Legal Issues Raised by the Environmental Impacts of Photovoltaic Energy and Wind Energy Conservation Systems

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I. INTRODUCTION

The use of renewable energy sources to generate electricity has great appeal, not least as a means to avoid some of the environmental consequences of dependence on fossil fuels. The use of alternatives to fossil fuels will not, however, eliminate environmental risks.[1] The focus of this Article is on the potential environmental consequences of using the sun and wind as primary sources of energy for the generation of electricity.

Each of the two parts of this Article begins with a brief description of the relevant technology for utilizing the energy of the sun and the power of the wind. This provides the basis for this Article's consideration of the environmental impact of these new energy developments and the regulatory controls necessary to manage their adverse impacts, risks and costs. The entire field of the utilization of solar energy and wind power is very recent and the legal developments in the area have been minimal.

The regulatory controls that are currently available to deal with their environmental impacts were, for the most part, originally formulated to address the problems of air pollution, water pollution and hazardous waste disposal which arose earlier from the use of other technologies. The consequences of the growing reliance on solar and wind technologies could, however, bring into play this existing pollution control legislation, as well as the National Environmental Policy Act[2] and parallel state legislation. Although modern uses of solar energy and wind power may be novel, many of their environmental impacts are similar to the impacts of earlier industrial and energy producing activities. They fall on different and variegated environments, *e.g.*, land, water and air. As in the case of other energy sources, the environmen-

1. *See generally* L. MEDSKER, NATIONAL AUDUBON SOCIETY, SIDE EFFECTS OF RENEWABLE ENERGY (1982).

2. National Environmental Policy Act, 42 U.S.C. §§ 4321-4370 (1982 & Supp. I 1983).

tal burdens and economic and other public interest advantages may not balance evenly. An examination of applicable regulatory controls should therefore provide a beginning for future consideration of local, state and federal controls that may be necessary to advance the widespread use of renewable resources in a manner consonant with the public interest.

II. Photovoltaic Energy Systems

A. *Introduction*

All photovoltaic installations consist of individual generating units—photovoltaic cells—grouped together. Photovoltaic cells convert sunlight into electricity. Individual cells range in size from a few millimeters to a meter in linear dimension.[3]

Photovoltaic cells are constructed in a variety of ways. Two of the most widely used materials are copper sulfide/cadmium sulfide (Cu_2A/CdS) and polycrystallen silicon (poly-si).[4] Copper sulfide/cadmium sulfide cells are constructed either by chemical spray deposition of cadmium sulfide onto a layer of heated glass, followed by a layer of chemically spray deposited copper sulfide (the "back-wall" method), or by applying copper sulfide to electroformed copper foil through vacuum deposition and then applying the copper sulfide by a wet chemical dip (the "front-wall" method).[5] Poly-si cells are fabricated in a number of ways, all utilizing silicon as a raw material.[6] Generally, groups of cells are mounted on panels which in turn are connected in arrays. These arrays can be quite large, covering rooftops or large ground areas. The electricity generated and not used on site must then be transported to its end use destination.

Photovoltaic systems can be used for separate, decentralized residential and commercial purposes, as well as for central stations like power plants.[7] Residential use involves solar panels mounted on rooftops or at ground level to provide electricity to

3. Office of Technology Assessment, U.S. Congress, Application of Solar Energy to Today's Energy Needs Vol. 1, 395-397 (1978) [hereinafter cited as OTA Study].

4. K. Lawrence, S. Morgan, D. Schaller & T. Wilczak, Environmental, Health, Safety, and Regulatory Review of Selected Photovoltaic Options 3 (1981) [hereinafter cited as Lawrence].

5. *Id.* at 4. Commercial production generally utilizes the front wall method.

6. *Id.* at 29-44.

7. *Id.* at 87.

individual homes.[8] Commercial use, providing electricity to industry, utilize a greater number of solar panels in the same manner. Centralized applications of photovoltaic cells are different in many respects from residential and commercial systems. Centralized photovoltaic systems require much larger land areas. For example, a small power plant with an output of 100 Mw requires approximately a square mile of level ground.[9] These large systems would most likely be placed in the desert areas of the southwest, where there is a high level of "insolation"—solar radiation received over a given surface area.[10] The electricity produced in these remote areas must then be transported to populated areas.

The potential for environmental or health damage from the utilization of photovoltaic technology depends in part on the raw materials used,[11] and in part on the size and location of the photovoltaic installation.[12] Decentralized photovoltaic applications are unlikely to have as great of an ecological effect as centralized systems, which are larger and more likely to be placed in fragile ecosystems.[13]

The manufacture, installation, operation and decommission of photovoltaic energy systems can each create a variety of environmental problems, but at present levels of production and use they are, in principle, addressable by currently available pollution abatement and waste disposal techniques.[14] Future regulatory needs must be assessed, however, in light of the impacts that would be experienced at stepped up rates of production and installation.

It is important to consider the potential environmental impact of photovoltaic energy systems at this early stage of their develop-

8. *Id.* A typical residential system will be about 8 kw and have an area of 500-1,200 square feet.

9. *Id.* at 88. A 1,000 Mw system would require 30 km^2 of space. P. MOSKOWITZ, P. PERRY & I. WILENTZ, PHOTOVOLTAIC ENERGY SYSTEMS: ENVIRONMENTAL CONCERNS AND CONTROL TECHNOLOGY NEEDS 14 (1981) [hereinafter cited as MOSKOWITZ]. The area would be covered with a vast array of solar panels mounted slightly above the ground. Perhaps twice this amount of land would also be taken up by access roads and service buildings for the station.

10. LAWRENCE, *supra* note 4, at 87-8.

11. For example, poly-si cells are of less concern because of the stability and low toxicity of silicon. *Id.* at vi. Cadmium on the other hand is highly mobile and its toxicity is of greater concern. *Id.* at 9. See *infra* notes 18-23 and accompanying text.

12. LAWRENCE, *supra* note 4, at 88.

13. *Id.* at iv.

14. *Id.*

ment, so that potential future side effects can be managed and minimized.[15] The first consideration in reviewing the environmental impact of the use of photovoltaics is to review the environmental regulations currently applicable to their control.[16] This leads to a determination of whether current regulatory controls are adequate, and how the environmental control of photovoltaics compares with the regulatory control of conventional, non-renewable energy sources. The use of photovoltaics employs very recent technologies, and this analysis must, therefore, proceed on the understanding that the full scope of environmental ramifications likely to follow from large-scale manufacture and installation of photovoltaic solar systems are not yet clear.

This section examines, first, the environmental legislation affecting the materials used in the photovoltaic cell manufacturing process, and, in particular, the regulations applicable to the toxic substances involved. Laws affecting solid, liquid and gaseous wastes resulting from the manufacturing process are then examined. A discussion of environmental regulation of deployment and use phases follows. Then the land use requirements that centralized systems will have to comply with and the safety requirements that particularly affect decentralized systems are discussed. Finally, issues relating to the disposal of photovoltaic cells are considered.

B. *The Production of Photovoltaic Cells: Environmental Implications*

1. The Materials at Issue

The primary environmental hazard associated with the production of photovoltaic cells is the potential release of toxic chemicals used in the manufacturing process. Three substances

15. MEDSKER, *supra* note 1, at 4-5. Some authors expect substantial use of photovoltaics by the early 1990's. Redfield, *Photovoltaics: An Overview*, 3 SOLAR L. REP. 217, 236 (1981). Estimates indicate that photovoltaic energy can provide up to 30% of total United States electricity needs. *Id.* at 243. However, others have a more pessimistic view of the growth of the photovoltaics industry. Some commentators contend that, under present circumstances, the necessary condition for significant solar-technology commercialization will not exist until the late 1990's at the earliest. I. SCHIFFMAN & G. D'ALESSIO, LIMITS TO SOLAR AND BIOMASS ENERGY GROWTH 277 (1983). Note also that the recent sharp drop in oil prices could affect the development of economically competitive photovoltaic systems. Additionally, drastic cuts in funding for solar energy in the proposed 1987 federal budget are likely to slow the growth of photovoltaics. 44 CONG. Q. WEEKLY REP. 2227-228 (1986).

16. *See generally* Slusarczuk, *The Environmental Implications of an Emerging Energy Technology: Photovoltaic Solar Cells—A Study of the Toxic Aspects*, 9 B.C. ENVTL. AFF. L. REV. 899, 901 (1981).

commonly used in photovoltaic cells are silicon, gallium arsenide and cadmium sulfide.[17] Silicon is not toxic, but gallium arsenide is moderately toxic and possibly carcinogenic, while cadmium sulfate is highly toxic.[18] The growth of photovoltaic cell production should not cause supply difficulties or unduly increase environmental hazards at the raw materials production level.[19] While gallium arsenide is of limited natural abundance,[20] silicon is plentiful and already widely used in existing industries; and cadmium can be recovered as a by-product of zinc refining.[21] Most environmental hazards relating to the mining or refining of materials used in photovoltaic cells are the hazards normally associated with mining operations, such as silicon dioxide emissions. Such emissions are largely controlled through current technology to comply with environmental regulations.[22]

2. Toxic Substances Control Act (TSCA)

Under the Toxic Substances Control Act (TSCA), the Environmental Protection Agency has jurisdiction over the toxic materials used in photovoltaic cell fabrication.[23] Although individual photovoltaic cells may contain small quantities of toxic materials, at current usage and production levels they probably pose minimal

17. *Id.* at 913. *See also* OTA STUDY, *supra* note 3, at 421-23 (In smaller quantities, a number of other hazardous chemicals are often used in cell manufacturing, *e.g.*, PH_3, BCl_3, H_2S_2, HCl, HCN).

18. OTA STUDY, *supra* note 3, at 422. Cadmium as used in the production of gallium arsenide (GaAs) cells is a heavy metal. Poisoning by it is believed to accelerate aging, and to increase the risk of cancer, heart disease, lung damage, birth defects and other problems. Undissociated gallium arsenide is harmful but not highly toxic. To ingest a lethal dose it is said that a person would have to eat the amount of GaAs in 200 square feet of flat-plate arrays. *Id.*

19. LAWRENCE, *supra* note 4, at v.

20. Redfield, *supra* note 15, at 225.

21. OTA STUDY, *supra* note 3, at 421-23.

22. LAWRENCE, *supra* note 4, at 21. Cadmium may present special problems because its greater mobility can result in appreciable amounts of dissolved cadmium in watershed runoff. However, available control measures can remove at least 95% of the heavy metals from liquid wastes and 98% of metal-bearing particulates in gaseous emissions. *Id.* at 9.

