# FEDERAL GIANTS

## and

# WIND ENERGY ENTREPRENEURS

**Utility-Scale Windpower in America**
**1970-1990**

by

Adam Harris Serchuk

Dissertation submitted to the Faculty of the
Virginia Polytechnic Institute and State University
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**(ABSTRACT)**

In 1994, the use of wind turbines for electricity generation verges on economic respectability. Two contradictory trends have prepared a fertile niche for utility-scale windpower. The introduction of "deregulatory," competitive principles onto the electric industry fostered a non-utility generating sector relying on unconventional technologies. Simultaneously, policy-makers using "hyper-regulatory" tactics to pursue social goals such as reduced pollution pushed utilities to include renewable energy in their resource plans. Both tendencies advanced windpower.

By comparing the Federal Wind Energy Program (FWEP) to California's entrepreneurial windpower industry, this dissertation argues that windpower constituted a conservative addition to the American electric utility system, rather than a radical challenge to it. True, venture capitalists producing and delivering windpower to the nation's transmission grid challenged the utilities' financial control. But participants in the windpower story have constructed a version of windpower largely compatible with the electric system.

The most notable products of the FWEP--multi-megawatt wind generators--proved too complex, too expensive and too unreliable for their environment. Windpower entrepreneurs, by contrast, devised smaller machines better suited to the market. Equally important, regulatory support shielded the windfarms from the political and economic turnabouts that scuttled the ambitious FWEP, which relied completely on ephemeral Federal

patronage. Today's wind entrepreneurs present their technology as a cost-effective addition to the conventional generating system, rather than as a social tool dependent on government support for environmentalism.

But the story of windpower does not constitute a self-contained drama. In addition to pitched negotiations over wind energy, the story implicates the changing utility industry, shifts in global energy politics, and emergent environmentalism. The windfarms' "success" and the FWEP's "failure" frequently depended on actors' ability to exploit or insulate themselves from events unrelated to windpower itself. Thus, the dissertation binds first-person accounts from participants in the windpower story to strands of larger histories, recounted through periodical and secondary literature. The dissertation speaks to historians, sociologists, energy managers, policy-makers and members of the community of "science and technology studies." Ultimately, it aims to produce a tool for the actors and policy-makers it describes.

## ACKNOWLEDGEMENTS

This project reflects the unselfish guidance of my friend and academic advisor, Dr. Richard F. Hirsh. My perspective on the American electric utility industry evolved while assisting Richard on a report concerning the Pacific Gas and Electric Company's $ACT^2$ energy efficiency project,[1] and on his grant from the National Science Foundation to study the origins of "demand-side management."[2] I first articulated some of the insights contained here on the nature of conservative change in the electric utility system while collaborating with Richard on a paper presented to the Society for the History of Technology.[3] Richard generously encouraged me to include in my dissertation the results of this research, some of which will find a place in his forthcoming book. I hope he will include elements of my project in his future work.

I also thank the other members of my dissertation committee, Carl Weinberg, Dr. Saifur Rahman, Dr. Ellsworth Fuhrman and Dr. Peter Barker, for their support during the past years. I owe Carl particular thanks for guiding me toward this topic, and for suggesting that I attend the 1993 NARUC/DOE Renewable Energy Conference in Savannah, GA, where I met and interviewed many players in the story of windpower.

My gratitude also goes to Virginia Tech's Graduate Program in Science and Technology Studies, directed previously by Dr. Robert Paterson, and currently by Dr. Richard Burian. Not only have I received an excellent education at Virginia Tech, but the program's Steering Committee graciously granted me a leave of absence and held my

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[1]Richard F. Hirsh and Bettye H. Pruitt, The Winthrop Group, "The Background, Origins and Formative Phase of the Advanced Customer Technology Test ($ACT^2$) for Maximum Energy Efficiency," prepared for the Pacific Gas and Electric Company (1993).

[2]"Renegotiating the Social Contract: The Demand-side Revolution and the Restructuring of the American Electric Utility Industry, 1978-1992," NSF grant, NSF Office of Science and Technology Studies, principal investigator Richard F. Hirsh.

