will carry out a second wave of questionnaires and interwieus [*sic*] to see the posible [*sic*] evolution of public opinion once ... the wind parks are operating, as well as their effects on the environment foccussing [*sic*] on birds, landscape and noise.

101. Lammen, C. and E. Hartwig. 1994. Vogelschlag an einem Sendemast auf Sylt: ein vergleich zu windkraftanlagen. (Bird strike at a LORAN-transmission tower on the Island of Sylt: a comparison to windplants; English summary). Aus dem Institut für Naturschutz—und Umweltschutzforschung des Verein Josdsand, Hamburg. Seevögel 15/1:1–4.

A total of 609 birds from 63 taxa were found dead at a 194 m LORAN transmission tower during seventy-five surveys over a two year period. The main cause of death was thought to be collision with the steel cables that were probably not seen as obstacles by migrating birds. Bird losses by strikes at tall towers and power lines were compared to losses by collision with wind turbines.

102. Larry Seeman Associates, Inc. 1986. Cumulative impacts on raptors, Howden Wind Parks, Inc., Vasco Road area, Contra Costa County, California. Prepared for Contra Costa County Planning Department, Martinez, California.

This report was an appendix to the Howden Wind Parks, Inc., EIR (see Darwin Myers Associates 1986). It provides background on wind turbine generation and windfarms as well as a literature review on impacts of human-made structures on birds until 1986. Anecdotal information from local specialists is also included; prior to 1986, data and literature specifically on wind turbines and windfarms were scarce. In the report, the effects of physical aspects of windfarms on raptor mortality are considered, including physical placement of turbines, associated facilities, the presence of guy wires, noise and vibration of operating turbines, aspects of the physical structure, and wire spacing on associated transmission lines. Species-specific effects of bird species on collision mortality are also considered, including body size, characteristic flight speed, characteristic flight height, foraging methods, sensitivity to humans, and sensitivity to disturbance. The status of a nearby golden eagle nest is discussed, a plan for establishing a buffer for the nest is recommended, and details of a proposed long-range cumulative impacts study are outlined.

103. Larry Seeman Associates, Inc. 1994. SeaWest Catellus I, biological assessment. Prepared for SeaWest, San Diego, California.

A biological survey was conducted to determine the potential for sensitive biological resources to occur on the proposed Catellus I windfarm in the San Gorgonio Pass area of Riverside County, California. The results of the survey are presented in this report. Topics covered include topography and soils; plant communities; wildlife; disturbances such as off-highway vehicle activity, roads, garbage, mining, and utilities; sensitive plants and animals; drainages; wildlife movement corridors; and bird collisions. Direct impacts resulting from the project could include general loss of plant communities that function as wildlife habitat and losses of individual wildlife. These impacts are analyzed according to their local, regional, and cumulative effects. Indirect impacts are those that result in decreased use of a site and/or adjacent habitats by wildlife due to increases in human-related activities. The following indirect impacts were not considered to be significant, either in the immediate area or in a regional context: construction-related impacts, human-related intrusion, noise, invasive nonnative plant species, fire, and hazardous waste. Mitigation requirements were minimal; they are outlined in the report.

104. Lawrence, K.A. and C.L. Strojan. 1980. Environmental effects of small wind energy conversion systems (SWECS). Prepared by Solar Energy Research Institute, Golden, Colorado, for the U.S. Department of Energy. Reference and summary taken or adapted from California Energy Commission 1995.

The authors conclude that the possibility of birds colliding with rotors and towers of SWECS is "extremely small . . . due to their [the SWECS] relatively low total height," with the exception of very large wind machines placed along a migratory route. Contributing factors noted are (1) solidity of the rotor design, (2) airfoil design, (3) number of birds flying through the blade sweep area, (4) behavior of birds within the blade sweep area, e.g., flight speed, evasive flight patterns, (5) weather conditions, and (6) total structure height.

105. Leitner, P. 1982. Potential WTG effects on wildlife. Appendix D in Cordelia Hills WTG Project final EIR. Prepared for City of Fairfield, California, by Environmental Science Associates, Inc., San Francisco, California.

Dr. Leitner summarizes literature and provides references on several subjects, including bird collisions with human-made structures; background of WTGs; WTG noise emissions; possible effects on animals; and possible effects of WTG downwind turbulence on birds. Among his major conclusions are: (1) many studies have shown that the greatest losses to human-made structures are suffered by songbirds (passerines) during nocturnal spring and fall migration flights; (2) it does not seem likely that diurnal raptors and waterfowl would strike large WTG structures because of the structures' high visibility; (3) it appears unlikely that animals could be exposed for enough time or at high enough sound pressure levels to suffer hearing loss or nonauditory health effects, and significant behavioral effects are also unlikely; and (4) potential turbulence and vortexes downwind of operating turbines could adversely affect hunting behavior of raptor species, but (for reasons that are explained in the report) significant adverse impacts seem unlikely.

106. LGL Ltd., environmental research associates. 1995. Proceedings of the national avian-wind power planning meeting, Denver, Colorado, 20-21 July 1994. Organized by the National Renewable Energy Laboratory, American Wind Energy Association, EPRI, DOE, National Audubon Society, and Union of Concerned Scientists. Proceedings prepared by LGL Ltd., King City, Ontario, Canada.

This is the proceedings of a meeting to discuss the research aspects of the avian-wind power issue. The proceedings includes a review of status of wind power in the U.S.A., a list of research questions, review of past and ongoing avian research, discussion of general design concepts for avian-wind power research, discussion of components of an integrated national research program, and the identification of next steps that should be taken. Several of the more detailed presentations are summarized in this bibliography.

107. Lindley, C.A. 1977. Wind machines for the California Aqueduct, vol. 2. Final report. Prepared for the U.S. Department of Energy, Division of Solar Energy, Washington, D.C., by The Aerospace Corporation, Energy and Transportation Division.

A study was made of the feasibility of using wind machines to provide part of the energy required to pump water in the California Aqueduct. Three potential sites were evaluated: Altamont Pass, San Gorgonio Pass, and the Tehachapi Mountains. The evaluation process consisted of a site evaluation, selection of wind machine type, system synthesis, and a comparative evaluation of technical,

operational, economic, and environmental factors. Potential environmental effects discussed include microwave and television interference, aircraft safety, aesthetics, and the possible impact to the endangered California condor. Conclusions are drawn about the feasibility of wind energy for this project and similar applications.

108. Lubbers, F. and L.R. Pheifer. 1993. Final results on the research programme concerning the social and environmental aspects related to the windfarm project of the Dutch Electricity Generating Board. European community wind energy conference, proceedings of an international conference at Lubeck-Travemunde, Germany, 8–12 March 1993. Published by H.S. Stephens and Associates, [location unknown].

The Dutch Electricity Generating Board and the Ministry of Economic Affairs of The Netherlands developed a joint scheme for the installation of an experimental windfarm of 18 wind turbines with a capacity of 300 kW each. One of the objectives was to gain experience in physical planning aspects and environmental aspects as well as social acceptance. Seven surveys were undertaken. The bird survey looked at behavior, collision, disturbance, and methodology. The traffic count attempted to evaluate impacts to meadow birds as well as to agricultural management. The agricultural survey looked at effects on arable farming practices. The landscape analysis looked at effects on the landscape. The survey of the visual experience researched how people rate a windfarm as a new visual-spatial element and the arguments they put forward. The socio-psychological survey looked at social experience and social acceptance. Finally, the undisturbed wind catch research examined the supply of wind, specifically the influence of changes in surface-roughness on production output. The results of these seven surveys are presented.

109. Luke, A. and A. Watts. 1994. Bird deaths prompt rethink on wind farming in Spain. WindPower Monthly, February:14–16.

This article discusses the environmental impacts and politics of a controversial wind development located at Tarifa along the southern tip of Spain. The windfarm, consisting of 269 lattice turbines, is situated along a major migratory route which traverses the Straits of Gibraltar. Birds stop over at Tarifa before and after they make the 14-km journey between Africa and Europe. Preliminary findings from independent experts and local conservation groups indicate that the number of birds killed by the project turbines is far higher than originally believed. Caused by both collision with turbines and electrocution on power cables, birds killed were of 13 species, most of which were raptors. A random count of dead birds revealed that approximately 30 griffon vultures were victims. Long-term plans could result in expansion to as many as 2,000 turbines at the site. A long-term study on the impacts of this project and future projects in this area should be completed by the end of 1994.

110. Manning, P.T. 1983. The environmental impact of the use of large wind turbines. Wind Engineering 7(1):1–11.

In light of experience showing that operation of wind turbines is not entirely environmentally benign, this paper reviews those aspects of operation that could produce adverse environmental effects. Although the paper treats horizontal-axis land-based machines, the information, according to the author, is applicable to other types. Among effects considered likely to be significant at all sites are visual impacts, TV interference, and noise. Other impacts, such as safety, icing that leads to chunks of ice being thrown, aircraft and wildlife collisions, propagation, and others, are unlikely to be significant provided some care is taken in design and siting.

111. Mariah Associates. 1995. Draft environmental impact statement, Kenetech/PacifiCorp windpower project, Carbon County, Wyoming. Prepared for the Bureau of Land Management, Great Divide Resource Area, Rawlins District, Rawlins, Wyoming.

This DEIS assesses the environmental consequences of a proposed windpower development project in Carbon County, Wyoming. The project entails the erection of approximately 1,390 wind turbine generators and associated facilities such as roads, substations, and distribution and communications lines, as well as a 230-kV transmission line to connect a proposed substation with an existing one. Key issues identified include wind turbine effects on birds, direct and indirect wildlife habitat loss, big game winter range and migrations, special-status (threatened, endangered, sensitive, or priority) plants and animals and their habitats, cultural resources and Native American spiritual values, and reasonable access to public land. Additional issues identified during public scoping include visual and aesthetics, soils, noxious weed control, wetlands and riparian areas, surface water and groundwater, land uses, noise, social and economic effects on local communities, public safety, traffic, and others. Potential negative impacts to many of these resources were identified, and 22 project-wide mitigation measures are to be implemented from the outset. The DEIS concluded that impacts to most resources would be negligible to moderate during the life of the project. Potentially significant impacts identified include avian mortality, declining avian populations, mortality and/or habitat loss of special-status species, noise disturbance to nearby residents, changes in visual resources, disturbance of important Native American traditional sites, changes in plant community species composition due to snow redistribution, displacement of big game due to windfarm operation, and loss of sage grouse nesting habitat. The proposed project could have beneficial impacts such as increased revenues generated by taxes, increased employment, and benefits derived from using a nonpolluting resource for electric power generation.

112. Mariah Associates. 1995. Final environmental impact statement, Kenetech/Pacificorp windpower project, Carbon County, Wyoming. Prepared for Great Divide Resource Area, Rawlins District, BLM, Rawlins, Wyoming.

This FEIS revises and supplements the DEIS (see above) for the KENETECH/PacifiCorp Windpower Project and addresses comments and concerns expressed during the public comment period on the DEIS. An additional 3½ months of field data on biological resources were incorporated into the FEIS, data that were not available at the time the DEIS was prepared. While there were extensive changes made to the Draft, a supplemental DEIS was not deemed necessary because the BLM did not make substantial changes to the proposed action that were relevant to environmental concerns, and there were no significant new circumstances or information relevant to environmental concerns and bearing on the proposed action or its impacts.

113. Martí, R. 1994. Bird/wind turbine investigations in southern Spain. Pages 48-52 in Proceedings of the national avian-wind power planning meeting, Denver, Colorado, 20-21 July 1994. Proceedings prepared by LGL Ltd., environmental research associates, King City, Ontario, Canada. Author's address: Sociedad Española de Ornitologia, Ctra. de Húmera No. 63-1, 28224 Pozuelo, Madrid, Spain.

This is a summary of a presentation on the preliminary results of an ongoing study at a wind development in Tarifa, Spain. Large numbers of migratory birds, including a high proportion of soaring raptors and storks, migrate through the Tarifa/Gibraltar area, an area considered to be of international importance for birds. The study now underway includes searches for dead birds near the turbines and direct observations of behaviors. During the first few months of study, a number

of birds were killed by collisions with turbine blades. The casualties included 14 protected species; the majority were griffon vultures. These are large birds that maneuver relatively poorly and they depend on slope winds and thermals. This study, and another one on wind resources, will provide the basis for further rational development of wind energy in the Tarifa area, if appropriate.

114. McCrary, M.D., R.L. McKernan, R.E. Landry, W.D. Wagner, and R.W. Schreiber. 1983. Nocturnal avian migration assessment of the San Gorgonio Wind Resource Study Area, spring 1982. Prepared by Los Angeles County Natural History Museum, Section of Ornithology, Los Angeles, for Southern California Edison, Research and Development, Rosemead.