23. 15 U.S.C. §§ 2601-2629 (1982). TSCA imposes broad regulatory control over companies that use any chemical substance (toxic and non-toxic) in their products. The goals of TSCA are to develop data on and to regulate the use of chemicals which may present unreasonable risks of injury to human health or to the environment. Such regulation should balance environmental concerns with economic and social concerns. *Id.* at § 2601.

danger.[24] Even at current levels of production, however, toxic substances are present in larger quantities at the manufacturing plants, thereby presenting potential environmental hazards. Consequently, the provisions of TSCA may apply to the manufacturing process. The potential impact of these provisions must be considered in the design and production of photovoltaic cells, both as a guideline to minimizing environmental harm and as a factor affecting the costs of production.

TSCA regulations can be divided into two broad areas: (1) data development and reporting and (2) regulation of activities, including manufacture, sale and use. The regulatory impact of TSCA must be taken into account in cost evaluations.[25]

Manufacturers or processors of chemical substances are required to maintain records and make any reports which the EPA determines are necessary.[26] These requirements pose no special problem for the photovoltaic industry.[27]

Manufacturers planning to introduce a new chemical substance or planning to create a significant new use for an existing sub-

24. LAWRENCE, *supra* note 4, at 90-92. Poly-si cells present little danger because of the low toxicity of silicon. *Id.* Although cadmium is of more concern, it is unlikely that a large enough quantity will enter the environment to be of major concern. *Id.* at 91.

25. Slusarczuk, *supra* note 16, at 929-34.

26. 15 U.S.C. § 2607 (1982). The types of information which may be required include the identity of the substances, categories or proposed categories of use, estimates of the amounts to be produced, a description of by-products, and all existing data concerning the environmental and health effects of the substance. Under this section, the EPA requires submission of data on any chemical substances regarding which the EPA lacks sufficient data to determine its potential hazards to human health and the environment. *See also* S. REP. NO. 698, 94th Cong., 2d Sess., 22 *reprinted in* 1976 U.S. CODE CONG. & AD. NEWS 4491, 4512; *see also* F. GRAD, TREATISE ON ENVIRONMENTAL LAW § 4A.02[8] (1984) [hereinafter cited as GRAD].

The Inventory Data Base compiled by the EPA contains only 1977 production information. An EPA proposed rule would require an update on production volume, plant size and site-limited status of the substances on the TSCA Chemical Substances Inventory. However, certain chemical substances will be exempted from this requirement including polymers, inorganic substances, microorganisms, naturally occuring chemical substances as defined under 40 C.F.R. § 710.4(b) (1985), and low volume substances. 50 Fed. Reg. 9,944 (1985). Thus, approximately three-fourths of the 60,000 chemicals on the TSCA inventory would be exempted from updating production information. 15 ENV'T REP. (BNA) 2036 (Mar. 22, 1985). As of February 1986, a final rule has not been promulgated. Telephone interview with Henry Lare, Office of Toxic Substances, Information Management Division (Feb. 24, 1986). Cadmium sulfide and gallium arsenide are inorganic substances making them exempt from production requirements.

27. Slusarczuk, *supra* note 16, at 924. *See also* 15 U.S.C. § 2607(a)(3)(A)(ii) (1985). Small manufacturers may be excluded from record requirements at EPA's discretion. Small manufacturers include businesses with annual sales under $5 million and manufacturing less than 100,000 pounds of a substance at any one site. 40 C.F.R. § 710.1 (1985).

stance are required to notify the EPA at least ninety days before initial use. The manufacturer should also submit data demonstrating that the substance will not create an unreasonable risk.[28] This does not apply to current uses of existing photovoltaic cell materials, but significant new uses of these materials or the use of new chemical substances will have to comply with this regulation, and compliance may cause delays and increased costs.[29] Even manufacturers using new chemicals solely for research and development are covered under these provisions and may be regulated by the EPA.[30]

TSCA authorizes the EPA to require the testing of any substance if it determines that it may present an unreasonable risk of injury to health or to the environment, and if there are insufficient data and experience to determine the risk involved.[31] It is possible that such testing will be required of manufacturers of photovoltaic cells. However, this is unlikely under current EPA practices.[32] Factors assessed in determining which substances will require testing include: the quantities used in manufacturing, the quantities entering the environment, the number of persons exposed, and the amount of data available regarding environmental or health effects of the substance.[33] Testing costs may be

28. 15 U.S.C. § 2604 (1982).

29. Slusarczuk, *supra* note 16, at 925.

30. Dow Chemical Co. v. E.P.A., 605 F.2d 673 (3d Cir. 1979) (small amounts of new chemical for testing purposes only, still covered by TSCA).

31. 15 U.S.C. § 2603(a) (1982). The statute does not define unreasonable risk, consequently it is left to the EPA to determine what substances present an unreasonable risk in their use. Slusarczuk, *supra* note 16, at 926.

32. Don R. Clay, the Director of the EPA's Office of Toxic Substances, said that "TSCA's major failure has been the agency's inability to get current test data on existing chemicals." There is a large backlog of chemicals slated for testing. Only one final test rule had ben issued as of May 1985, and testing rules proposed as early as 1980 are still awaiting final promulgation. *Control of Chemicals Under TSCA Seen Yielding Successes, Failures*, 16 ENV'T REP. (BNA) 8 (May 3, 1985). In Natural Resources Defense Council v. United States Environmental Protection Agency, 595 F. Supp. 1255 (S.D.N.Y. 1984), the court held that the EPA violated the mandate of the Toxic Substances Control Act that the EPA either initiate rulemaking procedures to require testing of toxic substances on the Interagency Testing Committee list or publish its reasons for not requiring testing. The court found that a lapse of three and four years since the proposed rulemaking, with no formal rules promulgated, constituted unreasonable delay of agency action. The possibility of long delays in TSCA implementation was noted as early as 1978, since "the likelihood of litigation, the rigorousness and complexity of the Act's regulatory scheme, and the profusion of as yet untested chemicals suggests that delays EPA has experienced will continue." *First Steps in Implementing the TSCA*, 8 ENVTL. L. REP. (ENVTL. L. INST.) 10032, 10035 (1978).

33. 15 U.S.C. § 2603(e)(1)(A)(i-viii) (1982).

shared with other industries using the same substances as the photovoltaics industry, an option that could lessen the economic impact of EPA testing requirements.[34]

Under TSCA, if the use of any substances present "unreasonable risks" to health or the environment, the EPA is empowered to impose restrictions ranging from labeling requirements to outright prohibition, though as of January 1986, EPA had rarely invoked this power.[35] When it does so, the nature of the regulation is qualified by the requirement that EPA use the least burdensome restrictions that adequately protect against the risks.[36] Additionally, the EPA may bring suit to seize imminently hazardous chemicals and to obtain injunctive relief against the processors of such chemicals.[37] Given the toxicity of gallium arsenide and cadmium sulfide, any future large-scale manufacturing of cells based on these materials may require the establishment of protective standards under TSCA. Given the recent regulatory history of the agency, to achieve adequate protective standards, new statutory means of assessing risk control and timetabling requirements may first be necessary.[38]

34. Slusarczuk, *supra* note 16, at 933-34. GRAD, *supra* note 26, at § 4A.02[4]; 15 U.S.C. § 2603(C) (1982).

35. 15 U.S.C. § 2605(a) (1982). The EPA has only imposed restrictions on four chemical substances pursuant to this section. They are PCBs, fully halogenated chlorofluoralkanes, asbestos and Tetra chloro dibenzo-p-dioxin (TCDD). *See* 40 C.F.R. §§ 750-775 (1985). *See also* 16 ENV'T REP. (BNA) 8 (May 13, 1985).

36. 15 U.S.C. § 2605(a) (1982).

37. 15 U.S.C. § 2605(a) (1982).

38. At present, actions to ban or restrict hazardous substances have been "bogged down in court proceedings or a quagmire of regulatory indecision, spurred in part by the stringent balancing of risks and benefits that Congress mandated in drafting the Act." *Control of Chemicals Under TSCA Seen Yielding Successes, Failures*, 16 ENV'T REP. (BNA) 8 (May 3, 1985). A report by the Conservation Foundation noted that toxic pollutants have not been controlled effectively and concluded that integrated statutes for all mediums are required to control toxic substances. 15 ENV'T REP. (BNA) 304 (June 22, 1984). However, the Director of EPA's Office of Toxic Substances believes that the actual regulation of specific chemicals will decrease and that information gathered under TSCA provisions will be referred to other agencies or other branches of EPA where the actual regulation will occur. 16 ENV'T REP. (BNA) 9 (May 3, 1985). An example of this regulation outside of TSCA is a bill introduced in the 99th Congress. H.R. 2576, 99th Cong., 2d Sess. (1985). This bill would repeal future use of the national emissions standards for hazardous air pollutants (42 U.S.C. § 7412) and require the EPA to regulate 85 hazardous substances as toxic air pollutants. This would eliminate EPA discretion to determine if a substance is a hazardous pollutant. The EPA has only listed six such pollutants since 1970. The expanded list includes arsenic trioxide and cadmium, which would affect photovoltaics manufacturers. Regulations would include inventory, monitoring, leak prevention, permits and labelling requirements for all substances covered under the bill, including any future

C. *Emissions, Effluents and Waste Resulting From the Manufacture of Photovoltaic Energy Systems*

The manufacture of photovoltaic cells will produce emissions, effluents and waste, which will be regulated respectively by the Clean Air Act,[39] the Clean Water Act,[40] and the Resource Conservation and Recovery Act.[41] The environmental regulations applicable to the manufacture of photovoltaic cells are likely to be similar to those regulating the semiconductor industry, and at current production levels will present few new problems.[42] However, there is as yet no clear evidence of the amount and kind of emissions, effluents and waste that will be generated in the future. This will depend on the growth of the industry, on future technological developments, and on the impact on the waste stream of the chemicals used.[43]

1. Emissions in Manufacturing—The Clean Air Act (CAA)

Under normal operating conditions, assuming the use of air pollution control equipment necessary to meet local, state and federal standards, the production of photovoltaic cells are expected to have little impact on air pollution levels as presently regulated. Most gases produced in their manufacture can be controlled or vented and dispersed into the air in a way that is considered safe under current law.[44]

We are constantly learning more about the nature and sources of air pollution requiring control, however. In order to achieve adequate controls in the face of stepped up production of photovoltaic cells or new evidence of risk factors attaching to the emissions produced, an understanding of the relevant provisions of the federal Clean Air Act (CAA),[45] and state laws implementing federal requirements is necessary.

Under the CAA, the federal government is charged with promulgating national air quality standards for "criteria pollutants," *i.e.*, those historically considered the most significant air

chemical additions. *Id.* As of February 1986, the bill has not emerged from the Health Subcommittee of the House Energy and Commerce Committee.