[3]Richard F. Hirsh and Adam H. Serchuk, "Momentum Shifts in the Electric Utility Industry: Catastrophic Change or No Change at All?" 1993 Annual Meeting of the Society for the History of Technology, Washington, DC (October 1993).

funding until I returned from a two-and-a-half year hiatus in the Peace Corps. Perhaps they will receive this document as a token of my thanks.

Finally, let me recognize those windpower pioneers that shared their time and insight for this project. If my admiration for their efforts does not appear clearly enough in these pages, let me now emphasize it. Energy constitutes a vital element of industrialized life. Those who courageously attempted--along whatever path--to make America's energy use sustainable, safer, and less profligate deserve our respect.

## INTERVIEW LIST

Federal Wind Energy Program:
Louis Divone, former head of the FWEP, now Associate Deputy Assistant Secretary for Buildings Technology;
Daniel Ancona, program manager for the FWEP since 1977 (interviewed once by telephone, and once in person);
Robert Thresher, formerly a contractor for the FWEP, now Director of the Wind Technology Division at the National Renewable Energy Laboratory.

American Wind Energy Association:
Randall Swisher, Executive Director of AWEA;
Thomas Gray, former Executive Director of AWEA, now Northeast Representative.

Utility perspectives:
Joseph Iannucci, formerly in charge of wind programs at Pacific Gas and Electric, now of Distributed Utility Associates;
Carl Weinberg, former director of research and development for PG&E, now President-elect of the AWEA;
Robert Bumgarner, Blue Ridge Electric Membership Corporation, liaison at utility which hosted a FWEP turbine;
Grant Ayers, Vice President for Engineering at BREMCo;
Edgar DeMeo, director of solar and wind projects for the Electric Power Research Institute, the utility trade association.

Developers' perspectives:
Janice Hamrin, founder of the Independent Energy Producers Association, now with Hansen, McOuat, Hamrin and Rohde, an energy consulting firm;
Michael Lotker, formerly of Renewable Energy Ventures and LUZ International, now with Ormat Inc.

Manufacturers' perspectives:
Jay Carter, Jr., manufacturer of turbines for windfarm market (interview by Robert Kahn, provided through the kindness of Mr. Kahn with the permission of Mr. Carter);
Donald Bain, formerly an engineer for Lockheed's windpower research effort, now a political analyst for the Oregon Public Utilities Commission;
Robert Lynette, formerly an engineer on Boeing's wind development effort, now principal of R. Lynette & Associates (interviewed by telephone).

Kenetech Corp.:
William Holley, Director of Research and Development for Kenetech Windpower;
James Eisen, General Counsel for Kenetech Windpower;
Margaret Rueger, formerly in PG&E's Division of Engineering Planning, now director of project finance group at Kenetech Energy Systems;

Glenn Ikemoto, formerly in PG&E's Division of Engineering Planning, now retired from Kenetech Corp.;
Deborah Guillory, Director of Business Development for Kenetech Corp.

Environmentalism:
Ralph Cavanagh, Director of Energy Programs at the Natural Resources Defense Council.

California:
David Morse, formerly of the California Energy Commission, now Chief of Energy Resources Branch at the California Public Utility Commission (interviewed by telephone);
Scott Cauchois, formerly of the CEC now Project Manager for the CPUC;
Karen Sinclair, formerly of CPUC, now staff analyst at NREL;
Gerbux Kahlon, Regulatory Program Specialist at the CPUC.

# LARGE MODERN AMERICAN WIND TURBINES

**MOD-0:** 100-kW FWEP "test bed" built by NASA and installed at NASA's Plum Brook Station near Sandusky, OH, in 1976. 100-foot steel-truss tower, 125-foot downwind rotor. Used to test components and gather data. Dismantled.

**MOD-0As:** Four 200-kW FWEP machines installed and operated between 1977 and 1980 at Clayton, NM, Culebra Island, Puerto Rico, Block Island, RI and Oahu, HI. Essentially an upgraded MOD-0. First unit built by NASA, last three by Westinghouse. Program considered a success. Dismantled.