In preparation for wind energy development of the San Gorgonio Pass WRA, Southern California Edison funded research to examine characteristics of nocturnal bird migration in the area (aided by modified vertical beam radar) and evaluate the potential for bird collisions. Research was conducted during four migration periods (spring and fall 1981, and spring and fall 1982). This paper summarizes the results of the spring data, while McCrary et al. (1984) covers the fall data. During spring migration, the WRA was heavily used by birds as a migratory flyway. Researchers recorded large numbers of passerines flying in the altitudinal zone of risk (area of potential impact), i.e., approximately 9 percent of the estimated spring population of nocturnal migrants that used the WRA were in the area of potential impact. The paper presents a theoretical analysis of potential collision rates based on turbine designs, number of birds at risk, and level of avoidance. The authors predicted that most collisions would likely occur during the first 2–3 hours of night when the migration rates were highest and altitudes were slightly lower. Collisions also were predicted to be higher along the crest of hills where the altitude of birds relative to ground level decreased as they flew over a ridge. Mitigation measures and recommendations for further study are included.

115. McCrary, M.D., R.L. McKernan, W.D. Wagner, and R.E. Landry. 1984. Nocturnal avian migration assessment of the San Gorgonio Wind Resource Study Area, fall 1982. Prepared by Los Angeles County Natural History Museum, Section of Ornithology, Los Angeles, for Southern California Edison, Research and Development, Rosemead.

This paper provides the results and analysis of research on the fall avian migration in the San Gorgonio Pass WRA and constitutes the alternate half of a study conducted by the Los Angeles Natural History Museum (see McCrary et al. 1983). The goals and methods of the fall study were essentially the same as those of the spring study. Results were also similar, except that migration rates were slightly higher in the fall.

116. McKernan, R.L., W.D. Wagner, R.E. Landry, and M.D. McCrary. 1984. Utilization by migrant and resident birds of the San Gorgonio Pass, Coachella Valley, and southern Mojave Desert of California, 1979–80. Prepared by Los Angeles County Natural History Museum Foundation, Section of Ornithology, Los Angeles, for Southern California Edison, Rosemead, California.

Southern California Edison, in preparation for development of a large scale wind energy development in the San Gorgonio Pass and Coachella Valley areas of Riverside County, funded a two-year study to gather baseline information on the dynamics of migratory and resident bird use of this area. The specific objectives of the study were to (1) collect baseline data on the extent of use by migratory and resident birds within and adjacent to the WRAs, (2) determine and evaluate seasonal trends in spring and fall migration, (3) obtain data on habitat utilization and identify high-use areas, and (4)

develop recommendations for mitigating the potential effects of the project. The complex habitat types within the WRAs support a diverse and abundant avifauna, and the areas are heavily used by migratory birds. The report recommended providing buffer zones of at least 500 m around sensitive nesting habitats and areas of high bird concentration.

117. Mead, C.J. 1982. The possible impact of wind power generators on flying birds. A report from the British Trust for Ornithology to the Nature Conservancy Council. Research report no. 6.

This paper examines the likelihood of direct loss of bird life through impact with the moving rotors of wind turbines and the possible means of avoiding such losses. An equation is provided that gives the probability of bird collision under a range of different scenarios using parameters including bird velocity, bird length, number and thickness of rotors, and rotor velocity. The authors speculate that there is little reason to expect collisions during daylight conditions with good visibility. Collisions at night or at dawn, however, are much more likely. Although results indicated that there is no serious likelihood of significant mortality to migrants, migrants were thought to be more at risk than local birds. Possible means of avoiding bird losses include installing a glowing strip along the rotor shaft.

118. Medsker, L. 1982. Side effects of renewable energy sources. National Audubon Society, Environmental Policy Research Department Report no. 15. Reference and summary taken or adapted from California Energy Commission 1995.

Barriers to wildlife movement are cited as direct impacts of wind energy conversion systems with the consequence of possible destruction of birds and insects colliding with wind machines. Choosing sites with migration and flight patterns in mind is recommended as a mitigation measure.

119. Meek, E.R., J.B. Ribbands, W.G. Christer, P.R. Davy, and I. Higginson. 1993. The effects of aero-generators on moorland bird populations in the Orkney Islands, Scotland. Bird Study 40:140–143. RSPB, Orkney Office, Smyril, Stenness, Orkney, United Kingdom.

The effects of three wind turbines (250 kW, 300 kW, and 3 MW) on breeding birds were studied on two moorland plots in Orkney's West Mainland in Scotland. One plot was immediately adjacent to the turbines while the other acted as a control site. Studies were conducted each year between 1981 and 1989; the first year was pre-construction surveys and the remaining eight years were post-construction. Species groups studied included loons, ducks, waders, skuas and gulls, and small passerines. Although the sample size in this study was small, the authors concluded that there was little evidence that the turbines affected the size of the local breeding bird population. Other factors such as vegetational change or human disturbance were thought to have a much greater influence on bird numbers. The number of dead or injured birds resulting from apparent collision with the turbines or their associated structures was very small; only three gulls and one peregrine falcon were found during the course of the eight-year post-construction study. However, no measures were taken to determine scavenger activity or search efficiency.

120. Minnesota Environmental Quality Board. 1995. 100 megawatt phase II generation project Buffalo Ridge, Minnesota. Environmental Impact Statement. Minnesota Environmental Quality Board.

This draft EIA assesses potential environmental impacts associated with two alternative sites for a 100-MW wind power development by Northern States Power Company in Minnesota. Both sites are located along Buffalo Ridge. The report contains discussions of the wind resource in the area, costs, and engineering and operational design and analysis, as well as the following environmental considerations: demographics, aesthetics, recreational resources, infrastructure (electrical service, traffic, water supply, radar, etc.), public health and safety, effects on land-based economies, mining, and archaeological and historic resources. In addition, topography, soils, climate, noise, geologic and groundwater resources, surface water and floodplain resources, wetlands, vegetation, wildlife, and rare and unique natural resources are also treated. Potential impacts and recommended mitigation measures are discussed for each area of concern.

121. Mitchell, D.L., M.O. Chichester, R. Rado, and J.C. Wilson. 1993. SeaWest raptor monitoring program, Seawest Mojave 1990 Project, Sections 3, 4 and 5 (T11N, R13E, SBB&M). Final report: two-year monitoring period, spring 1991 through winter 1992–93. Prepared for Seawest, San Diego, California.

As part of Kern County's Mitigation Monitoring Program for the Seawest Mojave Project, a monitoring program was conducted to study raptor mortality for two years within a 300-turbine wind park in Kern County, California. The wind park is situated in hilly terrain on the south slopes of the eastern end of the Tehachapi Mountains. Surveys consisted of counts of living birds, surveys for dead birds along turbine rows, and tests for observer acuity and scavenger removal rates. Raptor mortality within the study plots appeared to be nonexistent. Based on the low number of live birds observed, the probability of death or injury of raptors from collision with wind turbines appeared to be very low. The study area does not support the small-mammal prey base for raptors as do the more mesic California grasslands and woodland environments.

122. Møller, N.W. and E. Poulsen. 1984. Vindmøller og fugle (Windmills and Birds; English translation). Vildtbiologisk Station, Denmark. No other information available.

A study was conducted at two windmill sites located near the coast in Denmark; one site contained one turbine (tower height 27 m) and the other site had three turbines (tower height 32–45 m). The study focused on the disturbance of wind turbines to birds and the risk of collisions. A direct frightening effect on birds caused by the turbines was observed only a few times. The investigators did not find any birds that had been killed by collision with turbines. Scavenger presence was thought to be minimal. Based on one year of observations, the two windmill sites did not seem to have any negative effect on the bird life. However, they caution the reader that, under special circumstances or weather conditions, collisions or conflict situations may occur.

123. Moorehead, M. 1984. Reference guide to wind energy land use issues and actions. Oregon Department of Energy, Salem, Oregon.

This document identifies and explains the specific actions (plans, ordinances, legislation, permitting procedures) taken by federal, state, and local units of government to regulate large- and small-scale wind energy development. A discussion of how federal and state environmental laws directly and indirectly influence the siting of wind projects is presented. The text describes wind energy issues

and discusses how these issues and impacts are addressed in local ordinances. The discussion of issues is supplemented by examples of policy guidelines and mitigation measures addressing each issue. Issues discussed include safety, air traffic, noise, aesthetics, and flora and fauna. A comprehensive bibliography of wind energy publications, organized by topic, is included.

124. Moorehead, M. and L. Epstein. 1984. Wind energy planning guidebook for Oregon local governments. Oregon Department of Energy, Salem, Oregon.

This document discusses wind energy policy, regulatory and legal relationships, and recommends wind energy-related regulations for Oregon local governments. This guidebook contains chapters on the roles of federal, state, and local governments in wind development, wind energy data collection techniques and analysis, goals and policies for comprehensive land use plans, and wind energy impacts and mitigation measures. Model ordinances for wind energy facilities are also included. Environmental issues and mitigations addressed include safety, electromagnetic interference, noise, visual, land use, and flora and fauna impacts. The authors state that although the overall risk of birds colliding with rotating blades is low, large wetland birds such as geese and cranes and low-flying migratory song birds may be more susceptible to collisions. However, they state, migratory birds usually fly well above the height of most turbines. The authors theorize that collision potential will vary with weather conditions, terrain, turbine placement, rotor design, and rotor speed. The authors note that wildlife specialists have expressed concern that birds making short flights between nesting, feeding, or resting areas fly low and may be more susceptible to collisions.

125. Moorehead, M. and L. Epstein. 1985. Regulation of small scale energy facilities in Oregon—siting standards for hydroelectric, wind, geothermal, biomass and transmission facilities, vol. 1, 2nd ed. Oregon Department of Energy, Salem, Oregon.

This guidebook describes how counties in Oregon can regulate proposed small-scale energy facilities (< 25 MW). It is intended to promote review and consideration of energy planning, to increase understanding of siting needs and impacts, and to increase understanding of and coordination with federal and state laws. The guidebook contains a summary of small energy facility siting issues and recommendations, a model of a county siting ordinance, comments about the model ordinance, and a model staff report. Wind energy concerns that are addressed include safety, air traffic, setbacks, visual effects, communications effects, noise, and impacts to migratory birds. The authors suggest that bird impacts can be reduced through siting, imposing turbine height limits, and visual cues.

126. Moorehead, M. and L. Epstein. 1985. Regulation of small scale energy facilities in Oregon: background report, vol. 2, 2nd ed. Oregon Department of Energy, Salem, Oregon.

Volume 2 includes a discussion of the potential for small-scale energy facilities in Oregon, and the federal, state, and local laws that affect siting of these projects. The issues and impacts concerning five types of small-scale energy facilities are discussed. Wind energy concerns addressed include safety, electromagnetic interference, aesthetics, noise, and flora and fauna. Possible mitigation measures for all of these impacts are presented. An examination of the impacts of wind energy facilities includes a discussion of the potential for birds colliding with towers (for more details see Moorehead and Epstein 1984). Potential mitigation suggestions include setbacks, imposing turbine height limits, visual clues to alert birds to turbine presence, choosing sites outside critical areas, and monitoring bird deaths during turbine operation.

127. Montana State University. 1994. Avian use of Norris Hill Wind Resource Area: phase 1. Fish and Wildlife Management and Research, Department of Biology, Montana State University, Bozeman.

Proposed development of the Norris Hill Wind Resource Area (NHWRA) stimulated investigation of pre-impact avian use of the area, and this report summarizes data from Phase I, Vernal Migration, of the investigation. Considering the abundance and diversity of the avian resource in Montana, as well as the geographical situation, surrounding topography, and habitat associations of the NHWRA, "surprisingly few" species and individuals were observed during the study, but this may have resulted from problems associated with data collection. Data are discussed as are potential risks and considerations for future study.

128. Musters, C.J.M., G.J.C. van Zuylen, and W.J. ter Keurs. 1991. Vogels en windmollens bij de kreekraksluizaen (Bird casualties caused by a wind energy project in an estuary; English translation). Rapport, Vakgroep Milieubiologie, Rijksuniversiteit Leiden, Leiden, The Netherlands.

The impact of windmills on birds in a high-risk area on the southwest coast of The Netherlands was investigated. The project site had five 250-kW turbines with 15 more planned for the future. The project area was considered sensitive because of intensive use by waterbirds and considerable bird migration in this area. Only the effects of collision mortality were studied. During the one-year study, 26 dead waterbirds of 17 species were found. Of these, six appeared to have been killed by the windmills with certainty and three more were possibly killed by windmills. Based on these findings and scavenger survey results, the annual number of bird victims expected after the completion of 20 windmills was estimated at a minimum of 7 to a maximum of 142. An estimate of an average of 0.01 birds killed per turbine per day was lower than estimates from other Dutch studies. It was concluded on the basis of these results, that there was no reason to advise against expanding the number of windmills to 20.