39. 42 U.S.C. §§ 7401-7642 (1982).
40. 33 U.S.C. §§ 1251-1376 (1982).
41. 42 U.S.C. §§ 6901-6986 (1982).
42. LAWRENCE, *supra* note 4, at 62.
43. *Id.*
44. *Id.*
45. 42 U.S.C. §§ 7401-7642 (1982).

pollutants and known to have adverse health effects at exposure above the threshold level.[46] National air quality standards are to be achieved through the adoption and enforcement of federally approved state implementation plans (SIP).[47] The mechanisms of these plans will vary from state to state, but each plan must set emission standards for stationary sources so that the nationally established air quality standards for criteria pollutants are attained and maintained.[48]

In regions where air quality is better than required by the national standards, state plans must adopt measures for the "prevention of significant deterioration" (PSD).[49] In regions that had not yet attained national air quality standards by 1977, state plans are required to adopt special non-attainment requirements.[50]

Though most emission standards will be set by the states in light of the federal ambient air quality requirements, the federal government has the authority to set "new source performance standards" (NSPS) for the new sources of pollution listed pursuant to section 111(f) (a list which may be revised).[51] The federal government also retains the right to set national emission standards for hazardous air pollutants (NESHAP).[52]

46. GRAD, *supra* note 26, at § 2.03[2], § 2.03[4]; 42 U.S.C. § 7408(a)(1) (1982); 40 C.F.R. 50 (1985) (criteria pollutants as of 1985 include carbon monoxide, sulfur oxides, nitrogen oxides, hydrocarbons, particulate matter, photochemical oxidants and lead). Air quality "criteria pollutants" are those air pollutants "emission of which, in [the EPA Administrator's] judgment, cause or contribute to air pollution which may reasonably be anticipated to endanger public health or welfare; the presence of which in the ambient air results from numerous or diverse mobile or stationary sources; and for which air quality criteria had not been issued before December 31, 1970, but for which [the Administrator] plans to issue air quality criteria under this section." 42 U.S.C. § 7408(a)(1)(A)-(C) (1982). The EPA Administrator must promulgate national primary ambient air quality standards for "criteria pollutants" which are necessary to protect the public health, 42 U.S.C. § 7409(b)(1) (1982), as well as national secondary ambient air quality standards that protect the public welfare from known or anticipated adverse effects associated with the "criteria pollutant." 42 U.S.C. § 7409(b)(2) (1982). In *NRDC v. Train*, 545 F.2d 320, 325 (2d Cir. 1976), the court stated that the EPA Administrator "*must* list those pollutants which he has determined meet the two requisites" specified in 42 U.S.C. § 7408(a)(1)(A)-(b) (1982).

47. GRAD, *supra* note 26, at § 2.03[2], § 2.03[5].

48. *Id.*; 42 U.S.C. § 7410 (1982).

49. GRAD, *supra* note 26, at § 2.03[2], § 2.03[9].

50. *Id.* at § 2.03[2], § 2.03[10].

51. *Id.* at § 2.03[14].

52. *Id.* at § 2.03[15]; 42 U.S.C. § 7412 (1982).

As of early 1985, no federal NSPS had been developed for the photovoltaic cell industry.[53] Similarly, NESHAP regulations as of 1985 have had little impact on the photovoltaic industry. Silicon is not considered a hazardous pollutant,[54] and cadmium is not likely to be so designated.[55] The EPA Administrator is under court order to promulgate NESHAP regulations for inorganic arsenic, however, and such regulations could, though in all likelihood will not, effect the production of gallium arsenide.[56]

A large increase in photovoltaic cell manufacturing, however, will mandate further consideration of applicable CAA provisions. If solar energy becomes readily commercialized, secondary air pollution from photovoltaic manufacturing can have important regional and local effects in certain industrial areas.[57]

Although it is not likely that states will go beyond federal Clean Air Act requirements, photovoltaic cell manufacturers will need to be aware of the emissions standards set under their state clean air acts. For the most part, state requirements will be similar to what is necessary to attain national ambient air quality (NAAQ) standards, though state emission limitations may be more stringent than NAAQ attainment would require.[58] Similarly, states may independently regulate emissions which are neither national "criteria" pollutants nor subject to federal NSPS or NESHAP regulation.[59]

53. I. WILENTZ, V. FTHENAKIS & P. MOSKOWITZ, COSTS OF CONTROLLING ENVIRONMENTAL EMISSIONS FROM THE MANUFACTURE OF SILICON DENDRTIC WEB PHOTOVOLTAIC CELLS 3 (1985) [hereinafter cited as WILENTZ].

54. MOSKOWITZ, *supra* note 9, at 27.

55. *Id.* at 16.

56. New York v. Gorsuch, 554 F. Supp. 1060 (S.D.N.Y. 1983). Standards for inorganic arsenic were proposed July 20, 1983. A promulgation package has been developed and as of November 1985 was undergoing Agency review. Photovoltaic cell production did not fall within any of the source categories considered in the proposed standard, and the proposed standard is likely to be followed with the exception of provisions relating to glass plants and copper smelters. (Telephone interview with EPA Staff, Nov. 7, 1985).

57. SCHIFFMAN & D'ALESSI, *supra* note 15, at 129. "The construction emissions associated with installing 10^{12} BTU of residential photovoltaics . . . could equal or surpass the total emissions from 10^{12} BTU of controlled coal-combustion installation over 30 years." *Id.* at 128.

58. 42 U.S.C. § 7416 (1982).

59. *Id.* As examples of State Clean Air Acts, *see* Colorado: COLO. REV. STAT. ANN. § 25-7-114 (Supp. 1985); New York: N.Y. ENVTL. CONSER. LAW § 19-0101 (Consol. 1984-85).

2. Effluents in Manufacturing—The Clean Water Act (CWA)

The Administrator of EPA is empowered to set effluent limitations on point sources by classes and categories.[60] Special criteria apply to the setting of effluent limitation standards for toxic and other hazardous substances,[61] and for new sources of pollution.[62] Special criteria also apply to the adoption of pretreatment standards applicable to pollutants being introduced into publicly owned waste treatment works.[63]

Photovoltaic cell manufacturers will need to follow developments in each of these control mechanisms. Federal new source performance standards, for example, have already been established for industries such as the battery manufacturing and semiconductor industries, which share many characteristics with photovoltaic cell manufacturing.[64] Under the CWA, such standards must be set on the technically advanced criteria of "best available demonstrated control technology."[65] Thus, EPA may require—though it is not likely to—zero discharge of pollutants where practicable.[66] It is worth noting that any source of discharge which is constructed to meet all applicable standards at the time of construction will not be subject to any more stringent standards for at least ten years.[67]

Discharges of liquid waste from photovoltaic manufacturing will be subject to regulation under federal pretreatment standards if they are discharged into public treatment works,[68] and to municipal sewer ordinances where they are discharged into a municipal sewer system. The main waste treatment concerns of photovoltaic manufacturers appear to be the removal of heavy metals and the neutralization of acid.[69] Various technologies are

60. GRAD, *supra* note 26, at § 3.03[2][c], § 3.03[4][c], [e]; 33 U.S.C. § 1311 (1982 & Supp. I 1983).

61. GRAD, *supra* note 26, at §§ 3.03[4][g] and 3.03[8][c].

62. *Id.* at § 3.03[4][f].

63. *Id.* at § 3.03[4][g]; 33 U.S.C. § 1317 (1982). This is to ensure that all pollutants not treatable in public treatment facilities are adequately handled by the manufacturer.

64. 40 C.F.R. §§ 401.1, 461 (battery manufacturing), 469 (electrical and electric components) (1985).

65. GRAD, *supra* note 26, at § 3.03[4][f]. It is sufficient if there is one operating facility that demonstrates a certain level of control is achievable. American Iron and Steel Institute v. EPA, 526 F.2d 1027 (3d Cir. 1975), *cert. denied*, 435 U.S. 914 (1978).

66. 33 U.S.C. § 1316(a)(1) (1982).

67. 33 U.S.C. § 1316(d) (1982).

68. MOSKOWITZ, *supra* note 9, at 19.

69. LAWRENCE, *supra* note 4, at 62.

currently available to comply with environmental regulations concerning these pollutants.[70]

One means of ensuring compliance with these federal standards is the CWA provision requiring that pollution sources obtain an National Pollution Discharge Elimination System (NPDES) permit to discharge effluents.[71] Such a permit may be issued either by the EPA Administrator or by the state where the state has federal authorization to administer a state discharge permit program.[72] Regardless of the permitting authority, a permit will only be issued if the applicant demonstrates that effluent discharges will meet federal effluent limitations.[73] The EPA Administrator has the discretion either to issue a permit or to leave the discharger subject to the total proscription of § 301 of the Clean Water Act.[74] All manufacturers, including photovoltaic manufacturers, are required to obtain a permit if they discharge any industrial wastes into United States waters.[75]

State regulation of water quality also places obligations on polluters. Subject to federal approval, states establish water quality criteria and set ambient water quality standards for their internal waters.[76] States may also set effluent limitations more stringent than the federal limits.[77] This package of controls is implemented by a state implementation plan which must be submitted for federal approval.[78]

70. *See id.* at 66-69.

71. GRAD, *supra* note 26, at § 3.03[6].

72. *Id.*; 33 U.S.C. § 1342(b) (1982).

73. 33 U.S.C. § 1342(a)(1). The administrator of the EPA has discretion over issuing permits since they may be issued to carry out the purposes of the Act before all the implementing steps are complete. 33 U.S.C. § 1342 (1982).

74. NRDC v. Costle, 568 F.2d 1369, 1374 (D.C. Cir. 1977) ("Congress intended the NPDES permit to be the only means by which a discharger from a point source may escape the total prohibition of § 301(a)").

75. 40 C.F.R. § 122 (1985). *NRDC v. Costle*, 568 F.2d at 1380, indicated that it may be appropriate in certain circumstances for the EPA to require a permittee simply to monitor and report effluent levels; EPA manifestly has this authority. Such conditions might be desirable where full extent of the pollution problem is not known. This type of permit could be applied to the photovoltaics industry.

76. GRAD, *supra* note 26, at § 3.03[4][j].

77. *Id.*

78. *Id.* at § 3.03[4][k].

3. Solid Wastes from Manufacturing—The Resource Conservation and Recovery Act (RCRA)

If solid waste is determined to be non-hazardous, it may be disposed of in a conventional sanitary landfill, following Resource Conservation and Recovery Act (RCRA) guidelines.[79] "[The] EPA has determined that the problem of non-hazardous solid waste disposal is primarily a state and local government problem. . . ."[80] The wastes produced in silicon cell facilities are generally non-hazardous in the quantities currently produced, and are not presently regulated by the EPA.[81]

Hazardous wastes must be treated more carefully. Generators of hazardous solid wastes must keep records and properly identify and separate such wastes under a system of manifests that accounts for such wastes at every step, from their generation to their ultimate disposal.[82] Hazardous waste regulations require special precautions for disposal in landfills, increasing the cost of disposal.[83] Small quantity generators producing more than 100 kilograms but less than 1,000 kilograms of hazardous waste per month are separately regulated.[84] The hazardous compounds involved in photovoltaic cell manufacturing covered under RCRA include arsine, cadmium and flourine.[85] As of 1987, disposal of arsenic or cadmium exceeding specified limitations will be prohibited under RCRA unless the EPA determines the prohibition to be unnecessary.[86]

D. *Deployment and Use of Photovoltaic Energy Systems*

Environmental legislation will affect the use of photovoltaic energy as well as its manufacturing process. The environmental is-

79. 42 U.S.C. § 6944 (1982). *See* 40 C.F.R. §§ 257.1-257.4 (1985) for specific criteria for sanitary landfills.