**MOD-1:** One 2000-kW FWEP machine built by General Electric and installed at Boone, NC. 200-foot downwind rotor with pitch control. 131-foot steel truss tower. Operated 130 hours between 1979 and 1981 before final failure. Much more expensive than anticipated. Dismantled in 1981.

**MOD-1A:** NASA-directed "strawman" design study performed by GE in 1979, exploring the cost benefits of concepts such as teetered hubs and partial-span pitch control. Never built.

**MOD-2:** Built by Boeing. Three 2500-kW units installed by the Bonneville Power Administration near Goldendale, WA, in 1980; one by the Bureau of Reclamation near Medicine Bow, WY, in 1982; and one purchased by Pacific Gas and Electric and installed in Solano County, CA, in 1982. 300-foot, upwind, teetering rotor with partial-span pitch control. Tubular steel tower. Numerous operating problems. All dismantled by 1988.

**MOD-3:** Projected intermediate-size turbine. DOE canceled project in 1979. No manufacturer thought it possible to meet the MOD-3's cost goals, and the FWEP found its development schedule too rapid to take advantage of data from earlier models.

**MOD-4:** Projected large turbine, canceled with MOD-3.

**MOD-5A:** Designed for the FWEP as a 7300-kW machine by General Electric. 400-foot wood-epoxy rotor on soft tubular steel tower. DOE requested its MOD-5 contractors to share the project's cost. After failing to find a utility partner and worried by the expiration of tax credits for purchasers of wind equipment, GE abandoned project in 1983.

**MOD-5B:** Originally designed for the FWEP as 7200-kW machine with a 420-foot upwind rotor, but built as a 3200-kW unit with a 320-foot rotor. Purchase by Hawaiian Electric Industries and installed in Oahu in 1987. Sold to entrepreneurs in 1992.

**MOD-6H:** Advanced intermediate-size horizontal-axis turbine project; canceled in early 1980s due to lack of funds. No contracts awarded.

**MOD-6V:** Advanced intermediate-size vertical-axis project; canceled with MOD-6H.

**WTS-4:** One 4000-MW unit built by Hamilton Standard and Karlskronavarvet and purchased by the Bureau of Reclamation. 256-foot downwind rotor on a tubular steel tower. Installed 1982. Numerous operating problems. Sold as government surplus, destroyed in storm in 1994. Not financed by FWEP.

**Bendix/Schachle WTG:** One 3000-kW purchased by Southern California Edison and installed near Palm Springs, CA. 165-foot, three-bladed rotor, steel truss tower. Entire unit rotated into wind. Torque transferred to generator on ground by flexible coupling. Not financed by FWEP. Operational 1980, numerous problems. Dismantled. Not financed by the FWEP.

**WWG-600s:** Fifteen 600-kW turbines designed by Westinghouse and sold to Hawaiian Electric Company. Installed 1985. Sold in 1992 to entrepreneurs. Not financed by the FWEP.

## ACRONYMS AND ABBREVIATIONS

AB . . . . (California) Assembly Bill
AEC . . . . Atomic Energy Commission
AFUDC . . . . Allowance for Funds Used During Construction
ALCOA . . . . Aluminum Company of America
AWEA . . . . American Wind Energy Association
BEC . . . . Boeing Engineering and Construction
BPA . . . . Bonneville Power Administration
BREMCo . . . . Blue Ridge Electrical Membership Corporation
Btu . . . . British thermal unit
BuRec . . . . Bureau of Reclamation
CEC . . . . California Energy Commission
COE . . . . cost of energy
CPUC . . . . California Public Utilities Commission
db . . . . decibels
DOE . . . . Department of Energy
DPR . . . . Domestic Policy Review
EDF . . . . Environmental Defense Fund
EIS . . . . environmental impact statement
EPRI . . . . Electric Power Research Institute
ERDA . . . . Energy Research and Development Administration
ESI . . . . Energy Sciences, Inc.
FERC . . . . Federal Energy Regulatory Commission
FPA . . . . Federal Power Act
FPC . . . . Federal Power Commission
FWEP . . . . Federal Wind Energy Program
FY . . . . fiscal year
GAO . . . . General Accounting Office
GE . . . . General Electric Company
HAWT . . . . horizontal-axis wind turbine
HECo . . . . Hawaiian Electric Company
hp . . . . horsepower
IEPA . . . . Independent Energy Producers Association
IRS . . . . Internal Revenue Service
ISO4 . . . . Interim Standard Offer #4
kW . . . . kilowatt
kWh . . . . kilowatt-hours
LCC . . . . load carrying capability
MOSTAB . . . . Modular Stability Derivative Program
mph . . . . miles per hour
MW . . . . megawatt
NASA . . . . National Aeronautics and Space Administration
NEA . . . . National Energy Act of 1978
NEPA . . . . National Environmental Policy Act of 1970