129. National Environmental Research Institute. 1994. Impact from an off-shore wind turbine park on birdlife: a research project. National Environmental Research Institute, Department of Wildlife Ecology, Denmark.

This is a research proposal for a study to determine the effects of 10 wind turbines off the Danish coast. The purpose would be to elucidate the degree to which an off-shore wind turbine park might influence occurrence, distribution, and behavior of waterfowl and seals. This coastal area is the site of an important waterfowl migration and has a large population of common seals. Researchers proposed a three-year study to include pre-construction, during-construction, and post-construction data collection. Radar would be used to document the passage of migrating birds. The potential impacts to bird life include disturbance to resting/foraging birds, disturbance to migrating birds, and risk of collision. Portions of the research began in the fall of 1994.

130. National Science Foundation. 1977. Legal-institutional implications of wind energy conversion systems (WECS). Report to the National Science Foundation, RANN/Research Applied to National Needs (NSF/RA-770203). Prepared by the Program of Policy Studies in Science and Technology, George Washington University, Washington, D.C.

This report discusses the legal and institutional obstacles to the use of land-based WECS including zoning, environmental policy statutes, water and noise pollution control statutes, and wildlife and

plant protection statutes. The authors state that preliminary findings of recent research (Rogers et al. 1976) indicate that the operation of WECS will not significantly affect the plant and animal environment surrounding the WECS. Brief mention is given to the possibility of migratory birds colliding with the spinning blades. The features of the existing legal structure that may facilitate the implementation of such systems are discussed. A section is also devoted to the legal issues involved with offshore wind systems.

131. Nelson, H.K. 1993. A biological reconnaissance of Buffalo Ridge, Lincoln and Pipestone counties, Minnesota. Final report. Submitted to WindRiver Power Company, Davenport, Iowa. Prepared by Harvey K. Nelson Consulting Services, Bloomington, Minnesota.

The objective of this biological reconnaissance was to identify environmental impacts that construction of a wind power generating system might have on flora and fauna of the Buffalo Ridge area. Primary emphasis was given to migratory bird populations, endangered and threatened species, and other resident wildlife and related habitats. Other concerns included visual impact, noise level, site management, and regulatory requirements. Available existing information indicates that the installation would have little adverse impact on waterfowl or other waterbirds. Certain species of raptors, however, could be susceptible to collision with turbines. The author recommends a monitoring and evaluation program be conducted during pre-construction and post-construction periods to detect any significant adverse impacts that may occur.

132. Orloff, S. 1992. Tehachapi wind resource area avian collision baseline study. Prepared by BioSystems Analysis Inc., Tiburon, California, for California Energy Commission, Sacramento.

The goal of this study was to evaluate the potential for avian collisions by comparing baseline field data collected at the Tehachapi WRA to data from the Orloff and Flannery 1992 Altamont Pass WRA study. Mortality searches in the Tehachapi WRA consisted of a one-time survey of 156 (3.5%) turbines. The mortality rate for all bird species in the Tehachapi WRA was significantly lower than that in the Altamont Pass WRA; no dead or injured birds were found during the surveys. Because of several habitat and structure features of the site, however, we might have predicted higher mortality in the Tehachapi WRA than in the Altamont Pass WRA: the Tehachapi WRA had more end-of-row turbines, higher average elevation, and lower structure density, all factors associated with higher mortality in the Altamont Pass WRA. Possible reasons for the lower observed mortality in the Tehachapi WRA include lower raptor abundance, fewer perched raptors, and lower prey abundance.

133. Orloff, S. and E. Cheslak. 1987. Avian monitoring study at the proposed Howden windfarm site, Solano County. Prepared for Howden Wind Parks, Inc., Dublin, California, by BioSystems Analysis, Inc., Tiburon, California.

Results of 12 months of pre-construction surveys in the Benicia Hills, Solano County, California, between 1985 and 1986 are presented. The proposed Howden windfarm is near Suisun Marsh, an important wetland for wintering waterfowl and an important raptor winter foraging area. Eleven species of raptor and nine species of waterfowl were recorded at two experimental and one control site. Flight characteristic data were taken, and results of altitudinal and spatial distribution of observed birds are presented. Behavioral patterns are discussed. Duplicate observations (birds known to have been counted more than once) were included in some analyses and excluded in others. The

authors concluded that their data showed a potential for bird collisions with proposed wind turbines, noting that many birds were sighted at or below turbine blade height, and that many raptors hovered and foraged above ridgelines where turbines would be located. The authors stated that waterfowl and raptors may be more likely to collide with transmission lines or guy wires than with turbines because of their lower visibility.

134. Orloff, S. and A. Flannery. 1992. Wind turbine effects on avian activity, habitat use, and mortality in Altamont Pass and Solano County WRAs. Prepared by BioSystems Analysis, Inc., Tiburon, California, for California Energy Commission, Sacramento.

The purpose of the study was to evaluate the extent and significance of the impact of wind turbines on birds, to identify the causes and factors contributing to bird deaths, and to recommend mitigation measures. The study included searching turbine rows and transmission line structures for injured or dead birds, measuring the rate of bird carcass removal by scavengers, assessing the ability of observers to locate bird carcasses, determining the relative abundance of birds in the area, and observing bird behavior in relation to turbine and transmission line structures. Sample sites encompassed five types of turbines and covered about 16 percent of the total number of turbines in the Altamont Pass.

Most of the dead raptors found were red-tailed hawks, followed by American kestrels and golden eagles. Estimates of the annual number of raptors killed by windfarm-related injuries within the entire Altamont Pass WRA varied from 403 in the first year of the study to 164 during the second year. Of these raptor deaths, the authors conservatively estimated that 39 golden eagles were killed each year. American kestrels, red-tailed hawks, and golden eagles were killed more often than predicted from their abundance in the study area. In contrast, fewer turkey vultures and common ravens were killed than their abundance in the study area would suggest. Differences in foraging behavior and flight characteristics broadly explain observed differences in relative mortality for these five species.

Fifty-five percent of all raptor deaths were attributed to collisions with turbines, eight percent to electrocutions, 11 percent to collisions with wires, and 26 percent to unknown causes. Data indicated that mortality was significantly higher at end-of-row turbines, turbines close to canyons, turbines at higher elevations, and sites having lower structure density. Mortality differed among turbine types and was greater at three-blade lattice turbines than at any other turbine type.

The report includes mitigation recommendations for electrocution impacts and recommendations are included for experimental studies to further investigate factors contributing to mortality.

135. Orloff, S. and A. Flannery. 1993. Wind turbine effects on avian activity, habitat use, and mortality in Altamont Pass and Solano County WRAs. Pages 22-1 to 22-14 in Proceedings: avian interactions with utility structures—international workshop. September, 1992, Miami, Florida. EPRI, Palo Alto, California.

This is a summary paper of the report described above under Orloff and Flannery 1992.

136. Orloff, S. and A. Flannery. 1995. A continued examination of avian mortality in the Altamont Pass Wind Resource Area. Draft report. Prepared for the California Energy Commission, Sacramento.

This study is a continuation of the original Altamont Pass study by Orloff and Flannery (1992). Study objectives included: assess the potential effect of several new turbine-specific variables using

the original mortality data, assess whether original data collected on raptor perching behavior could help explain the observed mortality, and collect and analyze new mortality data to attempt to corroborate some of the original findings. Results showed that, of the new variables tested, only tip speed and the percent of time turbines actually operated were associated with higher raptor mortality: raptors were killed more frequently at turbines with faster tip speeds and at turbines that were in operation more of the time.

Perching behavior may make some species more susceptible to collision than others. Red-tailed hawks and American kestrels exhibited a higher relative perching frequency and had a higher relative mortality. In contrast, the turkey vultures' lower perching frequency may help explain its lower relative mortality rate. Perching frequency does not, however, help explain the relatively high mortality for golden eagles. Perching frequency was highest at lattice-tower turbines, which may partly account for the significantly higher mortality rate occurring at these types of turbines. Perching frequency was lowest at tubular-tower turbines, which may partly explain the relatively low mortality rate at these turbine types. Although the other three turbine types were commonly used by raptors for perching, perching frequency did not help explain mortality at these types. The authors provide possible explanations for why the design and operation of these three turbine types may make perching birds less vulnerable to collision mortality. Perching frequencies were higher at end turbines than at non-end turbines. This may be one reason the mortality rate the authors reported in their original study was higher at end turbines. The analysis of new mortality data corroborated the finding from the original report that both end turbines and turbines close to (within 500 ft of) canyons were significantly associated with mortality.

137. Pearson, D. 1992. Unpublished summary of Southern California Edison's 1985 bird monitoring studies in the San Gorgonio Pass and Coachella Valley. Presented at a joint Pacific Gas and Electric Company/California Energy Commission workshop on wind energy and avian mortality. San Ramon, California.

Diurnal pre-construction studies in San Gorgonio Pass, southern California, showed that avifauna were diverse and abundant; seasonal variation in bird density and species richness was substantial; bird density and species richness were higher in spring than in fall; the average number of migrants was highest in spring, lowest in fall; habitat quality had a major influence on bird density and diversity; and more migrant than resident birds were observed. Nocturnal pre-construction studies revealed that approximately 32,000,000 birds passed through San Gorgonio Pass and Coachella Valley in spring, 37,000,000 in the fall. Post-windfarm construction results included (1) some turbine fields were used by birds more heavily than others; (2) 38 bird carcasses were discovered, most in the spring; (3) most carcasses were of waterbirds and songbirds, none was a raptor; (4) mortality was highest in one wind turbine field situated close to water; (5) total estimated mortality for the turbine fields studied was 891 for 1985 (~89% occurring in spring); and (6) total mortality for the entire area could have been as high as 6,854, with ~89 percent occurring in spring and one wind turbine field claiming an estimated 42 percent for the year. Relative mortality during 1985 was estimated to range from 0.01–0.019 percent in the spring, 0.0017–0.002 percent in the fall, and 0.0057–0.0088 percent for all birds in 1985. No carcasses of sensitive or endangered species were discovered, and none was expected to have been impacted by wind turbine development.

138. Pedersen, M.B. and E. Poulsen. 1991. En 90m/2MW vindmølles indvirkning på fuglelivet—fugles reaktioner på opforelsen og idriftsaettelsen af Tjaereborgmollen ved det Danske Wadehav (Impact of a 90m/2MW wind turbine on birds—avian responses to the implementation of the Tjaereborg wind turbine at the Danish Wadden Sea; English summary). Danske Vildundersogelser, Haefte 47. Miljoministeriet & Danmarks Miljoundersogelser.

A study was conducted from 1987–1990 to determine the effects on birds from one large wind turbine (tower height 60 m) located near the Danish Wadden Sea region. The Wadden Sea region is of international importance as a staging and molting area for numerous waterfowl and wading birds. The study had two main objectives: to identify possible disturbance effects on breeding, staging, and migrating birds; and to evaluate collision risk. Results indicated that the number of breeding wading birds within the wind plant zone (within 300 m) was reduced from 30 percent in 1987 to 5 percent in 1989. Some species of waders have been shown to be sensitive to disturbance up to 800 m away. The authors concluded that the wind turbine has caused a "vacuum effect," preventing birds from exploiting areas close to the wind turbine. Foraging birds generally were observed closer to the wind turbine than "staging" birds. Whether or not the wind turbines were in operation, birds changed direction by as much as 30 degrees when passing the turbines. Seven bird deaths were attributed to collision with the wind turbine or meteorological tower. Search results and radar observations showed that the birds in general were able to detect and avoid the wind turbine. However, during the study period the wind turbine was operating only part of the time.

139. Peterson, B.S. and H. Nohr. 1989. Konsekvenser for fuglelivet ved etableringen af mindre vindmøller (Consequences of minor wind mills for bird fauna; English summary). Ornis Consult, Kopenhagen.

The aim of this paper was to elucidate the conflict between birds and windmills through an analysis of previous studies. It summarizes and discusses the results of several studies conducted primarily in Denmark on the impact of small wind parks on birds. The authors' analysis indicates that local birds normally habituate to the presence of windmills. Reactions to windmills are frequently seen in migrating waterfowl, which often change their course at a greater distance from the windmills. The most pronounced effects were seen where windmills were placed at locations being used as feeding grounds adjacent to extensive open areas. Present knowledge indicates that the construction of windmills should be avoided in certain areas, such as migration corridors and staging areas for species that appear sensitive to disturbance. The paper also includes the results of the authors' own study on the effects of a small wind park on birds. Only two birds, presumably killed by collision with turbines, were found during their investigation. The risk of collision from this wind park and others of comparable size and location was considered to be negligible.