80. LAWRENCE, *supra* note 4, at 132. State plans of those states receiving federal funding must prohibit the establishment of open dumps, as well as follow measures to close existing open dumps within a specified time frame. 42 U.S.C. § 6945(a) (1982).

81. WILENTZ, *supra* note 53, at 6.

82. 42 U.S.C. § 6922 (1983 and Supp. 1985); GRAD, *supra* note 26, at § 4.02[3][b][ii][C.

83. LAWRENCE, *supra* note 4, at 85. The hazardous waste program is a "cradle to grave" management system that must be complied with at every step from generation to transportation, storage and disposal. *Id.* at 134.

84. 42 U.S.C. §§ 6921(d), 6945(c) (1982 & Supp. I 1983).

85. Regarding the hazardous compounds from photovoltaic cell manufacturing that are covered by RCRA, *see* LAWRENCE, *supra* note 4, at 79. *See also* 40 C.F.R. § 261 (1984) for a full listing of hazardous wastes under RCRA.

86. 42 U.S.C.A. § 6924(d)(2)(B) (Supp. 1985).

sues raised by centralized photovoltaic applications will be somewhat different from those affecting decentralized systems. The scale of centralized systems raises both land and water use problems, most of which have yet to be regulated. Centralized systems are also likely to trigger requirements under both the National Environmental Policy Act (NEPA),[87] and under the state "Little NEPAs," as well as various other statutory provisions. Deployment of decentralized systems will primarily invoke safety and zoning regulation.

1. Centralized Photovoltaic Systems

Centralized photovoltaic energy systems are large scale electrical power producers, analogous to conventional power plants. They will most likely be run by utilities. Since these systems require large areas of land, they will affect the areas in which they are used. Because of the large land requirements—a square mile of land for a 100 Mw plant—the centralized facilities will need to be located in remote areas, raising the possibility of competition for farmland or threats to desert ecology.[88] The electricity generated will have to be transmitted to population centers through high tension wires. Areas most suitable for central station photovoltaic applications lie in the southern sections of the United States, where annual insolation[89] is high.[90]

a. Land Use Issues.

Central station facilities will have a significant impact on their immediate environment. The areas likely to be used for centralized photovoltaic facilities are desert areas with fragile ecosystems.[91] The effects of installing a centralized system can cause irreversible damage to the immediate environment. This can cause conflicts between ecological needs and the efficient operation of a centralized photovoltaic system.

87. National Environmental Policy Act, 42 U.S.C. §§ 4321-4370 (1982 & Supp. I 1983).

88. LAWRENCE, *supra* note 4, at 93. *See also supra* note 9 and accompanying text. It has been suggested that farmland may be threatened because the costs of installation are so high that even expensive land would account for a small proportion of total capital outlay. Telephone interview, J. Beyea, N.Y. National Audubon Society (Jan. 10, 1986).

89. Insolation is the rate of delivery of direct solar radiation per unit of horizontal surface. LAWRENCE, *supra* note 4, at 88.

90. MOSKOWITZ, *supra* note 9, at 43 (*citing* Union Carbide Corp., Low-Cost Solar Array Project: Feasibility of the Silane process for Producing Semiconductor Grade Silicon (1979) (DOE/JPL 954334-79/10, Jet Propulsion Laboratory, Pasadena, California)).

91. Slusarczuk, *supra* note 16, at 908.

Installation involves site preparation, mounting the photovoltaic panels into anchored physical supports, and electrical connection to the utility grid network.[92] For large installations, such as a 100 Mw photovoltaic facility, grading and clearing of land will be necessary to maximize insolation levels, prevent shading by vegetation, and to avoid animal intrusions which may damage the facility. Some sites may be totally cleared of vegetation.[93] Soil compaction will also occur due to the weight of heavy machinery during construction and afterward during maintenance. This will affect water infiltration into the soil, which in turn affects plant growth and runoff.[94] The dust generated can, in turn, hasten the destruction of the desert crust which protects the desert from wind and water erosion.[95] The presence of a central station photovoltaic facility will thus cause microclimatic changes in the immediate area.[96]

Controlling these problems involves either the use of plants, or some type of paving or gravel. The use of plants probably produces greater ecological and soil stability.[97] Maintaining the ecosystem surrounding the site with plants, however, involves careful planning in order to prevent shading of the photovoltaic panels, and to avoid creating conditions which attract animals, such as snakes, which can disturb installation controls.[98] Fencing off sites and using vegetation suppression techniques may be necessary.[99] Thus, the attempt to maintain the ecological balance in the area surrounding a photovoltaic facility results in inherent tension with the desire to improve the efficiency of the system.

States and municipalities are increasingly regulating the use to which wetlands, floodplains and farmland can be put.[100] By anal-

92. LAWRENCE, *supra* note 4, at 87.

93. *Id.* at 89. A test facility at Barstow, California was prepared in this manner. Wind erosion was severe, and the site's ecosystem was drastically affected.

94. *Id.* The need for access roads from main roadways may also be expected to increase off-road vehicle penetration of delicate ecosystems.

95. *See* MOSKOWITZ, *supra* note 9, at 43.

96. LAWRENCE, *supra* note 4, at 93-94. These changes include decreased air, surface and soil temperatures during the day, warmer ground temperatures at night, greater soil moisture from decreased evaporation, and decreased wind speeds within the photovoltaic panel field.

97. *Id.* at 93.

98. *Id.* Plants selected would probably be non-irrigated types of limited height.

99. *Id.* at 94.

100. A. RATHKOPF & D. RATHKOPF, THE LAW OF ZONING AND PLANNING, § 6.12[3]-[4] (4th ed. 1985 and Supp. 1985). *See also* Potomac Sand and Gravel Co. v. Governor of Maryland, 266 Md. 358, 293 A.2d 241 (1972) (upholding Maryland statute prohibiting

ogy, regulation of desert areas (limiting their use for central photovoltaic installations) could be based on environmental grounds, as an exercise of the police power to protect health, safety and welfare, so long as the owners of the affected property were not deprived of all beneficial use of it.[101]

If public utilities seek to build centralized photovoltaic facilities, local zoning restrictions may be less effective as control measures. Public utilities often enjoy a protected status with respect to local zoning and regulation, though they are likely to be subject to state and even federal regulations.[102]

b. Water Use Issues.

Both the cooling and cleaning of centralized photvoltaic systems can raise water use issues. Large fields of photovoltaic panels could generate large amounts of heat. Most centralized systems of polycrystalline silicon or copper sulfide/cadmium sulfide cells do not require cooling systems,[103] but if such a cooling system is necessary, large amounts of water are needed. A water cooling system may be necessary, for example, to reduce the heat effects of focused beam systems, since the high temperatures greatly reduce the efficiency of the photovoltaic process.[104] The regions most likely to use centralized photovoltaics are also re-

dredging in the wetlands of Charles County); Just v. Marinette County, 56 Wis. 2d 7, 201 N.W.2d 761 (1972) (although uses permitted in wetlands conferred little value on the land, the restrictions were held valid to prevent deterioration of navigable waters); Graham v. Estuary Properties, 399 So. 2d 1374 (Fla.), *cert. denied sub. nom.* Taylor v. Graham, 454 U.S. 1083 (1981) (upholding denial of an application to construct a major residential and commercial development on coastal mangrove wetlands); Wilson v. County of McHenry, 92 Ill. App. 3d 997, 416 N.E.2d 426 (1981) (upholding agricultural zoning ordinance requiring minimum lots of 160 acres, indicating obvious public interest in preserving good farmland). Centralized photovoltaic facilities or manufacturing plants located near farmland could cause substantial damage to crops, particularly if there is a large cadmium release.

101. RATHKOPF, *supra* note 100, at § 6.12[3]. *See also* Salamar Builders Corp. v. Tuttle, 29 N.Y.2d 221, 275 N.E.2d 585, 325 N.Y.S.2d 933 (1971) (holding rezoning of property from one to one and one-half acres valid where sewage and water systems would otherwise be inadequate, due to topography of the land); Moviematic Industries Corp. v. Bd. of County Comm'rs, 349 So.2d 667, (Fla. App. 1977) (upholding rezoning from heavy industrial use to residential use with minimum five acre lots to protect fresh water supply of underlying acquifier).

102. RATHKOPF, *supra* note 100, at § 55.01. *See also* Mammina v. Zoning Board of Appeals, 110 Misc. 2d 534, 442 N.Y.S.2d 689 (N.Y. Sup. Ct. 1981); Save the Bay, Inc. v. Department of Public Utilities, 336 Mass. 667, 322 N.E.2d 742 (1975).

103. LAWRENCE, *supra* note 4, at 90.

104. Slusarczuk, *supra* note 16, at 910-11. Focused beam systems use parabolic structures to bring a greater amount of sunlight to bear on a given area.

gions that often suffer from a scarcity of water. Consequently, the water demand created by these cooling systems would have to be met, and if necessary, the demand would have to be reflected in water use and apportionment legislation. The need to clean photovoltaic panels may also add to water requirements,[105] although even minimal rainfall may be adequate for cleaning purposes.

c. Federal Regulation of Environmental Impacts.

The Solar Photovoltaic Energy, Research, Development and Demonstration Act of 1978[106] could ultimately affect centralized photovoltaic facilities. The Act established a Solar Photovoltaic Energy Advisory Committee,[107] one purpose of which was to study and advise the Department of Energy (DOE) of the environmental consequences of photovoltaic energy systems.[108] The Act also provided for a testing program for photovoltaics that could lead to recommendations such as the setting of performance criteria for photovoltaic components and systems to be used in centralized facilities.[109] The Secretary of DOE was also directed to make recommendations to the President and congress regarding the implications of widespread photovoltaic energy systems for land use and urban development.[110]

While the DOE currently maintains an advisory panel regarding its solar energy research, known as the Solar Panel of the Energy Research Advisory Board,[111] most of the environmental research work in photovoltaics has been transferred to the Solar Energy Research Institute (SERI) in Colorado.[112] A meeting was held at SERI in January, 1986 to discuss environmental issues in the

105. LAWRENCE, *supra* note 4, at 89-90. Cleaning large reflector arrays with detergent is not only environmentally unsound, it also does not appear to be significantly more effective than cleaning them with plain water. A. RABL, ACTIVE SOLAR COLLECTORS AND THEIR APPLICATIONS 389 (1985).