NREL . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . National Renewable Energy Laboratory
NSF . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . National Science Foundation
OMB . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . Office of Management and Budget
OPEC . . . . . . . . . . . . . . . . . . . . . . . . . . Organization of Petroleum Exporting Countries
PG&E . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . Pacific Gas & Electric Company
PNL . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . Pacific Northwest Laboratories
PUHCA . . . . . . . . . . . . . . . . . . . . . . . . . Public Utility Holding Company Act of 1935
PURPA . . . . . . . . . . . . . . . . . . . . . . . . Public Utility Regulatory Policies Act of 1978
QF . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . qualifying facility
RANN . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . Research Applied to National Needs
REA . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . Rural Electrification Administration
REV . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . Renewable Energy Ventures
rpm . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . revolutions per minute
SCE . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . Southern California Edison Company
SDG&E . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . San Diego Gas and Electric Company
SERI . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . Solar Energy Research Institute
TVA . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . Tennessee Valley Authority
USDA . . . . . . . . . . . . . . . . . . . . . . . . . . . . United States Department of Agriculture
VAWT . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . vertical-axis wind turbine
WECS . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . wind energy conversion system
WTG . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . wind turbine generator

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# INTRODUCTION
# Windpower:
# A Conservative Alternative

## PART I: Windpower on Howard's Knob and in the Altamont Pass

Howard's Knob rises four thousand windy feet over Boone, NC. A visitor to the small park at the top finds little trace of its former occupant, a giant electricity-generating "windmill" that adorned the peak between 1979 and 1981. Old-time residents gladly recall the ill-fated behemoth, built by General Electric for a Federal program managed by the National Aeronautic and Space Agency. During the cold winter nights of the "energy crisis" of the 1970s, young hippies and crusty townsfolk alike applauded the government's effort to explore the nation's energy options. But Boone's towering neighbor, the old-timers chuckle, turned out to be a thirty-million-dollar failure, auctioned off ignominiously for scrap to a nearby yarn factory.

For a more sympathetic account, one can visit the Blue Ridge Electric Membership Corporation. A poster-sized photograph of the "MOD-1" wind turbine hangs conspicuously in BREMCo's foyer, showing the machine's tall steel-truss tower, a boxy white nacelle the size of a hefty truck, and a 200-foot, two-bladed rotor. BREMCo's District Manager, Robert Bumgarner, who worked closely with the wind turbine's Federal overseers, gleefully drags a cache of memorabilia from his office closet: a two-foot model, boxes of slides, a dumbbell-sized bolt from the rotor, and even an apparently empty can labeled "Air Sliced by the World's Largest Windmill." But Bumgarner's fond memories notwithstanding, the Federal government's effort to design and commercialize multi-megawatt wind machines retains few fans. Only one of the dozen or so giant turbines erected in the 1970s and 1980s still turns. In 1994, the resurgent Federal Wind Energy Program limits its activities to assisting private technology development, rather than acting as a central planning authority.

By contrast, the facilities erected in California by the world's premier private wind energy developer, Kenetech Windpower, reveal wind generators as a living, competing technology. On the dry, grassy ridges of the Altamont Pass overlooking Interstate Highway 580, the wind drives the fifty-six-foot rotors of thousands of lean, three-bladed turbines. Nearby, a stand of larger, more robust machines faces the steady breeze; a guide explains that Kenetech hopes that the cost of electricity generated by this new model will match that of conventional fossil-fueled generating capacity.