140. Phillips, J.F. 1994. The effects of a windfarm on the upland breeding bird communities of Bryn Titli, Mid-Wales: 1993-1994. Royal Society for the Protection of Birds, The Welsh Office, Bryn Aderyn, The Bank, Newtown, Powys.

Pre- and post-construction data were collected on the breeding birds of an upland area in mid Wales, where the Bryn Titli windfarm is now sited, to determine whether the 22 wind turbines affected the upland breeding bird community. The windfarm site is located in an area of ornithological importance. The primary wildlife value of the site is its use by such species as red kites, hen harriers, merlins, golden plovers, lapwings, dunlins, snipes, curlews, red grouse, and short-eared owls. Data were collected on two plots: one within the area containing the wind farm and a control

site in an adjacent area. Sample sizes were small, but the study showed no significant changes in the populations found on the windfarm site between pre- and post-construction phases, suggesting that the operational windfarm is having no significant effect on the breeding populations of the birds found on the site. The authors state, however, that the data set may be too small to draw such conclusions.

141. Phillips, P.D. 1979. NEPA and alternative energy: wind as a case study. Solar Law Reporter 1(1):29–54. Reference and summary taken or adapted from California Energy Commission 1995.

This article examines the issue of whether and when NEPA applies to alternative energy sources, using wind as a case study. Potential environmental impacts of wind development are discussed, and construction of a 1.5-MW wind machine is used for illustrative purposes. The hazard of bird collisions is noted, especially with regard to migratory birds. The author states that "the risk would be small for high flying migratory waterfowl, but would increase for low flying nocturnal migrants, such as many songbirds."

142. Plowden, B. 1992. Wind power and the local environment—no free lunches. Pages 341–344 in B.R. Clayton, ed. Wind energy conversion proceedings of the 1992 fourteenth British Wind Energy Association wind energy conference. Mechanical Engineering Pub. Limited, London.

This paper attempts to put wind development in a broad context, in terms of other sources of renewable energy, energy and planning policy, and environmental issues. It makes the point that, contrary to common perceptions, there is still no such thing as a "free lunch" when it comes to environmental issues. Like all energy technologies, wind power generates real environmental costs that must be recognized in the policy process and in land-use planning. An analysis of the costs and benefits associated with wind projects is considered a critical part of the planning process. Public support for the continuation of wind energy development is of crucial importance in these early stages of renewable energy development.

143. Portland General Electric Company. 1986. Cape Blanco Wind Farm feasibility study. Tech. rep. no. 11: terrestrial ecology. BPA, Portland, Oregon. DOE/BP-11191-11. Reference and summary taken or adapted from California Energy Commission 1995.

This report evaluates the potential terrestrial ecology impacts of the construction and operation of a wind energy conversion system located near Cape Blanco in Curry County, Oregon. The authors consider that all three Cape Blanco windfarm alternatives under consideration pose a potential threat of collision for birds flying at low altitudes. Nocturnal songbirds are expected to be especially vulnerable. Guy wires and lighting of the units are identified as probable collision hazards. Potential impacts of support facilities — two transmission line routes to an existing BPA 230-kV line — are evaluated. Mitigation measures are discussed, including building the windfarm in increments and monitoring for bird kills after each increment as a condition for building the next increment.

144. Robin M. Towne and Associates, Inc. 1974. Environmental study of low frequency noise and vibration, Bethel Turbine Generating Facility, East Salem, Oregon. Prepared for Portland General Electric Company.

This study was designed to accurately quantify noise and vibration levels associated with wind turbine operation. It dealt specifically with noise directivity measurements in the eight compass directions at the 50-MW power level; variable power measurements in the quadrant of highest radiation to establish turbine power versus generated noise characteristics; and noise and vibration at both complaining and noncomplaining residences, magnitude of impact, subjective considerations, and quantitative determination of contribution of turbine noise in study residences. The study reports the following conclusions: (1) indoor noise levels at study residences with turbines operating meet generally accepted building noise criteria; (2) the recommended sound pressure levels can be met with additional attenuation; (3) the turbine noise spectra exhibit a peak in the 30–40 Hz region, falling off at a rate greater than 15 dB/octave above and below this; (4) noise sensitivity differed in complaining and noncomplaining residences; and (5) background noise levels in the surrounding community were typical for a rural-suburban community.

145. Robothan, A.J. 1992. Visual impact assessment: there's more to it than meets the eye. Pages 345–349 in B.R. Clayton, ed. Wind energy conversion proceedings of the 1992 fourteenth British Wind Energy Association wind energy conference. Mechanical Engineering Pub. Limited, London.

This paper describes the author's approach to visual impact assessment and is based upon the experience of preparing six such assessments in the United Kingdom (U.K.). The visual impact of a windfarm is one of the major causes of concern for all current U.K. windfarm projects. The author's approach uses an objective method of visual impact assessment based on the methods used for landscape assessment. This objective approach, in conjunction with subjective assessments, can be used to derive some overall assessment of visual impact. Based on experience, the author reviews the usefulness and suitability of this approach to visual impact assessment and makes recommendations for future practice.

146. Robson, A. 1983. Environmental aspects of large-scale wind-power systems in the U.K. Proceedings of the IEEE 130(9):620–625.

Environmental issues relating to the introduction of large, MW-scale wind turbines at land-based sites in the U.K. are discussed. Areas of interest include noise, television interference, hazards to bird life, and visual effects. A number of areas of uncertainty are identified, but the author concludes that enough is known about large wind turbines elsewhere in the world to enable the first U.K. machines to be introduced in a safe and environmentally acceptable manner. Various research activities underway will serve to establish siting criteria more clearly.

147. Rogers, S.E. 1975. Environmental effects of wind energy conversion system. Pages 375–379 in F.R. Eldridge, ed. Proceedings of the second workshop on wind energy conversion systems, Washington, D.C. Sponsored by the Energy Research and Development Administration of the Environmental and Resource Assessment Branch, Division of Solar Energy, and by the National Science Foundation.

This paper presents the research design and objectives of a study that was being conducted by Battelle's Columbus Laboratories to evaluate the potential environmental effects of wind energy

systems. The study objectives included (1) a compilation of the literature dealing with the effects of wind energy generation, including microclimate alterations and hazards to migratory biota, (2) the initiation of a site-specific baseline study at NASA's Plum Brook Facility near Sandusky, Ohio, and (3) the development of a longer-term field program to evaluate potential impacts. The final results of this study can be found in Rogers et al. 1976 and 1977.

148. Rogers, S.E. 1977. Wind energy conversion—environmental effects assessment. Pages 402–406 in Proceedings of the third biennial conference and workshop on wind energy conversion systems, in Washington D.C., U.S. Department of Energy.

This paper presents a summary of a study undertaken to evaluate the possible environmental effects of the then-emerging wind energy technology (see Rogers et al. 1977). Specific field studies were conducted on a 100-kW turbine at NASA Plum Brook Research Station near Sandusky, Ohio. The study attempted to evaluate changes to the microclimate, the effect of noise on wildlife, and impacts to birds as a result of wind turbine development. Results did not indicate any significant microclimate effect of the wind turbines. Sound levels were insufficiently high to result in disturbance to wildlife. The author determined that the turbine did not appear to be a high risk to birds.

149. Rogers, S.E., B.W. Cornaby, C.W. Rodman, P.R. Sticksel, and D.A. Tolle. 1977. Environmental studies related to the operation of wind energy conversion systems. Final report. Prepared by Battelle Columbus Laboratories, Columbus, Ohio, for the U.S. Department of Energy, Division of Solar Technology, Wind Systems Branch, Washington, D.C.

This biophysical impact assessment explores the environmental consequences of the then-emerging wind energy technology through field studies on a 100-kW turbine (two-bladed, horizontal-axis) located at the NASA Lewis Research Center's Plum Brook Station near Sandusky, Ohio. The authors tested theoretical predictions from an earlier study (Rogers et al. 1976) that birds or other airborne fauna (e.g., insects) risk collision with rotating turbine blades. Field studies emphasized the microclimate effect of the operating turbine and the potential effect on night-migrating birds. The microclimate field studies indicated a negligible effect to the area immediately downwind of the turbine. Radar studies revealed that the number of nocturnal migrants during peak migration periods for songbirds in the area averaged 5,380 birds/mile of front/hour. During four migratory seasons of searching for dead birds, two birds were found dead near the meteorological tower and one bird was found dead near the turbine. Scavenging studies indicated that about 5 percent of carcasses were removed by predators before researchers could find them. The authors concluded that this wind turbine was not a high risk to airborne fauna, including the most vulnerable night-migrating songbirds. Behavioral studies indicated that the birds will avoid the turbine if they see it. The authors predicted that if blade tips reach higher than 500 ft (equivalent to the minimum altitude of most nocturnal migration) or if turbines are sited in locations where birds fly closer to the ground, birds could be at greater collision risk during inclement weather at night.

150. Rogers, S.E., M.A Duffy, J.G. Jefferis, P.R. Sticksel, and D.A. Tolle. 1976. Evaluation of the potential environmental effects of wind energy conversion systems development. Final interim report. Prepared by Battelle Columbus Laboratories, Columbus, Ohio, for the National Science Foundation under contract with the Energy Research and Development Administration, Division of Solar Energy.

This is the first phase of an evaluation of the potential for environmental effects from the development of wind energy. The goals of this research include (1) conducting a literature review to identify potential environmental effects, (2) conducting a baseline climatological and biological survey at a future wind turbine site, and (3) developing a research program to evaluate and quantify any theoretically identified effects. A keyword bibliography of 600 selected publications is presented in this report. The potential for environmental effects from wind energy conversion systems was assessed based on the literature review. Topics reviewed and evaluated included the size and extent of the microclimate effect, its effect on adjacent plant and animal life, hazards to migratory birds, and the potential for collision of the rotating blades with birds. The authors state that the number of birds and/or insects that will collide with the blades is dependent on four factors: design solidity of the rotor (area swept by blade), the airfoil design, the number of organisms flying through the rotor area, and the behavior of the organisms. Given a particular set of conditions, the authors estimate the probability of a bird being struck by a blade. The potential for major bird kills was thought to be greatest where wind turbines are sited on isolated hills or coastlines where birds are flying at low altitudes relative to the ground. Overall, the authors conclude, the operation of wind energy conversion systems does not appear to involve any unusual environmental effects. For continuing studies see Rogers et al. 1977.

151. Royal Society for the Protection of Birds. 1994. Memorandum to the Welsh Affairs Committee Inquiry to wind energy. RSPB, The Lodge, Sandy, Bedfordshire.

This is a position paper which expresses the views of the RSPB on wind power in Wales. The RSPB presents a background of potential impacts of wind energy including habitat loss, disturbance, and mortality. The RSPB believes that environmental impacts can be reduced by sensitive siting and design. Recommendations include locating windfarms away from known bird migration routes or from regular flight paths, and away from areas of national or international importance for wildlife where it is likely to have an adverse impact. Windfarm proposals also should be accompanied by a comprehensive environmental statement. An environmental monitoring system should be designed for each project until the likely effects are better understood.

152. Sacramento Municipal Utility District. 1993. Draft environmental impact report for the SMUD—Solano wind project. Sacramento Municipal Utility District, Sacramento, California.

In accordance with the California Environmental Quality Act, an EIR was developed to identify and address the potentially significant environmental impacts associated with a proposed 50-MW wind turbine plant located in the Montezuma Hills area of southern Solano County. Potentially significant impacts addressed include visual, air quality, traffic, and biological impacts. The potential impact from the project on the resident bird population, particularly raptors, is addressed at length in the report. The potential for golden eagle collisions with wind turbines was considered a potentially significant impact of the proposed project. Project design elements to lessen potentially significant impacts on bird populations include continued monitoring of raptor abundance in the area and relocating turbines that have a high level of mortality.

153. Sacramento Municipal Utility District. 1993. Final environmental impact report for the SMUD—Solano wind project. Sacramento Municipal Utility District, Sacramento, California.

This is the FEIR for a proposed 50-MW wind turbine plant located in the Montezuma Hills area of southern Solano County, California. The FEIR summarizes potential impacts to land use; geology, hydrology, and soils; wildlife and vegetation; air quality; water quality; traffic and circulation; visual resources; and human health and safety. It also includes copies of all the comments received on the draft EIR and responds to each as appropriate. Specific impact information is contained in the draft.

154. Sadler, S., M. Walters, R. Adams, and D. Bain. 1984. Windy land owners' guide. Prepared by the Office of Appropriate Technology, Inc., under contract for the Oregon Department of Energy, Salem, Oregon.