106. Pub. L. No. 95-950, 92 Stat. 2518 (1978).

107. 42 U.S.C. §§ 5588, 5586(d) (1982).

108. 42 U.S.C. § 5588(a)(4) (1982).

109. 42 U.S.C. § 5586(c)-(d) (1982).

110. U.S.C. § 5589(c)(3) (1982). *See also* 42 U.S.C. §§ 5553-54 (1982), establishing a Solar Energy Coordination and Management Project. Among its goals were recommendation of legislation on the use of photovoltaics on federal lands and waters. The Project produced no results.

111. 50 Fed. Reg. 39,166 (1985).

112. Telephone interview with Robert Annan, Department of Energy, Director of Photovoltaics (Feb. 25, 1986).

photovoltaics industry.[113] It is worth noting that this meeting may represent an awareness that the environmental preferability of increased solar use should not excuse careful review of associated environmental damage.[114]

Where the construction of a facility is supported in whole or in part through federal contracts, grants, subsidies, loans or other forms of funding assistance, and where some federal supervision is maintained, the National Environmental Policy Act (NEPA) will probably apply.[115] It requires all federal agencies to give considerable weight to the environmental consequences of any federal project, and it requires them to file an Environmental Impact Statement (EIS) where "major Federal action" "significantly" affects the human environment.[116]

Under some circumstances, other statutory barriers may confront interests trying to justify the development of centralized photovoltaic facilities. The Endangered Species Act,[117] for example, may preclude the use of large tracts of land for centralized systems if such use would endanger protected plant or animal life.[118]

d. State Regulation of Environmental Impacts.

State environmental legislation will have at least as great an impact on centralized photovoltaic systems as federal regulation. Since the environmental impacts of future higher levels of photovoltaic cell use are not yet clear, the state is an appropriate forum within which to ensure a public airing of new research and to develop approaches by which to manage emerging risks. State environmental policy acts, "Little NEPAs," exist in many states,[119] and are one way the states may perform this function. "Little NEPAs" will apply to centralized photovoltaic systems that must

113. *Id.* Present at the meeting were government, industry, and university personnel. A meeting of international experts on photovoltaics from Japan, France Italy and Germany is planned for June 1986.

114. Congress made a finding in 1978 which oriented Federal policy away from an emphasis on the environmental risks of photovoltaic use. "The widespread use of solar photovoltaic energy systems to supplement and replace conventional methods for the generating of electricity would have a beneficial effect on the environment." Pub. L. No. 95-590, 92 Stat. 2518, codified at 42 U.S.C. § 5581(a)(14) (1982).

115. 42 U.S.C. § 4332(C) (1982). *See also* GRAD, *supra* note 26, at § 9.02 (particularly [c][2]).

116. 42 U.S.C. § 4332(C) (1982).

117. 16 U.S.C. §§ 1531-1543 (1982).

118. LAWRENCE, *supra* note 4, at 88.

119. GRAD, *supra* note 26, at § 9.08(1).

obtain permits from state agencies. Also, many states have other environmental legislation which may affect the use of centralized photovoltaics. The following discussion of the environmental legislation is based on New York, Florida, Michigan, Texas and Colorado and shows the varied nature of the requirements which may apply to a centralized photovoltaic facility.

New York has enacted legislation relating to energy supply and production for alternative energy sources supplying up to 80 Mw of electricity.[120] Under this statute, solar energy systems located outside of the Catskill and Adirondack State Parks and outside of cities of one million or more people only need to fulfill a few requirements.[121] The environmental requirements, in addition to all applicable federal requirements, include regulations for disposal of waste,[122] the protection of water resources,[123] and the State Environmental Quality Review Act (SEQRA).[124] Under SEQRA, an environmental impact statement is required unless the photovoltaic facility would require a certificate under Article 8 of the Public Service Law, relating to the siting of power plants over 50,000 kilowatts.[125] The general requirements of SEQRA still apply, even if no EIS is required.[126]

Florida legislation declares it is a state policy to encourage the use of renewable energy sources in the light of their environmental impact, and the need to minimize any detrimental effects of state solar energy activities.[127] Florida has no state NEPA, but under the Florida Environmental Land and Water Management Act, areas designated of critical state concern require a consideration of environmental impact before any land development oc-

120. NEW YORK ENERGY LAW § 21-106(c) (Consol. Supp. 1985).

121. *Id.*

122. N.Y. ENVTL. CONSERV. LAW § 27 (Consol. 1982).

123. N.Y. ENVTL. CONSERV. LAW § 15 (Consol. 1982).

124. N.Y. ENVTL. CONSERV. LAW § 8 (Consol. 1982). SEQRA is the New York analog to the federal NEPA. It differs in one very important respect: SEQRA allows courts to halt projects on the substantive ground that they are environmentally damaging. In contrast, NEPA permits judicial review on procedural compliance only.

125. N.Y. ENVTL. CONSERV. LAW § 8-0111(5)(b) (Consol. 1982).

126. Marsh, *SEQRA's Scope and Objectives*, 46 ALB. L. REV. 1097, 1107 (1982). This includes the requirement that state agencies, to the maximum extent practicable, make decisions which minimize or avoid adverse environmental effects. *Id.* at 1100-1102.

127. FLA. STAT. ANN. § 377.601(4)(i), (j) (West Supp. 1985).

curs.[128] Only five percent of Florida's total land area, however, can be designated of critical state concern.[129]

In Michigan, the Environmental Protection Act of 1970 would cover any environmental harm caused by a centralized photovoltaic system.[130] "Under section two of the act, a party may bring an action for declaratory and equitable relief against any other party for the protection of the air, water and other natural resources and the public trust therein from pollution, impairment, or destruction."[131] A court will only permit an injunction on an action like the construction of a photovoltaic facility if the activity "has, or is likely to pollute, impair or destroy" natural resources.[132]

Besides the applicability of Michigan's Environmental Protection Act to centralized photovoltaic energy systems, there is specific legislation relating to municipal electric utility systems. A municipal electric utility system may purchase or build energy sources, including solar energy, and it may take action "for the control, abatement or prevention of pollution or damage to the environment which might otherwise be caused. . . ."[133]

Texas and Colorado are two states without "Little NEPAs." In Texas, pollution regulation for power plants applies only to those plants producing more than 80 megawatts of electricity.[134] Thus, centralized photovoltaic facilities in Texas producing less than 80 megawatts may not be subject to any direct environmental regulation. Under the Colorado Natural Areas Act, areas of the state determined to have a threatened ecosystem are protected from development.[135] Centralized photovoltaic facilties built outside of those areas in Colorado may, however, avoid direct environmental regulations.

128. FLA. STAT. ANN. § 380.05(1)(b) (West Supp. 1985).

129. FLA. STAT. ANN. § 380.05(20) (West Supp. 1985).

130. MICH. COMP. LAWS ANN. § 691.1201 (West Supp. 1985).

131. City of Portage v. Kalamazoo County Road Comm'n, 136 Mich. App. 276, 280, 355 N.W.2d 913, 915 (Mich. Ct. App. 1984) (holding the removal of trees did not rise to the level of impairment or destruction of the environment within the meaning of the Michigan Environmental Protection Act.)

132. *Id.* at 280, 355 N.W.2d at 915.

133. MICH. COMP. LAWS. ANN. § 460.807 (West Supp. 1985).

134. TEX. REV. CIV. STAT. ANN. art. 1446C, § 3(e)(1), § 73(A)(a) (Vernon Supp. 1986).

135. COL. REV. STAT. § 36-10-102 (Supp. 1985).

2. Decentralized Photovoltaic Systems

While environmental legislation can affect large photovoltaic facilities, zoning ordinances and safety regulations affect the use of decentralized photovoltaic systems. The potential environmental impact of decentralized photovoltaic systems, in the view of current commentaries, is not likely to be very large, particularly given that they will be sited in situations where the environment is already disturbed in major ways by industry or housing development. The cumulative effects of small disturbances can, however, take on characteristics of their own. All that can be asserted confidently is that, barring a change in technology, the impact of centralized uses of photovoltaic cells is likely to be greater than that of decentralized ones. Nevertheless, many zoning ordinances, building codes and aesthetic requirements exist to control the use of decentralized photovoltaic energy systems.[136]

a. Hazards of Decentralized Photovoltaics: Fire, Safety and Glare.

There is some danger that roof mounted systems using decentralized photovoltaics may result in fires. The risks, however, are considered to be minimal.[137] The danger of toxic gases being spread by fires in photovoltaic systems is also minimal, due to the limited amount of toxic material present in photovoltaic cells. Given proper cell design and installation, the toxic effects of chemicals released in fires would be extremely limited both in area and time.[138]

Even though the risks are small, photovoltaic systems must provide a level of fire safety consistent with applicable sections of the National Fire Protection and Control Act.[139] Hence, fire safety standards for roof structures, which would include roof-mounted photovoltaic systems, need to be met.[140] New designs for improved encapsulating materials are undergoing fire resistance

136. Slusarczuk, *supra* note 16, at 909.

137. Moskowitz, *Rooftop Photovoltaic Arrays*, 9 SOLAR CELLS 327 (1983). Crude upper-boundary estimates for fire-related risk are less than one reportable fire and less than 10^{-2} (.01) deaths per year per 10 Mw cumulative installed capacity. The risk to any one individual is equivalent to the risk of death in a plane crash. *Id.* at 335.

138. LAWRENCE, *supra* note 4, at 92. While firefighters may be exposed to health hazards, proper use of respirators would limit the danger. *See also* OTA STUDY, *supra* note 3 at 423. The amount of arsenic, for example, used in a concentrating collector is extremely small. A device with a concentration ratio of 1,000 uses an arsenic concentration 250 to 1,500 times smaller than the concentration of As_2O_3 recommended by the U.S. Dept. of Agriculture for weed control.

139. 15 U.S.C. §§ 2201-2223 (1982).

140. 46 Fed. Reg. 32,737, 32,773 (1981).

testing, although panels in use already meet fire code regulations.[141]

The structural design of decentralized photovoltaic energy systems could result in safety problems. These systems must be able to support expected pressure from wind, water, snow and ice.[142] Existing building codes and standards will have to be met in the structural designs for photovoltaic systems.[143] Collapsing systems could result in personal injuries, as well as property damage to neighboring homes and lands.

A further problem could arise from the glare produced by solar panels. Intense glare could be dangerous for passing motorists. Regulation to assure proper placement of the photovoltaic system and surrounding vegetation should alleviate the problem.

b. Federal Regulation.