This book was developed as a guide for landowners who are considering allowing a developer to use their land for a windfarm. The guidebook includes chapters on the history of the wind industry, putting together a viable project, choosing a developer, legal issues, determining payment, daily operations, the permitting process, and environmental impacts. Environmental considerations include topographic, soil, hydrology, microclimate, air quality, vegetation, wildlife, noise, electromagnetic interference, visual, land use, and socioeconomic impacts. The authors state that it is unlikely wind turbines may be a collision hazard to birds. Resident birds learn to avoid obstacles and most migrants fly above the highest turbines. The risk of bird collision can be reduced, state the authors, by not siting windfarms near bird sanctuaries, critical nesting grounds, marshes, and flight paths.

155. Seebold, J.C., ed. 1982. Proceedings of InterNoise 82, international conference on noise control engineering, May 17–19, 1982, San Francisco, California. Vols. I and II. Reference and summary taken from Hubbard and Shepherd 1988b.

This document contains extended abstracts of seven papers presented in the special session on wind turbine acoustics. Included are noise emission characteristics of large wind turbines, noise prediction methods, wind tunnel noise measurements, parametric evaluations, and acoustical criteria for siting and operations.

156. Sengupta, D.L. J.E. Ferris, and T.B.A. Senior. 1981. Assessment of electromagnetic interference effects of the Solano Windfarm. Final report. Prepared by Radiation Laboratory, University of Michigan, Ann Arbor, for Windfarms, Ltd., San Francisco, California.

This paper theoretically assesses the potential interference effects of 67 wind turbines in the proposed Solano Windfarm on five VOR systems within 20 mi of the windfarm; nine microwave links; two earth stations receiving signals from geo-stationary satellites; 11, 3, and 9 TV channels originating from San Francisco, San Jose, and Sacramento, respectively; and one cable TV head-end receiving the desired TV signals. A number of systems were excluded, including AM and FM broadcast reception. AM and FM broadcast reception outside the windfarm was not expected to be affected significantly; within the windfarm, reception within a few rotor diameters of individual turbines could experience some unacceptable interference effects. Because the choice of turbine type had not been made, the assessment was carried out for three candidate machines: MOD-2, MOD-5A, and WTS-4. The fundamental parameter required to estimate the electromagnetic interference effects of a turbine is the equivalent scattering area of its blade. Unacceptable or worst interference effects would be

caused by a windfarm composed of 67 MOD-2 turbines. "It is conceivable that with a judicious combination of MOD-2 and other machines (i.e., the windfarm not consisting of MOD-2 only) such effects may be lessened considerably for the large residential areas of Cordelia, Vallejo and Benicia. This would require more study."

157. Sengupta, D.L. and T.B.A. Senior. 1978. Electromagnetic interference to TV reception caused by windmills. Pages 407–408 in Proceedings of the third wind energy workshop, vol. 1, [workshop location unknown]. Coordinated for U.S. Department of Energy, Washington, D.C.

This paper investigates the interference to TV reception caused by the scattering of TV signals by windmills. The objectives of the study were to determine if such interference exists, to quantify the levels of interference, and to assess the impacts of these levels on the siting of windmills. In general, it was found that a windmill will produce video distortion of TV reception. The upper VHF channels were found to be particularly vulnerable. The maximum distance from the windmill at which adverse interference may occur is a function of the dimensions and orientation of the windmill blades as well as characteristics of the receiving antenna.

158. Sengupta, D.L. and T.B.A. Senior. 1978. Electromagnetic interference by wind turbine generators. Final report. Prepared by Radiation Laboratory, University of Michigan, Ann Arbor, for the U.S. Department of Energy, Division of Solar Technology, Wind Systems Branch, Washington, D.C.

Abstract by authors: The interference produced by horizontal-axis wind turbine generators (WTGs) on a number of electromagnetic systems has been identified and quantified. The interference to TV reception has been exhaustively studied, and a method has been developed to approximate the interference zone of a WTG. This can be used to estimate the effects on [*sic*] a WTG on TV reception and thereby establish minimal criteria for siting of such a machine. No significant interference to FM broadcast reception has been found. Studies of the interference to two specific air navigation systems (VOR and DVOR) indicate that no significant degradation in the performance of these systems should occur if the WTG is sited according to the standard guidelines established by the FAA. The performance of a repeating station of a typical microwave communication link system located in the vicinity of a WTG has been analyzed and guidelines have been developed which can aid in siting a WTG so that it produces minimum impact on the link system performance.

159. Sengupta, D.L. and T.B.A. Senior. 1979. Electromagnetic interference to television reception caused by horizontal axis windmills. Proceedings of the IEEE 67(8):1133–1142.

This paper addresses a study undertaken to determine whether windmills could interfere with TV reception, to quantify the levels of interference found, and to assess the impact of these levels on the siting of windmills. The study included an investigation of the impact of windmill-produced interference on the performance of broadcast FM receivers, aircraft navigation, and microwave link systems, but this paper addresses only the interference to TV reception. The most important conclusion is that the rotating blades of a windmill can produce pulse amplitude modulation of the total TV signal received. For an antenna located so that it picks up the specular or forward scattering off the blades, this extraneous modulation can distort the video portion of a TV signal reproduction in the vicinity of the windmill. The level of observed interference increases with frequency and is

therefore worst at the upper UHF frequencies. It decreases with increasing distance from a windmill, but in the most severe cases can still produce objectionable video distortion at distances up to a few km. No audio distortion was observed.

160. Sengupta, D.L. and T.B.A. Senior. 1981. Measurements of television interference produced by large horizontal axis wind turbines. Pages 151–157 in I.E. Vas, ed. Fifth biennial wind energy conference and workshop, Washington D.C. Sponsored by the Solar Energy Research Institute, Golden, Colorado.

This paper discusses the on-site measurements needed to estimate the television interference effects of large wind generators. The authors describe the necessary experimental setup, measurement techniques, and data reduction to estimate the effects. Typical results obtained from a large generator are included.

161. Senior, T.B.A. and D.L. Sengupta. 1978. Wind turbine generator siting and TV reception handbook. Tech. rep. no. 1. Prepared by Radiation Laboratory, University of Michigan, Ann Arbor, for the U.S. Department of Energy, Division of Solar Technology, Wind Systems Branch, Washington, D.C.

The rotating blades of a horizontal-axis wind turbine can distort the video portion of a TV signal and thereby interfere with TV reception in the vicinity of the turbine. The nature of this interference is discussed in this report and methods are described for calculating the approximate zone within which the interference can significantly affect TV reception. Information is given for predicting the interference zones for MOD machines for any given TV transmitter using graphical procedures.

162. Shepherd, K.P., F.W. Grosveld, and D.G. Stephens. 1983. Evaluation of human exposure to the noise from large wind turbine generators. Noise Control Engineering Journal 21(1):30–37.

The authors developed a procedure to evaluate human exposure to the noise from large wind turbine generators. Their evaluation was based on noise at the receiver location, either measured directly or inferred from a knowledge of the noise at the turbine site along with an estimate of the atmospheric propagation effects. The evaluation involves comparing turbine-generated noise and any noise-induced building vibration with human perception thresholds that have been developed for wind turbine noise. This paper summarizes the procedure, which may be of use in the design, siting, and assessment of wind turbine generator systems for community acceptability. A companion paper (Hubbard et al. 1983) describes in detail the generation and propagation of sound associated with large horizontal-axis wind turbines.

163. Shepherd, K.P. and H.H. Hubbard. 1986. Prediction of far field noise from wind energy farms. National Aeronautic and Space Administration, CR 177956, Langley Research Center, Hampton, Virginia. Reference and summary taken or adapted from Hubbard and Shepherd 1988b.

This paper includes a review of the basic physical factors involved in making predictions of wind turbine noise. The approach presented allows for differences in the machines, wind energy farm configurations, and propagation conditions. Sample calculations are presented to illustrate the sensitivity of the radiated noise to such variables as machine size, spacing and numbers, atmosphere variables such as relative humidity and temperature, and wind direction.

164. Shepherd, K.P. and H.H. Hubbard. 1989. Environmental noise characteristics of the MOD5-B (3.2 MW) wind turbine generator. National Aeronautic and Space Administration, Langley Research Center, Hampton, Virginia.

This study provides basic acoustic data for the MOD5-B machine and extends the previously available data base. The MOD5-B is a two-bladed (97.6 m diameter rotor) upwind machine that incorporates several advanced technology features such as variable rpm, trailing edge tabs, and vortex generators. Both narrow band and broad band acoustic data were obtained for a range of wind speeds, angles, and distances. Comparisons were made with other large machines and with predictions by available methods. The highest levels of noise occurred at the lower frequencies and generally decreased as the frequency increased. Low frequency rotational noise components were more intense than expected for an upwind turbine.

165. Shepherd, K.P., D.G. Stephens, and F.W. Grosveld. 1981. Development of wind turbine noise criteria. Pages 163–174 in I.E. Vas, ed. Fifth biennial wind energy conference and workshop, Washington D.C. Sponsored by the Solar Energy Research Institute, Golden, Colorado.

This paper describes the status of an ongoing test program to develop noise standards for wind turbine generators that minimize annoyance and that can be used in designing and siting future machines. The approach to the development of noise criteria and standards is described. Results established the threshold of detectability for impulsive noise associated with blade/tower-wake interactions and broad band noise associated with blade boundary layer/trailing edge interactions.

166. Solano County. 1985. Solano County wind turbine siting plan and EIR. Public hearing draft. Prepared by Wagstaff and Brady for Solano County Department of Environmental Management, Fairfield, California.

A specific plan was prepared for future use of the wind energy resource areas in Solano County, California, for purposes of regulating and guiding wind energy development within the County. This document includes the plan and an EIR on the plan. The EIR addresses likely generalized consequences of development under the plan, including impacts on or of land use, visual resources, biological resources, geotechnical conditions, hydrology, noise, air quality/meteorology, electromagnetic interference, and public safety. Each topic is discussed and measures to mitigate adverse effects are presented. Comments on the plan and EIR are presented in Solano County 1986.

167. Solano County. 1986. Solano County wind turbine siting plan and EIR. Final report. SCH 85012906. Prepared by the Solano County Environmental Management Department, Fairfield, California.

This document presents all verbal and written comments received on the DEIR and responds to each as appropriate. Together with the DEIR, this report constitutes the FEIR. Comments on the DEIR covered visual or scenic resources, noise, siting requirements, recreational and residential use, biological resources, and other areas of concern.

168. Solar Energy Research Institute. 1979. Wind energy: legal issues and institutional barriers. Prepared by Solar Energy Research Institute, Golden, Colorado, for the U.S. Department of Energy.

Potential obstacles to commercial development of wind development include various institutional and legal barriers, such as conflicts with existing zoning and other land-use planning schemes, guaranteeing access to the wind, possible tort and environmental law issues, and creating financial incentives. This paper discusses the implications of each of these issues and suggests solutions where practicable. Environmental concerns discussed include microwave interference, climate modification, noise, aesthetics, and bird collisions. The analysis of bird kills relies heavily on the Rogers et al. (1977) study. According to the report, the possibility of bird kills presents a legal problem only when a rare, endangered, or otherwise regulated species is involved. Such conflicts can usually be avoided by appropriate siting decisions, it states.

169. Sørensen, B. 1980. Environmental impact of wind energy utilization. Energy series no. 1. Roskilde Universitetscenter, Roskilde, Denmark.

This paper presents a discussion of the various impacts potentially associated with wind energy development and operation. Topics addressed include human safety and health hazards, noise impact, interference with telecommunications, environmental impact on ecosystem, visual impacts, effects on the microclimate, and global climatic influence. The author theorizes on the potential for impact on birds based on previous studies. For migrating birds the potential for impact should be low, since they usually fly at altitudes above wind turbines. Impacts would depend on the percentage of birds flying at lower altitudes and may increase with the presence of bird rest areas near the turbines. Based on a past study, Sørensen states it is likely that nonrotating wind turbines may present a higher risk than rotating ones, because the birds should sense the motion of the moving blades and take evasive action. The author also postulates that large turbines with slow-moving blades may present less hazard than small turbines with faster-moving blades.

170. Spencer, R.H. 1981. Noise generation of upwind rotor wind turbine generators. Pages 419–423 in R.W. Thresher, ed. Wind turbine dynamics. Proceedings of a workshop sponsored by the U.S. Department of Energy, Division of Wind Energy Systems, and NASA Lewis Research Center, held in Cleveland, Ohio. NASA Conference Publication 2185, DOE Publication CONF-810226.

This paper discusses noise associated with wind turbines that have rotors upwind of the support structure. It also discusses methods for sound level prediction and presents estimated noise levels for the Boeing MOD-2 wind turbine operating in both the upwind and downwind configurations. The predominant source of noise for the downwind rotor configuration of the MOD-1 turbine appeared to be fluctuating airloads arising from interaction of the rotor and the wake trailed by the tower support structure. Upwind rotor configurations, such as the MOD-2 turbine, did not experience the same magnitude of airload fluctuations as the blade passed upstream of the tower, and other noise sources dominated. Results indicated that upwind rotor configurations may be advantageous from an acoustical standpoint. Predictions for the MOD-2 turbine indicated that the noise signature would be of a broad band nature. Although noise measurements had not been made on the MOD-2 turbine to the date of the publication, observers indicated that the predominant noise is a swishing sound characteristic of a broad band noise source. Noise levels between 60 and 65 dBA were predicted at a distance of 200 ft, similar to those near a freeway with moderate traffic at an equivalent distance.

The existing empirical broad band methodology lacks a rigorous analytical understanding that must be developed from an adequate data base to accurately quantify broad band, nonperiodic noise associated with the MOD-2 turbine.

171. Stephens, D.G., K.P. Shepherd, and F. Grosveld. 1981. Wind turbine acoustic standards. Pages 431–434 in R.W. Thresher, ed. Wind turbine dynamics. Proceedings of a workshop sponsored by the U.S. Department of Energy, Division of Wind Energy Systems, and NASA Lewis Research Center, held in Cleveland, Ohio. NASA Conference Publication 2185, DOE Publication CONF-810226.

The development of wind turbines that are acoustically acceptable to the community requires an understanding of the human perception of and response to wind turbine noise and any noise-induced building vibrations resulting from turbine operation. This paper discusses a program to develop noise standards for wind turbines, a program that minimizes annoyance and that can be used in design specifications. The approach consisted of presenting wind turbine noise stimuli to test subjects in a laboratory listening chamber. The responses of subjects were recorded for a range of stimuli that encompassed the design, operating conditions, and ambient noise levels of current and future installations. Results to date established the threshold of detectability for a range of impulsive stimuli of the type associated with blade/tower-wake interactions. The thrust of the program was to develop the psycho-physical functions relating human response to each of the wind turbine noise components, such as "thumping" and "swishing." The general use of these psycho-physical relationships was intended to guide the designer/operator in pinpointing the exact frequency components and, hence, source mechanisms that cause problems with wind turbine operations.

172. Stephens, D.G., K.P. Shepherd, H.H. Hubbard, and F.W. Grosveld. 1982. Guide to the evaluation of human exposure to noise from large wind turbines. National Aeronautic and Space Administration, TM 83288. Reference and summary taken or adapted from Hubbard and Shepherd 1988b.

This document is intended for use in designing and siting future large wind turbine systems as well as for assessing the noise environment of existing wind turbine systems. Guidance for evaluating human exposure to wind turbine noise is provided and includes consideration of the source characteristics, propagation to the receiver location, and exposure of the receiver to the noise. The criteria for evaluation of human exposure are based on comparisons of the noise at the receiver location with the human perception thresholds for wind turbine noise and noise-induced building vibrations in the presence of background noise.

173. Still, D., B. Little, S. Lawrence, and H. Carver. 1994. The birds of Blyth Harbour. [editor unknown]. Proceedings of the British Wind Energy Association No. 16. No other reference information available.

This is a summary report of an on-going study to evaluate the effects of a windfarm located in Blyth Harbour, England. Nine Windmaster turbines were erected in 1992 in this industrial harbor setting which supports over 108 varieties of birds with a relatively high density of marine birds. The site is now a Site of Special Scientific Interest due to the presence of a significant population of purple sandpipers. A program to monitor flight behavior, bird disturbance, and mortality included collecting data before, during, and after construction. Experiments to measure detection efficiency and scavenger loss were also conducted. In spite of the large winter bird population in close proximity to the windfarm (> 1,000 bird movements/day) there have been only 19 windfarm collision victims

over a 15-month period. This represents less than four percent of the background mortality (bird deaths from natural and other unnatural causes). Both the eider and greater black-backed gulls appeared to be represented as windfarm casualties disproportionately more often than based on background mortality and abundance near the windfarm. The susceptibility of these birds is thought to be due to a combination of their behavior within the harbor basin and their flight characteristics. The occurrence of collisions appears to be associated with conditions of poor weather and visibility. Based on extrapolated annual mortality rates, the level of mortality was not thought to have a significant adverse impact on the population of these species.

174. Strojan, C.L., K. Lawrence, and D. O'Donnell. 1980. A field study of the aesthetics of small wind machines: a preliminary report. Prepared by Solar Energy Research Institute, Golden, Colorado, for the U.S. Department of Energy, under Task No. 3531.39.

A field study was conducted at the Rocky Flats Small Wind Systems Test Center to determine whether aesthetic preferences exist for particular designs of small wind machines, and to gather data on the importance of aesthetics relative to other wind system issues. Participants in the study were asked to answer several general questions and to rate the visual appearance of various working parts (rotor and nacelle), towers, and complete machines. Working parts included vertical- and horizontal-axis designs (both upwind and downwind); towers included wood, concrete, and steel columns, and various truss designs. Results indicated definite preferences for particular designs, with downwind horizontal-axis working parts and columnar towers receiving the highest ratings. These results, however, were confounded by other factors which are discussed. Moreover, results were based on responses from an admittedly small (139), nonrandom sample of individuals.

175. Thayer, R.L. and C.M. Freeman. 1987. Altamont: public perceptions of a wind energy landscape. Prepared by Center for Design Research, Department of Environmental Design, University of California-Davis, Davis.

This report presents the results of research conducted to examine public response to the Altamont Wind Energy Development. A questionnaire accompanied by representative photographs of the area was sent to six hundred subjects, half of whom lived within 10 mi of Altamont. The other half lived approximately 50 mi away in a similar landscape with no wind turbines. Results showed that respondents nearly universally regarded Altamont as a highly conspicuous, human-made landscape. Beyond that one point of agreement, respondents displayed a range of attitudinal responses. External, symbolic attributes such as safe and natural energy production, appropriateness, progress, and safety figured highly in attitudes of those favoring the development, while basic visual characteristics such as clutter and conspicuousness contributed to negative attitudes. Those who lived closer to Altamont and those more familiar with the area liked it less than those less familiar with the area and those living farther away. Females, older persons, and subjects with less education held more positive attitudes, while males, younger subjects, and subjects with more education held less positive attitudes. Advantages of wind developments most often chosen as important included lack of pollution, safety, long-term availability of wind, and wind as a good alternative to other energy sources. The disadvantage most often chosen was the day-to-day unreliability of the wind. Other factors such as visual impacts and turbine color, arrangement, size, and number were also considered. Perceived reliability equaled or exceeded siting, design, and scenic character in causing negative attitudes, i.e., when the wind is blowing and large numbers of turbines are not operating, the public is led to a perception of technological or managerial incompetence or tax fraud.

176. Thayer, R.L. Jr. and H.A. Hansen. 1989. Consumer attitude and choice in local energy development. Prepared by Center for Design Research, Department of Environmental Design, University of California-Davis, Davis.

This report summarizes results of a questionnaire mailed to 1,000 residents of Solano County, California. The questionnaire was designed to assess the nature and strength of local resident opposition to two local wind energy developments, one already established and one proposed. 188 of the 238 questionnaires returned were used in the final analysis. The authors conclude that "[s]iting of new power plants necessitates compromise on the part of consumers, who, for the most part, want the power but neither the responsibility for, nor the consequences of, producing it. In return for accepting a power plant close to their homes, consumers are looking for more tangible evidence of payoff to them personally, yet the current nature of the electricity delivery systems offers no such personalized or localized advantages." Information now exists about which energy sources are preferred by the public and about some of the spatial or geographic variables involved in public preferences for siting new facilities. To personalize the advantages of one energy supply condition over another, consumers must perceive and comprehend the tradeoffs between alternatives and must have some positive incentives before they will accept socially desirable alternatives. Such positive feedback could consist of energy prices that better represent the true costs of supply options, more local decision-making power and control, more tangible benefits to the affected public, or more visual feedback concerning the environmental impacts associated with the consumers' own energy demands.

177. Thayer, R.L., Jr. and H.A. Hansen. 1991. Windfarm siting conflicts in California: implications for energy policy. Prepared by Center for Design Research, University of California-Davis, Davis.

This report summarizes and examines the results of a mail survey administered to a six-county random sample of 3,000 California residents and focused samples of county planners, supervisors, wind energy enthusiasts, and utility representatives. It also examines the public records involving three major windfarm proposals, two of which were defeated when homeowners and housing development interests actively opposed the windfarm developments. Results indicated that visibility from residential and highway areas, public fears of turbine abandonment, concerns over lack of localized benefits such as increased jobs or reduced utility rates, and general competition between housing developers and windfarm developers on rural lands loom as the major obstacles to windfarm siting. Results further indicate that county residents are more likely to accept windfarms closer to their places of residence if they: (1) are male, (2) are not wealthy, (3) are politically liberal, (4) feel more personally responsible for the environmental impacts of their own energy use, (5) consider their home region to be of higher scenic quality, (6) consider their home region to have a higher quality of life. The paper concludes that competition from housing development, potential of raptor deaths, and turbine nonoperation and abandonment are the major sources of windfarm siting conflict. Recommendations are made regarding land use controls and placement distances for future windfarm developments.

178. Tomalin, E.C.E. 1992. Planning and consultation of two large windfarm sites in Mid-Wales. Pages 15–19 in B.R. Clayton, ed. Wind energy conversion proceedings of the 1992 fourteenth British Wind Energy Association wind energy conference. Mechanical Engineering Pub. Limited, London.

This paper describes some aspects of the process of applying for planning permission for two large windfarms in Mid-Wales, which would together comprise the largest windfarm in Europe. A summary of the issues discussed in the EA is presented, including visual, noise, ecology, and environmental benefits. The conclusion was that if wind generators are carefully sited and installed, the resulting "impacts on wildlife should not be too great."

179. Traci, R.M., G.T. Phillips, P.C. Patnaik, and B.E. Freeman. 1977. Development of a wind energy site selection methodology. Final report, May 3, 1976–June 3, 1977. Prepared by Science Applications International Corporation, La Jolla, California, for the U.S. Department of Energy, RLO/2440-11.

This report summarizes progress on the development of a "New Wind Energy Site Selection Methodology" achieved during the second year of a three-year program. The approach used mathematical models of meso- and micro-meteorology over complex terrain to supplement conventional siting studies to achieve greater accuracy and cost-effectiveness. The models used climatological data from meteorological stations where weather records were available and predicted climatology of sites where actual data were unavailable. These forecasts were subsequently analyzed to predict site characteristics and to aid in the design of supplemental meteorological measurements at promising sites. Details of formulation of the methodology, collection and analyses of data, and development and initial verification of models are summarized in the paper, as are recent numerical and physical modelling improvements. A preliminary application of the methods and models is applied to a wind energy survey of the Tehachapi Mountains.

180. U.S. Department of Energy. 1979. Environmental assessment: installation and field testing of a large experimental wind turbine generator system near Kahuku Point on the island of Oahu, Hawaii. USDOE, Wind Systems Branch, Washington, D.C.

This EA evaluates the potential consequences of installing a MOD-OA wind turbine for a two-year field test period on the island of Oahu, Hawaii. The MOD-OA is a 200-kW, two-bladed machine with a rotor diameter of 125 ft and total height of 165 ft. The effects of site preparation and construction activities on transportation, local economy, aesthetics, and animal life are assessed. The potential for collision hazard to birds also is discussed. The assessment predicts that the primary hazard will be to nocturnal migrants flying below their normal cruising altitude due to storm or overcast conditions or landing near the site to feed or rest. Although the possibility of bird kills at the turbine could not be ruled out, the risk of this occurrence was predicted to be similar to that posed by other nearby tall structures.

181. U.S. Department of Energy. 1979. Environmental assessment—eighteen prospective sites for MOD-2 2500-kW wind turbine generator systems. Supplement, the Goodnoe Hills, Washington State installation site. USDOE, Wind Systems Branch, Washington, D.C.

The findings in this report were used by the USDOE to choose one of eighteen prospective wind sites for installation and field testing of three MOD-2 turbines. The majority of the environmental information included in the assessment came from project proposers. Potential environmental impacts

of the construction and operation of the three turbines are discussed for each of the eighteen proposed sites. The DOE analysis has shown that there is the potential for bird kills by collision with rotating blades. Primary hazards relate to low-flying migrants, particularly during low visibility conditions. However, no significant bird kills have been noted at other MOD wind turbine sites in Plumbrook, Ohio; Block Island, Rhode Island; and Puerto Rico. Based on the competitive selection process, the Goodnoe Hills site was chosen. The Goodnoe supplement of this report presents the potential environmental impacts specific to the Goodnoe site, which is located in the south central part of the state of Washington (see Bonneville Power Administration 1979).