There is little federal law affecting the use of decentralized photovoltaics. By statute[144], federal authorities are required to consider the environmental effect of photovoltaic utilization,[145] in particular, the implications of the widespread use of photovoltaics on land use and urban development.[146] These provisions have not, however, led to federal laws imposing a degree of standardization on zoning and safety regulations affecting decentralized photovoltaic applications, despite the recommendations of the American Bar Foundation that revision of land use regulations, building codes, and fire codes is needed to avoid potential legal conflicts while maintaining adequate safety.[147]

c. State Regulation.

Many states have specific regulations affecting decentralized photovoltaics. Florida excludes the prohibition of solar use in local ordinances.[148] However, this does not insure easy access for photovoltaics users. For example, the planning committee for Coral Gables, Florida, initially rejected solar rooftop collectors

141. LAWRENCE, *supra* note 4, at 91.

142. 46 Fed. Reg. 32,737, 32,776 (1981).

143. *Id.* at 32,776. Photovoltaic structures will be designed according to resistance and load requirements of the various state and local building codes.

144. 42 U.S.C. § 5588 (1982).

145. See text accompanying notes 106-113 *supra*.

146. 42 U.S.C. § 5589(c)(3) 1982).

147. W. THOMAS, A. MILLER & R. ROBBINS, OVERCOMING LEGAL UNCERTAINTIES ABOUT THE USE OF SOLAR ENERGY SYSTEMS 72-73 (1978). Although memoranda were prepared on the subject, a model act was never drafted.

148. FLA. STAT. ANN. § 163.04 (West Supp. 1984).

outright. The committee later reversed its decision, but set such strict controls based on aesthetics that costs were substantially increased.[149] Also, under the Solar Energy Standards Act,[150] the Florida Solar Energy Center was established to set mandatory minimum safety standards for solar energy systems sold or manufactured in Florida.[151]

In California, minimum safety standards for solar devices may be set by the California Energy Resources and Conservation Commission.[152] California also prohibits unreasonable restrictions on the use of solar energy systems, unless the restrictions are necessary to preserve the public health and safety.[153]

New York has specific solar legislation as well. Under the State Energy Conservation Construction Code, housing should utilize solar energy to the greatest extent practicable without affecting the reasonable health and safety of the building occupants.[154] Also, the state energy office has public health and safety rules, but these do not apply to solar facilities for on-site residential use of four or fewer units.[155]

Thus, there are widely varied regulations and restrictions for decentralized photovoltaic applications. This creates difficulties for manufacturers, but the presence of specific state statutes encouraging the use of decentralized photovoltaic systems should help overcome specific legal problems arising from varied standards.

d. Local Regulation.

Municipalities concerned with the possible environmental consequences of decentralized photovoltaic use could seek to regulate such use by means of zoning. Such an exercise of local police power should be able to withstand constitutional and other challenges since the data and other evidence will probably show that there is a reasonable relationship between the evil apprehended and the provisions of the ordinance enacted to prevent them.[156] The reasonableness of ordinances to control photovoltaic use can

149. Slusarczuk, *supra* note 16, at 909, n.76. *See also* Sampson & Charo, *Access to Sunlight: Resolving Legal Issues to Encourage the Use of Solar Energy*, 11 COLUM. J. ENVTL. L. 417 (1986).

150. FLA. STAT. ANN. § 377.705(4) (West Supp. 1984).

151. S. KRAEMER, SOLAR LAW 81 (1978 & 1985 Cumulative Supp.).

152. *Id.* at 311.

153. CAL. HEALTH & SAFETY CODE, § 17959.1 (West 1984).

154. N.Y. ENERGY LAW § 11-104(2) (Consol. Supp. 1985).

155. N.Y. ENERGY LAW § 21-106(4) (Consol. Supp. 1985).

156. *See generally* RATHKOPF, *supra* note 100, at 4-26.

also be supported on the basis of community policy, to advance aesthetic values.[157]

E. *Disposal of Photovoltaic Cells*

Solar photovoltaic cells wear out approximately twenty to thirty years after their initial use.[158] If these cells are not recycled, they must be disposed of somewhere. Most likely the will come to rest in a sanitary landfill as solid waste under RCRA. While the silicon photovoltaic cells are non-hazardous, cells using cadmium and arsenic compounds are classified as hazardous substances.[159] However, generators of less than 1,000 kilograms of hazardous waste in a particular month are currently not required to follow EPA regulations.[160] Thus, the owner of a small number of cells who seeks to dispose of them is unregulated. If the spent photovoltaic cells are not replaced, the entire photovoltaic system, including support structures and circuitry for the transmission of electricity, will have to be dismantled and either recycled or legally disposed of.

Any attempt to regulate photovoltaic cell disposal would be difficult to enforce. A major problem would be the inability to monitor individuals using solar energy systems. "Decentralized disposal by individual homeowners . . . could result in the release of small quantities of cadmium to the atmosphere (from combustion at municipal incinerators) or to terrestrial and aquatic systems (from disposal in municipal landfills)."[161] Disposal procedures for utilities using centralized photovoltaic systems would be much more effective, since they are much easier to monitor.

III. WIND ENERGY CONVERSION SYSTEMS

A. *Introduction*

The establishment of the Rural Electrification Administration in the mid-1930's was thought to sound the death knell of wind

157. *See, e.g.*, Berman v. Parker, 348 U.S. 26 (1954). *See also* discussion *infra* notes 207-221 and accompanying text.

158. MOSKOWITZ, *supra* note 9, at 45.

159. 40 C.F.R. § 261, Appendix VIII (1985).

160. 40 C.F.R. § 261.5(a) (1985). Generators of less than 1000 kilograms per month must also comply with certain other regulations to maintain their exemption from hazardous waste disposal regulations. *See* 40 C.F.R. § 261.5(e)-(g) (1985).

161. MOSKOWITZ, *supra* note 9, at 6.

turbines as a significant source of energy in rural areas of the United States.[162] The energy crisis of the 1970's, however, and the reassertion of interest in renewable energy supplies that attended it, generated new research into means to economically harness wind power.[163] Congressional support for this trend was evidenced in the passage of the 1980 Wind Energy Systems Act,[164] which was designed to meet the following three objectives: 1) to reduce the average cost of electricity produced by wind conversion systems to a level competitive with that produced by other sources by late 1988; 2) to reach a total rated output capacity[165] from wind conversion systems of at least 800 Mw, of which at least 100 Mw are provided by small systems;[166] and 3) to accelerate the growth of a commercially viable and competitive industry in wind systems, so as to make them available to the general public.[167] To these ends the Act directed the Secretary of Energy to initiate or accelerate research and development in wind energy systems;[168] to give assistance to qualifying public or private entities investigating, purchasing or installing wind energy systems;[169] and to initiate a three-year wind resource assessment program.[170]

162. F. EDLRIDGE, WIND MACHINES 5 (1975).

163. H.R. REP. No. 662, 96th Cong., 2d Sess. 3, *reprinted in* 1980 U.S. CONG. CODE & ADM. NEWS 2691, 2693 (The National Science Foundation began research in 1971 to investigate possible applications of major aeronautical advances to wind conversion systems. Similar research is continuing today under the direction of the Department of Energy with support from NASA).

164. The Wind Energy Systems Act of 1980, Pub. Law No. 96-345, 94 Stat. 1139 (1980), codified at 42 U.S.C. §§ 9201-9213 (1982).

165. For a definition of rated output capacity, see *infra* note 175.

166. Kw: kilowatt, a measure of power, equal to 10^3 watts. Mw: Megawatt, a measure of power, equal to 10^6 watts.

167. H.R. CONF. RES. 1217, 96th Cong., 2d Sess. 12, *reprinted in* 1980 U.S. CODE CONG. & ADM. NEWS 2705, 2706. Appropriations to the DOE Wind Program since the passage of the Wind Energy Systems Act were $54.2 million for FY 1981, $34.4 million for FY 1982, $31.4 million for FY 1983, $26.5 million for FY 1984, $31.6 million for FY 1985, and $25.8 million for FY 1986. *Energy and Water Development Appropriations for Fiscal Year 1985: Hearings Before the Subcomm. of the Senate Comm. on Appropriations*, 98th Cong., 2d Sess. 673, 726 (1984) (statement of William P. Collins, Under Secretary and Acting Assistant Secretary, Conservation and Renewable Energy, DOE); telephone interview with Jack Cadogan, Conservation and Renewable Energy, DOE (Dec. 6, 1985).

168. 42 U.S.C. § 9204 (1982).

169. 42 U.S.C. § 9205 (1982).

170. 42 U.S.C. § 9206 (1982).

The Federal Energy Tax Act,[171] by providing tax credits for qualifying investments in wind generated energy, contributed to the goals of the Wind Energy Systems Act, as did favorable state tax schemes. Largely as a consequence of these incentives, the wind energy business experienced a sizeable renewal.

Currently, there are a variety of wind collecting devices on the market.[172] Most systems have one or more rotors mounted on an axis which may be either horizontal or vertical. Because power rating increases in relationship to the diameter of a machine's blades, increasing the size of the blades can increase the cost-effectiveness of a machine.[173] At present, however, the inability to adequately strengthen stressed components, *e.g.*, bearings, blades, etc., both limits the size of wind systems and increases the risk associated with very large machines.[174] The most powerful machines currently available have a rated output capacity[175] of about 3 Mw.[176] By contrast, a small turbine generates up to 200 Kw, an intermediate-sized turbine delivers from 100 to 1,000 Kwe and most large systems produce approximately 1 Mw.[177] The tower of one of the biggest vertical axis machines—the Darrieus turbine—may be 250 meters high, while a propellor-type system of equal power rating will measure approximately 90 meters at the top of its arc.[178]

Apart from building more powerful machines, one means of generating larger quantities of electricity is to group individual wind systems together into "arrays" or "wind farms." This ap-

171. Energy Tax Act, Pub. Law No. 95-628, 92 Stat. 3173 (1978) as amended by Pub. Law No. 96-223, tit. II, § 232(a)(3), 94 Stat. 273 (1980), and Pub. Law No. 97-248, tit. II, § 294, 96 Stat. 575 (1980).

172. *See* ELDRIDGE, *supra* note 162, at 20.

173. *Id.* at 32, 58 (the amount of power available to a Wind Energy Conversion System (WECS) is a function of the square of the blade diameter and the cube of the wind speed. A 20 Mw output would be desirable).

174. OFFICE OF TECHNOLOGY ASSESSMENT, U.S. CONGRESS, NEW ELECTRIC POWER TECHNOLOGIES: PROBLEMS AND PROSPECTS FOR THE 1990'S, at 92 (1985) [hereinafter cited as OTA, NEW ELECTRIC POWER TECHNOLOGIES].

175. *Id.* at 71. Rated output capacity is equal to the output power of a wind machine operating at a constant speed and the output power corresponding to the rated wind speed, *i.e.*, the lowest wind speed at which the rated output power of a wind machine is produced.