182. U.S. Department of Energy. 1980. A preliminary analysis of the audible noise of constant-speed, horizontal axis wind-turbine generators. DOE/EV-0089, UC-11,60. USDOE, Washington, D.C.

An analytical procedure was developed for calculating certain aerodynamic sound levels produced by large, horizontal-axis wind turbine generators. It was concluded that the infrasonic component of turbine sound is at a very low level compared with existing limits of acceptability for human health. However, it could be a source of annoyance to people inside lightweight structures such as residences at the wind turbine site. The authors emphasize the preliminary and conservative nature of this work. They suggest that further work would be advisable in order to minimize the risk of noise restrictions that might limit the widespread application of wind energy technology.

183. U.S. Windpower, Inc. 1989. Application for windfarm development. Submitted to Solano County Department of Environmental Management, Fairfield, California. U.S. Windpower, Inc., is now known as Kenetech Windpower, Inc.

This report contains information on environmental setting and site constraints for a proposed windfarm development in Solano County. It includes a project description as well as potential environmental impacts and proposed mitigation measures. Potential impacts addressed include erosion and storm runoff, the potential for ground shaking and earthquake-induced land sliding, impacts to visibility, increased noise levels, loss of agricultural land, electromagnetic interference, equipment and public safety, and impacts to cultural and biological resources. Among other things, appendixes include greater detail on geotechnical considerations, impacts to residences, pole line design for raptor protection, visual impacts, noise impacts, avian monitoring studies, and botanical and archaeological inventories.

184. U.S. Windpower, Inc. 1990. Wildlife response and reporting program. U.S. Windpower [now Kenetech Windpower, Inc.], San Francisco, California.

This manual outlines the reporting and response procedures to be initiated when an injured or dead bird (or other species of wildlife) is found within the WRA. The purpose of this manual is to standardize the actions taken by Company personnel in response to injury and mortality of wildlife.

185. Ultrasystems, Inc. 1985. Potential effects of the proposed Fayette Manufacturing Corporation Bald Mountain wind energy project on the California condor: preliminary draft report. Submitted by Ultrasystems, Inc., Environmental Systems Division, Irvine, California, to Fayette Manufacturing Corporation, Tracy, California. Reference and summary taken or adapted from California Energy Commission 1995.

Wind turbine collision is the principal issue concerning the California condor. "The loss of a single individual is considered significant by persons associated with the recovery effort" because of the bird's critical status. The report presents a table of persons contacted regarding windfarm development effects on raptors and other animals.

186. Ultrasystems, Inc. 1985. Draft environmental impact report—WindAmerica's Sierra Pilona WindRanch. Conditional use permit 2564. Prepared by Ultrasystems, Inc., Irvine, California, for the County of Los Angeles.

This EIR encompasses the proposed development of up to eight hundred 100-kW wind turbines on a site of approximately 3,800 acres located near the City of Palmdale in northern Los Angeles County. The main issues addressed include potential impacts to the California condor, flood and erosion control, noise, and scenic quality. Avian mortality arising from collisions was considered possible, but was expected to occur infrequently and was not expected to be of biological significance to most species. The project's potential to impact the condor population was considered remote, based on the fact that the site was not near any condor flyways and no sightings have occurred in or near the site. All other impacts were considered to be insignificant.

187. Vauk, G. 1990. Biologisch-ökologische begleituntersuchungen zum bau und betrieb von windkraftlanlagen (Biological and ecological study of the effects of construction and operation of wind power sites; English summary). 3. Jahrgang/Sonderheft, Endbericht. Norddeutsche Naturschutzakademie, Germany.

From 1989 to 1990, investigations were conducted into the effects of wind energy stations on birds at eleven sites in Germany. The studies gathered data on breeding bird populations, changes in bird behavior and flight, and bird deaths. Results indicated that there were behavioral changes in migrant birds and the number of birds resting in some of the windmill areas was considerably lower than in other similar places. However, there was no indication of any effect on breeding birds. Thirty-two individuals of 15 species were recorded as casualties. Comparative investigations at sites of other anthropogenic hazards (e.g., radio towers) were contrasted with mortality rates at wind energy sites.

188. Wells, R.J. 1981. GE MOD-1 noise study. Pages 389—395 in R.W. Thresher, ed. Wind turbine dynamics. Proceedings of a workshop sponsored by the U.S. Department of Energy, Division of Wind Energy Systems, and NASA Lewis Research Center, held in Cleveland, Ohio. NASA Conference Publication 2185, DOE Publication CONF-810226.

This paper presents results of noise studies initiated to study the problem of adverse community reaction to the noise of the General Electric MOD-1 wind turbine generator in North Carolina. Because early data were confusing from the standpoint of variability, especially in the far field, a simple mathematical model was developed that could correlate the data. Wind turbine noise is characteristically different from that of any other machine. All noise of interest is confined to low frequencies. For these reasons, commonly-used acoustic measures such as dB(A) and PNL (perceived

noise level) were recognized to be inapplicable, so a suitable simple acoustic measure was also of concern. The results of these studies indicated that for a given type of wind turbine design, the mathematical model concept presented should provide a useful tool for estimating wind turbine noise. An acoustic measure consisting of the total sound level within the frequency range from 20 to 50 Hz seemed to be suitable for correlating wind turbine noise with possible complaints. The use of the 31.5-octave band level is believed to be satisfactory as a rough approximation to this measure. The brief statistical study indicates that there are occasions when atmospherical focusing is sufficient to increase MOD-1 sound levels to more than 25 dB higher than would be expected with simple spherical divergence.

189. Wilshire, H. and D. Prose. 1987. Wind energy development in California, USA. Environmental Management 11(1):13–20.

With a 1976-legislated goal to generate 10 percent of California's electricity with wind power by the year 2000, and generous state and federal tax incentives, windfarms have been developed rapidly in California. Wind power is being promoted as environmentally benign. Benefits of wind power include relatively inexpensive construction, low operation costs, and a substantial net yield of energy, with no water consumed and no toxic chemicals or highly toxic wastes produced. The authors conclude, however, that realization of the legislated goal will cause degradation of substantial amounts of scenic lands, could increase air and water pollution from erosion, could degrade habitat for domestic and wild animals, could damage archaeological sites, and will result in only a modest offset of oil consumption at current rates. The paper details potential and actual impacts associated with construction and operation of windfarms, as well as the potential for saving oil. At 1984 production rates, 600,000 turbines occupying more than 685,000 ha would be required to supply 10 percent of the state's electricity.

190. Winkelman, J.E. 1985a. Vogelhinder door middlegrote windturbines—ver vlieggedrag, slachtoffers en verstoring (Bird impact by middle-sized wind turbines—on flight behavior, victims, and disturbance; English summary). Limosa 58:117–121.

In the fall and winter of 1983–1984, a study was conducted on the possible danger to birds of medium-sized wind turbines (tower height 10–30 m) situated on six small windfarms located along or near the Dutch coast. The main points addressed by the study were the flight behavior of birds approaching turbines in daylight, the number of birds killed at night, and the possible loss of breeding and feeding habitat around turbine sites. Diurnal migrants seemed to respond more to operating turbines than local birds. An average of 13 percent of migrating flocks and five percent of local flights showed a change in flight behavior that could be attributed to the turbines. The results suggest that local birds habituate to wind turbines. Within 12 species groups during diurnal migration, the greatest response to operating turbines was shown in ducks and geese. Of the diurnal migrants, three percent of the flocks came within reach of the rotor and one percent showed a panic reaction. At present sites, the disturbing effect of turbines on breeding and feeding habitat of birds has been negligible. No collisions with turbines were recorded. However, there were no data on carcass removal by scavengers and sites are situated in areas of low bird life. The study concluded that the chance of collisions of birds with medium-sized turbines in daylight and in weather with good visibility is almost zero. The author advised caution that the study does not indicate the danger of collisions at night or in poor visibility, by large groups of turbines, and by turbines at sites in the open field.

191. Winkelman, J.E. 1985b. Impact of medium-sized wind turbines on birds: a survey on flight behavior, victims, and disturbance. English summary. Netherlands Journal of Agricultural Science 33:75–78.

This is an English synopsis of the original study conducted by J.E. Winkelman (see Winkelman 1985a). This paper presents more detailed information in English than the English summary from the original paper. Pertinent data are presented in Winkelman 1985a.

192. Winkelman, J.E. 1987. Vogels en vindturbines (Birds and windturbines; English translation). Limosa 60(3):153–154.

This paper is a brief summary of the on-going work being conducted by the Research Institute for Nature Management in The Netherlands. Due to concerns over wind turbine developments in areas rich in birds, the Institute initiated three studies to determine how birds are being affected by wind turbines. Emphasis was placed on shorebirds and waterbirds. At the time this paper was published, two of the studies had only collected pre-construction and during-construction data (preliminary and final results are presented in Winkelman 1989, Winkelman 1990a–c, and Winkelman 1992a–d), while the third study, which only included post-construction data, was already completed (see Winkelman 1985a, 1985b). The studies focused on several concerns including collision with turbines, loss and/or fragmentation of territory by sound, influence on the general migration patterns, effect on flight behavior, and general disturbance to birds. Specialized night vision equipment was used in one of the studies to determine abundance and behavior and height of birds flying at night or under poor visibility. The paper also mentions several other studies on the effects of wind turbines on birds being conducted in other European countries.

193. Winkelman, J.E. 1989. Vogels en het windpark nabij Urk (NOP): aanvaringsslachtoffers en verstoring van pleisterende eenden, banzen en zwanen (Birds at a windpark near Urk: bird collision victims and disturbance of wintering ducks, geese and swans; English summary). Rijksinstituut voor Natuurbeheer, Arnhem. RIN-Rapport 89/15.

A study was conducted from 1987 to 1989 on the possible impact of a wind park on birds. The wind park consisted of 25 medium-sized wind turbines (tower height 30 m) extending 3 km along a dike in The Netherlands. The study focused on the number of birds that collided with the wind turbines and the effects of disturbance to wintering waterfowl. Of the 63 dead birds found, 17 were certainly or very probably killed by wind turbines. The estimated number of bird deaths from collisions incorporated scavenger and observer errors. On average, 0.5 to 1.2 birds collided per day in the entire wind park. For the entire study period, the estimated number of bird deaths in the wind park was on average 150 to several hundred. Two to three times more birds collided in the fall than in the winter or spring. More dead birds were found after bad flight conditions and/or poor visibility than during good flight and visibility conditions. Some species were found in significantly smaller numbers within the wind park area compared to control areas. Most disturbance to waterfowl was found within 300 m of the wind park.

194. Winkelman, J.E. 1990a. Vogelslachtoffers in de Sep-proefwindcentrale te Oosterbierum (Fr.) tijdens bouwfase en half-operationele situaties (1986–1989) (Bird collision victims in the experimental wind park near Oosterbierum [Fr.] during building and partly operative situations [1986–1989]; English summary). Rijksinstituut voor Natuurbeheer, Arnhem. RIN-Rapport 90/2.

The paper is part of a series of preliminary reports presenting the results of a study to determine the impact of an experimental wind park on birds. The wind park consisted of 18 medium-sized (35 m tower height) turbines located on 55 ha in the northern part of The Netherlands, 3–4 km inland from the sea. This paper deals with bird collisions with wind turbines and meteorological towers. Other aspects of the study such as disturbance of breeding, resting, and migrating birds, and behavior of birds approaching the wind turbines during day and night are discussed in two other preliminary reports (Winkelman 1990b, 1990c). At the time of these publications, data were collected only from before and during the building phase, and when the wind park was partly operational. During the study periods (spring 1986–1989 and fall 1986–1988), 35 dead birds (14 species) were found, of which 10 were very probably or certainly killed as a result of collision with a wind turbine. Most dead birds were found during the first fall that the wind park was partly operative. The total number of bird collision victims was estimated using a formula that incorporated scavenger and search errors. For the entire study period, the estimated number of birds that were certainly or very probably killed by wind turbines averaged 107. Mean numbers of estimated victims per wind turbine agree with the literature, with the exception of a fully operative wind park near Urk (Winkelman 1989), where two to four times more collisions were reported.

195. Winkelman, J.E. 1990b. Verstoring van vogels door de Sep-proefwindcentrale te Oosterbierum (Fr.) tijdens bouwfase en half-operationele situaties (1986–1989) (Disturbance of birds by the experimental wind park near Oosterbierum [Fr.] during building and partly operative situations [1984–1989]; English summary). Rijksinstituut voor Natuurbeheer, Arnhem. RIN-Rapport 90/9.

This paper is part of a series of preliminary reports on the effects of an experimental wind park on birds (Winkelman 1990a, 1990c). The subject of this report was the disturbance effects of the wind park on breeding, resting, and migrating birds. Primary species under investigation were shorebirds, waterbirds, and some passerines. Disturbance was assessed by comparing data before and after the construction in a control area and an impact area. There was no indication of disturbing effects on *breeding* birds. Some species of *staging* birds had significantly smaller numbers in the wind park compared to control areas. Most disturbing effects were found up to 250 to 500 m, and depended on species, time of day and year, and operation of wind turbines.

196. Winkelman, J.E. 1990c. Nachtelijke aanvaringskansen voor vogels in de Sep-proefwindcentrale te Oosterbierum (Fr.) (Nocturnal collision risks for and behavior of birds approaching a rotor in operation in the experimental wind park near Oosterbierum, Friesland, The Netherlands; English summary). Rijksinstituut voor Natuurbeheer, Arnhem. RIN-Rapport 90/17.

This is part of a series of preliminary reports on the effects of an experimental wind park on birds (Winkelman 1990a, 1990b). The report deals with the behavior of birds approaching wind turbines during day and night conditions. Specific questions include how many birds pass the turbines at tower height and what proportion of these birds have collided with the turbines. Specialized equipment (search approach radar, passive image intensifiers in combination with infrared lights, and

thermal image intensifiers) were used to determine abundance, behavior, and height of birds flying at night or during poor visibility. Ninety-two percent of birds approached the rotor without any hesitation during the day compared to 43 percent during the night. Most of them did so with strong wing beats or a fluttering flight, particularly when there were head winds compared to tail winds. During high-use nights, 56–70 percent of the birds passed at rotor height (21–50 m). More birds collided with the rotor at night and twilight than during the day. Of 51 birds recorded trying to cross the rotor area during twilight and total darkness, fourteen (28%) collided. During daylight, only one of fourteen birds (7%) collided. Bird accidents were not always real collisions. In 43 percent (6 of 14) of the nocturnal accidents observed, the birds were swept down through the wake behind the moving rotors during tailwinds. Half of these birds recovered soon after these "collisions." The report also compares flight heights of birds during day and night conditions. Based on the number of birds passing at rotor height and the proportion of birds colliding, an estimated one out of 76 birds passing the towers at night was expected to collide mortally with the turbines when the park was fully operational.

197. Winkelman, J.E. 1990d. Impact of the wind park near Urk, Netherlands, on birds: bird collision victims and disturbance of wintering waterfowl. ACTA XX Congressus Internationalis Ornithologici, Christchurch, New Zealand. 2–9 December 1990. Abstract only.

This abstract summarizes Winkelman 1989 (annotated above). Data on mortality, however, are presented by season. Winkelman found two to three times more collisions in the fall than in the spring and winter, probably due to the passage of migrating birds at that season. On average 0.9–3.4 birds/day collided in autumn and 0.5–1.0 in winter/spring.

198. Winkelman, J.E. 1992a. De invloed van de Sep-proefwindcentrale te Oosterbierum (Fr.) op vogels, 1. Aanvaringsslachtoffers (The impact of the Sep Wind Park near Oosterbierum [Fr.], The Netherlands, on birds, 1. Collision victims; English summary). Rijksinstituut voor Natuurbeheer, Arnhem. RIN-Rapport 92/2.

This paper is the first of a four-part series of reports presenting the results of a continuing study to determine the impact of an experimental wind park on birds. The preliminary results of this study were presented under Winkelman (1990a, 1990b, 1990c) above. This first report addresses the results of the searches for birds that died or were injured by collision with turbines and meteorological towers from 1986 to 1991. Other aspects of the study such as nocturnal collision risks, flight behavior, and disturbance are discussed in the other reports (Winkelman 1992b, 1992c, 1992d). Seventy-six injured or dead birds were found, representing 25 species. Of these, 36 percent were certainly or very probably killed as a result of collision with turbines, while 17 percent were injured. Fewer birds probably collided with the middle row of wind turbines. Consequently, Winkelman suggests that a cluster formation of turbines may cause fewer impacts than a line formation. All birds that were thought to be killed by turbines were found in the area behind the rotor or on the right front side of it. Most victims were found after nights with both poor flight and sight conditions. The total number of bird deaths from collisions was estimated incorporating scavenger and observer errors and was 72 in the fall of 1990 and 110 in the spring of 1991. Most of the victims were killed during the period when the wind park was fully operational. On average less than 0.01 percent of the birds passing the wind park during nocturnal or diurnal migration collided with an obstacle in the wind park. Lighting of wind turbines is believed to be harmful rather than beneficial, particularly when weather and visibility are bad.

199. Winkelman, J.E. 1992b. De invloed van de Sep-proefwindcentrale te Oosterbierum (Fr.) op vogels, 2. Nachtelijke aanvaringskansen (The impact of the Sep Wind Park near Oosterbierum [Fr.], The Netherlands, on birds, 2. Nocturnal collision risks; English summary). Rijksinstituut voor Natuurbeheer, Arnhem. RIN-Rapport 92/3.

This is the second part of a series of reports on the effects of an experimental wind park on birds (Winkelman 1992a, 1992c, 1992d). This report deals with the nocturnal collision risk and is almost identical to Winkelman's earlier (1990c) report. No additional data are presented. However, the estimate of the number of birds expected to collide with turbines was higher in this report than in the previous paper for the same time period. This paper estimated that one out of 40 birds (2.5%) passing at rotor height during the night were expected to collide mortally with wind turbines in the fully operational park. Winkelman also estimates that of all birds passing the wind system at night, an average of 1.1 percent would die due to collision.

200. Winkelman, J.E. 1992c. De invloed van de Sep-proefwindcentrale te Oosterbierum (Fr.) op vogels, 3. Aanvlieggedrag overdag (The impact of the Sep Wind Park Near Oosterbierum [Fr.], The Netherlands, on birds, 3. Flight behavior during daylight; English summary). Rijksinstituut voor Natuurbeheer, Arnhem. RIN-Rapport 92/4.

This is the third part of a series of reports on the effects of an experimental wind park on birds (see Winkelman 1992a, 1992b, 1992d). This report deals with the behavior of birds approaching the wind turbines during both the day and night. Reactions of birds to the turbines varied with species, whether the turbines were in operation, wind conditions, distance and height from turbines, and configuration and density of turbines. Significantly more reactions were recorded when the wind park was fully operational than when it was not. Large birds showed more reaction to operating turbines when there was a tailwind, compared to most smaller birds which showed more reaction in headwinds. Large birds also reacted more when wind speed was high. Some species reacted more often when their flight heights were at rotor height. The majority of reactions took place within 100 m of the turbines. Ducks and geese reacted at the greatest distances, small songbirds at the smallest. Most birds reacted less when approaching parallel to the row of turbines than when approaching the wind park at an angle. Specific types of behavioral reactions were noted, including shifts in flight path, height, speed, and direction. The most common reaction was a shift in the flight path in the horizontal plane. Only two percent of the birds gained height to cross the wind park above the turbines. Large birds tended to avoid the wind park more often than small birds. Habituation of local birds was expressed by a larger proportion of gradual and calm shifts in flight path and a smaller proportion of accelerated wing beats compared to migrating birds.

The report discusses the turbine arrangement having the lowest potential for disturbance. To wintering and feeding birds, and maybe breeding as well, the best option is a dense cluster of wind turbines. For migrating birds, a line formation parallel to the main migration direction or an open cluster would be best.

201. Winkelman, J.E. 1992d. De invloed van de Sep-proefwindcentrale te Oosterbierum (Fr.) op vogels, 4. Verstoring (The impact of the Sep Wind Park near Oosterbierum [Fr.], The Netherlands, on birds, 4. Disturbance; English summary). Rijksinstituut voor Natuurbeheer, Arnhem. RIN-Rapport 92/5.

This is the forth part of a series of reports on the effects of an experimental wind park on birds (Winkelman 1992a, 1992b, 1992c). This report deals with the disturbance to breeding, feeding or resting, and migrating birds. The degree of disturbance varied depending on the species, season,

operation of the park, density of the turbines, and whether the birds were breeding, feeding and resting, or migrating. The study showed that the wind park did not significantly influence breeding bird populations. Because of some possible negative trends, however, they recommended that the study be continued. Significantly fewer feeding and resting birds were found in the wind park area after construction. Decreases in bird numbers within the wind park area up to 60–95 percent were common. The fully operational wind park was measured to have a disturbance effect for feeding and resting birds of up to 500 m beyond the wind park, but mostly limited to a 100–250 m distance. Ducks, plovers, and curlews were among the feeding and resting species most sensitive to disturbance. Migrating birds also often showed disturbance effects. Disturbance effects included the changing of groups during passage of the wind park or avoidance of the wind park. With the wind park fully operational, the number of birds migrating through was reduced by up to 67 percent.

202. Winkelman, J.E. 1994. Bird/wind turbine investigations in Europe. Pages 43-48 in Proceedings of the National Avian-Wind Power Planning Meeting, Denver Colorado, 20-21 July 1994. Proceedings prepared by LGL Ltd., environmental research associates, King City, Ontario. Author's address: Birdlife/ Vogelbescherming Nederland, Driebergweweg, The Netherlands.

This paper provides an overview of research carried out in Europe with special emphasis on the results of the two most in-depth studies (Winkelman 1989, 1992a, 1992b, 1992c, 1992d). Winkelman provides data and tables that are not available in any of the English summaries of these reports. Up to 1994, 14 studies have been finalized in Europe, covering 108 different sites. Most studies include small, solitary turbines (100–150 kW). Studies on bird collisions were mostly carried out by searches for dead birds. The proportion of birds colliding in relation to the total number passing the wind turbines was studied at 13 sites. Estimates of the total number of bird victims could only be made in two studies. At the 108 sites, 303 dead birds were found, of which at least 41 percent were proven collision victims. The estimated average number of collision victims in the two in-depth studies by Winkelman varied between 0.04 to 0.09 birds/turbine/day, depending on site and season. Of 14 collisions observed, 43 percent were caused by birds swept down by the wake behind a rotor, 36 percent by a rotor, and 21 percent unknown. The author states that total numbers likely to be killed per 1,000 MW of wind power capacity are low relative to other human-related causes of death. Findings on disturbance and the effect of turbines on flight behavior, which were investigated in most studies, were summarized. Up to 95 percent reduction in bird numbers has been shown to occur in the disturbance zones (250–500 m from nearest turbines). From the European point of view, in most circumstances disturbance/habitat loss is thought to be of much more importance than bird mortality. New or ongoing research in Spain, The Netherlands, and Denmark was also mentioned.

203. Wisconsin Department of Natural Resources. 1995. Draft Wisconsin windfarm siting guidance. Wisconsin Department of Natural Resources, Madison, Wisconsin.

This draft document identifies recommended guidelines for the environmentally sound siting of wind electric generating facilities. The guidelines are intended to be applied to geographical areas that are not already identified as sensitive to windfarm development because of use and aesthetic conflicts and the presence of natural resources that could be adversely affected by windfarm development. To help identify areas with good potential for development with minimal adverse impacts, project proponents should develop overlays, preferably on a GIS system, with the following areas delineated: wildlife areas, bird migration corridors, current or proposed major state ecological acquisition and restoration projects, state and local parks and recreation areas, active landfills, wetlands, major tourist/scenic

areas, and airport/landing strip clear zones. Moreover, it is recommended that the trust and cooperation of neighboring property owners and occupants be secured early in the siting process. Applying the criteria described in this document should help wind developers identify areas with the least potential for adverse impacts. Comparing the GIS maps with wind potential maps can help pinpoint sites for more detailed site-specific evaluation.

204. Wolsink, M., M. Sprengers, A. Keuper, T.H. Pedersen, and C.A. Westra. 1993. Annoyance from windturbine noise on sixteen sites in three countries. European community wind energy conference, proceedings of an international conference at Lubeck-Travemunde, Germany, 8–12 March 1993. Published by H.S. Stephens and Associates, [location unknown].

The annoyance caused by wind turbine noise was investigated at sites in Denmark, The Netherlands, and Germany. Residents of communities living around existing turbines were interviewed and emitted noise levels were computed based on site measurements. The number of people actually indicating annoyance by wind turbines noise was fairly small. However, the degree of annoyance was not related to an objective level of sound. The paper discusses the problems associated with objectively measuring annoyance caused by noise.

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