176. P. HOFFMAN, SITE SELECTION CONSIDERATIONS FOR LAND-BASED BIOMASS AND WIND ENERGY CONVERSION SYSTEMS (WECS) FROM A LEGAL VIEWPOINT 10 (Solar Energy Research Institute July 1980).

177. OTA, NEW ELECTRIC POWER TECHNOLOGIES, *supra* note 174, at 92.

178. Eldridge, *supra* note 162, at 20, 23.

proach has been adopted, in particular, by entrepreneurs seeking to produce and sell electricity to the public utilities.[179] One such wind farm in California consists of 461 machines.[180] Obviously, installations of this type require related equipment. Apart from the transmission lines to carry the energy produced, they are likely to include power conditioning equipment, system protection devices, security sensors, metering devices for measuring turbine output, monitoring equipment, control buildings and equipment storage. A farm of 50 intermediate-sized turbines could thus occupy anywhere between 300 and 2,000 acres.[181]

The extent to which wind conversion will develop as an alternative to electricity produced by fossil fuel is uncertain. A primary advantage is to enable the production of electricity without the use of scarce or polluting fuels. Generation of electricity by conventional means requires approximately three quads of oil, gas or coal to produce one quad of electricity.[182] Wind energy conversion systems, by contrast, require no fuel consumption to produce energy.[183] By the end of the century, one recent estimate suggests that the market potential for wind turbine will be 21,000 Mw.[184] The California Energy Commission expects wind machines to supply at least 8% of the state's electric power by the year 2000, enough electricity to run all the homes in Los Angeles.[185] The 1984 *Audubon Energy Plan* projects that, following their proposed tax policies with respect to imported oil, 1.6 quads of windpower, primarily in large-scale utility owned configurations, could be used to displace fossil and nuclear fuel in the year 2000; a figure that, based on the data in the *Plan*, represents less than 3% of North American high wind potential.[186]

179. R. MUNSON, THE POWER MAKERS 156 (1985). By late 1984, U.S. Windpower sold 800 Mw of power to Pacific Gas & Electric; by 1988, it expects to sell an additional 400 Mw to California utilities. *Id.*

180. Paris, *Palm Springs and the Wind People*, Forbes, June 3, 1985, at 170, 171.

181. OTA, NEW ELECTRIC POWER TECHNOLOGIES, *supra* note 174, at 93.

182. HOFFMAN, *supra* note 176, at 9. A quad is a unit of energy equal to one quadrillion British thermal units.

183. *Id.*

184. OTA, NEW ELECTRIC POWER TECHNOLOGIES, *supra* note 174, at 92 (citing SCIENCE APPLICATIONS INTERNATIONAL CORP., EARLY MARKET POTENTIAL FOR UTILITY APPLICATIONS OF WIND TURBINES, PRELIMINARY DRAFT (Electric Power Research Institute, Palo Alto, California, 1984)).

185. MUNSON, *supra* note 179, at 155.

186. NATIONAL AUDUBON SOCIETY, AUDUBON ENERGY PLAN, Vol. 1, at 52 (1984).

Given current levels of technology, the cost-efficiency of wind as an energy source is not always clear, however. One group of commentators have asserted that well-designed machines placed at windy sites generate power for less than 10 cents per kilowatt hour, but that such cost must be reduced by half to make wind power less expensive than power from new coal or nuclear plants.[187] However, future technological improvements are expected.

Wind availability also limits the spread of this technology. Relatively few sites have average wind speeds of at least 15 miles per hour, however, this speed is necessary to competitively produce electricity at the present time.[188] It is feared that the expiration, in 1985, of the federal renewable tax credit for investment in wind power property will both force many small firms out of the market and lower demand for wind conversion machines.[189]

Nevertheless, with technological advances and sustained interest in conservation, the appeal of wind conversion may attain renewed momentum. For individuals or commercial entities seeking to install wind conversion systems there may be a number of legal hurdles which may be encountered during a project. The following discussion addresses three primary legal issues raised by the adoption of wind as a source of energy: 1) Federal and "Little NEPA" requirements; 2) zoning restrictions; and 3) tort liability for private nuisance.

B. *Deployment and Use of Wind Energy Conversion Systems*

1. NEPA Requirements

The National Environmental Policy Act of 1969 (NEPA),[190] as noted earlier, requires that an Environmental Impact Statement (EIS) be prepared for "every recommendation or report on proposals for legislation or other major federal actions significantly affecting the quality of the human environment."[191] The prepa-

187. MUNSON, *supra* note 179, at 156.

188. *Id.* at 157; OTA, NEW ELECTRIC POWER TECHNOLOGIES, *supra* note 174, at 92. California, Texas, Oklahoma and the northwest have most of the existing machines, but there are promising sites in Michigan, Kansas and the rest of the northwest. *Id.*

189. OTA, NEW ELECTRIC POWER TECHNOLOGIES, *supra* note 174, at 264. *See* Tax Analysts, TAX NOTES Nov. 25, 1985 (committee action on November 15, 1985 was to recommend that residential and business energy tax credits for wind property not be renewed).

190. 42 U.S.C. §§ 4321-4370 (1982 & Supp. I 1983).

191. *Id.* at § 4332.

ration of an EIS can be time consuming and expensive. On the other hand, failure to meet NEPA obligations can lead to lengthy court proceedings and to significant litigation costs.

Wind energy projects directly conceived and carried out by the federal government, *e.g.*, government research and testing conducted under the Wind Energy Act, would clearly meet the "federal action" requirement. Whether a residual federal role in a given project will also mean that it is characterized as "federal action" for NEPA purposes is, however, an issue of concern for projects operating on federal grants, under cooperative contracts, or requiring some federal permit. Because the purpose of an EIS is to inform a federal decision maker, the distinguishing feature of "federal" action is the ability of a federal body to influence or control the outcome of action in material respects.[192] The use of federal funds without the exercise of federal controls is unlikely to satisfy the threshold requirement of a "federal action."[193]

The second threshold issue in deciding when an EIS must be prepared is whether the proposal constitutes "major" action "significantly affecting" the environment. The Council on Environmental Quality regulations define "major" actions in broad terms, encompassing all "actions with effects that may be major."[194] According to the regulations, this definition is not to be considered independently, however, from the meaning ascribed to "significantly."[195] Important factors which should be considered in assessing significance include: 1) the degree to which the proposed action affects public health and safety; 2) the uniqueness of the area affected; 3) the extent to which effects are likely to be highly controversial; 4) the extent to which the action may establish a precedent for future similar actions; 5) the extent to which the action is related to other actions that may have a cumulative effect; 6) the extent to which it may affect endangered or threatened species; and 7) whether the action threatens to violate requirements for the protection of the environment.[196]

192. W.J. RODGERS, JR., HANDBOOK ON ENVIRONMENTAL LAW 763 (1977).
193. GRAD, *supra* note 26, at § 9.02.
194. 4 C.F.R. § 508.18 (1985).
195. GRAD, *supra* note 26, at § 9.02.
196. *Id.* (9-47); 40 C.F.R. § 1508.27 (1985).

Given the decreasing involvement of the federal government in supporting renewable energy projects,[197] it is probable that federal NEPA requirements will only be triggered by very large wind conversion installations. State environmental policy statutes—little NEPAs—may, themselves, however, impose impact statement obligations. State law in this area varies greatly in its applicability and requirements. Some state statutes apply only to direct state action, others would effect private actions as well.[198] The following possible environmental consequences of wind conversion installations should therefore be borne in mind.

The impact of a wind conversion project will likely be magnified with the increasing scale of a project.[199] Wind farms are, therefore, more likely to face EIS requirements than are individual installations.[200]

During the construction phase of WECS installation, the primary environmental impact is the potential effects of site-clearing on air and water quality.[201] If on-site construction time is minimized, the problems of dust and siltation can also be minimized by prompt replanting of the surrounding area. Prefabricated rotors and towers can assist in this respect.[202] Access roads to larger, more remote installations will necessarily have a more permanent impact on the environment and proper maintenance of them will be required both during construction and afterward.

After construction, the environmental impacts of WECS are primarily aesthetic. Little can be done to hide a 225 foot tower without obstructing wind flow. Furthermore, locating systems in remote areas is only a partial solution since some of the most

197. As evidenced by decreasing expenditures, see *supra* note 167, and non-renewal of the energy tax credit schemes.

198. *See generally* GRAD, *supra* note 26, at § 9.08. *See, e.g.*, CAL. PUB. RES. CODE §§ 21080, 21160 (West 1977) ("project" includes private activity subject to public agency review); MINN. STAT. ANN. § 116C.01 (West Supp. 1986) (impact statements required of private actions "of more than local significance").

199. L. COIT, WIND ENERGY: LEGAL ISSUES AND INSTITUTIONAL BARRIERS 17 (Solar Energy Research Institute June 1979).

200. *See, e.g.*, L. COIT, *supra* note 199, at 17 (citing and discussing EPA, DEVELOPMENT STATUS AND ENVIRONMENTAL HAZARDS OF SEVERAL CANDIDATE ADVANCED ENERGY SYSTEMS (June 1977); expressing concern that the cumulative effect of a large array of wind machines might be significant). *But see* S. ROGERS, ERDA REPORT, AN EVALUATION OF THE POTENTIAL ENVIRONMENTAL EFFECTS OF WIND ENERGY SYSTEM DEVELOPMENT (1975) (the environmental effects of an array may be determined by observing a single machine).

201. U. COTY, WIND ENERGY MISSION ANALYSIS: FINAL REPORT 10-1 (1976) [hereinafter cited as COTY, MISSION ANALYSIS].

202. *Id.*

promising remote wind collection sites are currently appreciated for their scenic beauty. Ocean coastlines are a good example of areas where aesthetic environmental impacts will need to be considered in justifying the installation of wind conversion systems.

The operation of WECS has very little effect on the biological community, since high wind areas do not typically support thriving plant and animal life. Concern has been expressed, however, that low-flying migratory birds might be hit by the rotors. Thus, it is essential that site selection consider the flight patterns of bird species within the construction area.

The use of metallic rotors may also interfere with television reception. Such interference may be avoided by using non-metallic blades,[203] or siting machines in remote areas where most residents tend to use an interference-free cable or a highly directional antenna. With such an antenna, interference would not occur unless the unit was close to the line-of-sight television transmission path.[204] Similarly, interference with microwave transmission is only possible where a rotor passes directly through the line-of-sight beam path.[205]

Detailed early planning for a WECS project is necessary to avoid these adverse environmental effects, whether or not an EIS is required.

2. Zoning and Safety Restrictions[206]

Zoning ordinances are the primary means by which local governments exercise control over land use within their jurisdictions. Long recognized as a legitimate exercise of police power,[207] such laws are most likely to impinge on the installation of individual wind systems on private residential properties. Specifications of particular relevance include those pertaining to acceptable land uses, allowable structure heights, and the distances that must be maintained between structures and the property line (set-back re-

203. COIT, *supra* note 199, at 17.

204. COTY, MISSION ANALYSIS, *supra* note 201, at 10-3.

205. *Id.*

206. This section relies heavily upon work published as PROGRAM OF POLICY STUDIES IN SCIENCE AND TECHNOLOGY, GEORGE WASHINGTON UNIVERSITY, LEGAL-INSTITUTIONAL IMPLICATIONS OF WIND ENERGY CONVERSION SYSTEMS (1977) (NSF/RA-770203) [hereinafter cited as PROGRAM STUDY].

207. Village of Euclid v. Ambler Realty Co., 272 U.S. 365 (1926). *See generally* RATHKOPF, *supra* note 100, at §§ 12.02[4], 15, 42.

strictions).[208] Restrictions based on aesthetic acceptability such as requirements to screen structures, may also apply.[209] In rare cases, wind conversion systems may be specifically addressed in such provisions;[210] usually, however, general standards will have to be applied. This may raise difficulties of interpretation. For instance, is the height of a wind turbine to be measured from the top of its tower or from the highest point in the rotor arc? Similarly, should the distance to the property line be measured from the face of any above-grade tower footing, from the nearest surface of a tower "leg," or from the nearest guy-wire?[211] Unless the widespread use of wind systems places pressure on legislators to clarify the application of zoning ordinances to wind systems, idiosyncratic application of general provisions may be a source of frustration for WECS developers.[212]

Though zoning ordinances can be challenged if they are discriminatory, unreasonable, arbitrary or confiscatory,[213] these challenges are often unsuccessful. There are a number of devices, however, that allow zoning ordinances to be flexibly applied including provisions for variances, special permits, special exception uses, planned unit development, etc.[214]

208. PROGRAM STUDY, *supra* note 206, at 78.

209. Berman v. Parker, 348 U.S. 26 (1954) (strong dictum in favor of zoning for aesthetic objectives). On the scope and development of zoning to achieve aesthetic objectives, see RATHKOPF, *supra* note 100, at 14-1—14-60.

210. *See, e.g.*, Old Lyme, Connecticut Zoning Regulations, discussed in Shippee v. Zoning Board of Appeals of the Town of Old Lyme, 39 Conn. Supp. 436, 437, 466 A.2d 328, 329 (1983):

> Article II, § A.6.2 provides: "Alternative energy systems such as solar collectors and wind turbines may be erected upon the granting of a Special Exception by the Zoning Board of Appeal subject to such conditions and standards as the Board may establish: (a) giving consideration to the effect of the proposed alternative energy system on present and future dwellings in the vicinity; (b) that the proposed site is of adequate size and location to accommodate the alternate energy system without encroachment into open space yard set back requirements. A 30,000 sq. ft. minimum lot shall be required for installation of a wind turbine; (c) for wind turbines, (i) the tower's height shall not exceed 80 feet measured from its base (ground level) to the center line of the wind turbine; (ii) the tower shall be engineered and commercially available; (iii) the wind turbine shall be commercially available; (iv) the set back from any lot line shall be required to be, at a minimum, one tower height from the nearest boundary line."

211. PROGRAM STUDY, *supra* note 206, at 75.

212. In this connection, the development of a model zoning ordinance would be valuable to communities who wish to encourage wind energy conversion. *See* CORT, *supra* note 199, at 9.

213. *See generally* RATHKOPF, *supra* note 100, Chs. 4-6, 8.

214. For discussion of these devices, *see id.* at § 38-1 (variances); § 19-25 and § 20-9 (special permits); Ch. 41 (special exception uses); § 71-45 (planned unit development).

The grant of a variance usually requires a showing of unnecessary hardship, which may inhibit its use with respect to wind system installations.[215] Where provision is made for special uses conditionally permitted, general language may be more easily interpreted to include wind system installation, especially where an analogy to permitted television antenna towers can be made.[216] Such permits are usually discretionary, however, and may be subject to a variety of conditions, making the likelihood of obtaining one largely dependent on local attitudes and politics.

Safety codes may also establish standards which will affect wind system components. A tower, for example, might have to satisfy specified wind-resistance requirements, and height or base-area/height ratio requirements.[217]

Rural, farm or isolated areas are less likely to be subject to zoning ordinances and safety codes. To the extent that they do apply, however, they are likely to be less restrictive, varying with the needs of the locale.[218] Thus, wind farms or arrays will not find these provisions such of a deterrent, especially if conversion systems are installed by a municipality or utility, in which case local codes and ordinances may not apply, may be subject to state power plant siting statutes,[219] or may be subject to state public service commission exemption or review.[220]

3. WECS Installations as Nuisances

WECS installations located in populated areas face the possibility of suits brought for private nuisance. Actions in private nuisance are civil suits which offer either injunction or damages as a remedy. Generally, they are based on a claim that the plaintiff's use and enjoyment of his land has been interfered with substantially and unreasonably.[221] An interfering activity is unreasonable only if a reasonable person would conclude that the gravity of

215. *See id.* at § 38-22.

216. PROGRAM STUDY, *supra* note 206, at 77.

217. *See* ENVIRONMENTAL LAW INSTITUTE, LEGAL BARRIERS TO SOLAR HEATING AND COOLING OF BUILDINGS 57, 60-62 (1977).

218. PROGRAM STUDY, *supra* note 206, at 82.

219. *See, e.g.*, OHIO ADM. CODE ANN. § 4906.13 (1985).

220. *See, e.g.*, IND. CODE ANN. § 8-1-2-010 (Burns 1982); CONN. GEN. STAT. ANN. § 16-235 (West Supp. 1985) (zoning commissions and inland wetland agencies retain power to regulate *inter alia* the location of public service company "antennas" and "towers" where the public service company is not subject to the jurisdiction of the power facility evaluation council).

221. W. KEETON, PROSSER AND KEETON ON THE LAW OF TORTS § 87 (5th ed. 1984).

harm outweighs the utility of the activity.[222] Nevertheless, the activity may be found unreasonable despite a finding that the utility outweighs the harm, if an alternative means exists which would avoid the substantial amount of harm without sacrificing the benefits.[223]

Analysis of the New Jersey case of *Rose v. Chaiken*[224] provides insight into the possible application of private nuisance standards to wind turbines. The New Jersey Superior Court held that a wind turbine, located in a quiet residential area, constituted an actionable private nuisance.[225] New Jersey case law allows private nuisance actions if two elements are present: (1) injury to the health and comfort of ordinary people in the vicinity, and (2) unreasonableness of that injury under all circumstances.[226] The plaintiffs persuaded the court that their health and comfort had been injured by the noise produced night and day by the windturbine.[227] Against this harm, the court weighed the social utility of this particular wind turbine. Although the court recognized that the device represented a scientific advance which offered social utility, it found such benefit insignificant compared to the harm resulting when people were prevented from enjoying the "sanctity" of their homes.[228] The finding of unreasonableness was supported by judicial notice that less intrusive means to conserve energy and save on electric bills were available.[229] An additional factor, although not dispositive, was the fact that the sound levels (56-61 decibels) exceeded the 50 decibel limit permissible under the local zoning ordinance.[230] The violation of the zoning ordinance provided an alternative basis for granting injunctive relief.[231]

As in *Rose v. Chaiken*, where an activity violates municipal zoning ordinances, such ordinances may be considered as one indicator of the reasonable standards of a community. The converse is

222. *Id.* at § 88.
223. *Id.*
224. 187 N.J. Super. 210, 453 A.2d 1378 (1982).
225. *Id.* at 218, 453 A.2d at 1382.
226. *Id.* at 217, 453 A.2d at 1381.
227. *Id.* at 216, 453 A.2d at 1380-1381. The court accepted claims that the noise disturbed such activities as reading, eating, watching television and general relaxation, and caused nervousness, dizziness, loss of sleep and fatigue. *Id.*
228. *Id.* at 219, 453 A.2d at 1383.
229. *Id.* at 219, 453 A.2d at 1382.
230. *Id.* at 217, 453 A.2d at 1380, 1382.
231. *Id.* at 220-222, 453 A.2d at 1384.

not necessarily true. An interfering activity may be deemed unreasonable although it meets the limits of zoning ordinance.[232] Reasonable care to minimize the extent of interference with others is required. Legislation may declare certain activities a nuisance or it may authorize an activity which would otherwise be considered a nuisance.[233]

Despite complaints similar to that in *Rose v. Chaiken* about the noise produced by wind energy conversion units,[234] some proponents of wind systems claim the machines can be operated quietly. Standing a few feet from the passage of a blade tip of a 125 foot diameter unit, some people, for example, have described the sound as a barely noticeable "swish."[235] Even a quiet wind turbine may, however, constitute a nuisance on other grounds. If, for example, a wind turbine causes vibrations which damage neighboring property, a nuisance action might be brought.[236] Generally, actions for nuisance cannot be based solely on aesthetics,[237] but aesthetic offensiveness may strengthen a claim being argued on other grounds.

The threat of a nuisance-based suit is greatest in the case of wind installations in a residential area. Large-scale projects located in remote regions run a lower risk for two reasons: (1) they have fewer neighbors who might be affected by the noise and (2) the courts may require that those who build residences in areas beyond the limits of a city and the protection offered by zoning regulations accept a degree of discomfort resulting from activities which are not unreasonable, given the character of the area.[238]

232. KEETON, *supra* note 221, at 633.

233. *Id.* Lobbyists for zoning ordinances which favor windmills should bear in mind, however, that statutory authorization of a nuisance may meet a constitutional challenge for "taking."

234. Paris, *supra* note 176, at 171, 181, reports that homeowners in Palm Springs, California complain that windfarms in the area create a "highly irritating whirring and humming."

235. COTY, MISSION ANALYSIS, *supra* note 201, at 10-3, reporting personal experiences with the ERDA/NASA unit at Plumbrook.

236. KEETON, *supra* note 221, at 616.

237. *See* Annot., 84 A.L.R.2d 653, 658 § 4 (1962).

238. KEETON, *supra* note 221, at 630 (citing Oak Haven Trailer Ct., Inc. v. Western Wayne Co. Conservation Assoc., 3 Mich. App. 83, 141 N.W.2d 645 (1966), *aff'd*, 380 Mich. 526, 158 N.W.2d 463 (denying an injunction in a nuisance-based suit against a gun club located in an area not zoned for residences)).

IV. CONCLUSION

The legal issues raised by the environmental impacts of two technologies on the cutting edge of renewable resource development have been examined in this paper.

It is evident that the development of solar energy and wind power provides important resources for the future. Widespread adoptions of these technologies in either decentralized or centralized contexts are a future possibility. Their costs, including environmental and regulatory costs, should be a matter of concern. It may be anticipated that technological advances, and the removal of barriers through legislation, may further this development so that the promise of renewable energy sources, such as solar energy and windpower, may be fully realized.