Back at the firm's headquarters in San Francisco's business district, Kenetech projects a corporate image of suits, hardwood and glossy literature. Presumably, the firm intends this serious mien to soothe potential investors, utility customers or government regulators who associate windpower with bib overalls and hippies. Company employees present their technology as the result of decisions made and risks taken by private entrepreneurs; most know little about the Federal giant turbines except that they "failed."

Indeed, in 1994 windpower seems poised to take off, after benefitting in previous years from two shifts in the American electric utility industry. During the 1980s, a *de*-regulatory trend created and nurtured a non-utility generating sector, in which entrepreneurs using unconventional energy technologies such as wind turbines sold power to established electric companies for re-sale over the nation's transmission grid. This trend promoted reliance on market principles to structure the energy industry. Simultaneously, policy-makers pursued a *hyper*-regulatory course, using government power to further social goals such as reducing particulate pollution. Often, they required the nation's regulated utilities to include "renewable" energy capacity in their resource plans. While these contradictory historical movements seem headed for a showdown,[4] they have up to now created a

[4]I use the term "hyper-regulation" to denote a qualitative transformation of government oversight of the electric industry. Whereas utility commissions traditionally promoted universal service at reasonable rates, regulators in past decades have added non-economic goals such as environmental quality to their agenda. Some even foresee environmental protection as regulation's primary purpose in a coming era of economic deregulation. For a succinct articulation of the tension between deregulation and hyper-regulation, see Daniel Yergin, Gary Simon and I.C. Bupp, "Caught in the Muddle: The Dilemma of Today's Electric Power Industry," *Natural Resources and Environment* 8 (Winter 1994), pp. 3-4.

protected niche in which windpower has matured. California, America's most populous state and the international center of renewable energy development, generates some 2.8 billion kWh of energy from windpower annually,[5] or over 1% of the power consumed by its 30 million residents.

Many observers contend that windpower has reached commercial viability. Between 1995 and 2000, windpower may become the cheapest source of renewable energy, beating out solar, biomass, geothermal and new hydroelectric power.[6] Kenetech Windpower claims that its new turbine can generate power for 5 cents/kWh, making it competitive with new fossil-fueled capacity. This feat, if possible, could relieve Kenetech from dependence on special governmental support for environmentally-preferred technologies.[7] Attracted by windpower's perceived environmental and economic benefits, a number of private utilities now ponder purchases of wind-generated power, and some may even install their own wind facilities.[8] An editorial in *Science* magazine considers it "realistic" that windpower might ultimately provide 20% of the nation's electricity.[9]

The Federal government, meanwhile, retains its commitment to fostering a renewable energy sector. The National Energy Policy Act, passed in the waning months of George Bush's presidency, offers a 1.5 cent/kWh tax credit for the production of electricity from

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[5]Utility Wind Interest Group, "An old idea takes new shape for electric utilities," Electric Power Research Institute (November 1990, reprint November 1992), no pagination.

[6]Jan Hamrin and Nancy Rader, *Investing in the Future: A Regulator's Guide to Renewables* (Washington, DC: National Association of Regulatory Utility Commissioners, 1993), table 3.3.

[7]Kenetech Windpower, "The 33M-VS Wind Turbine," brochure (no date), no pagination.

[8]See, for example, "East breaks West's wind-power monopoly," *The Wall Street Journal* (31 August 1993), p. B1, and; Eric Harrison, "Utilities Study Ways to Harness the Wind," *The Los Angeles Times* (5 November 1991), p. A5.

[9]Philip H. Abelson, "Power from Wind Turbines (editorial)," *Science* 261 (3 September 1993), p. 1255.

renewable resources such as wind.[10] In 1993, President Bill Clinton's Secretary of Energy, Hazel O'Leary, indicated her own preferences by placing photographs of windfarms and solar energy installations in the corridor leading to her office, where pictures of nuclear plants and submarines once hung.[11] All told, the future for wind energy seems promising. While no-one expects windpower to supplant other forms of generation, advocates and observers expect it to become a valuable and cost-effective element of the nation's generating mix.

## PART II: The Thesis, and Why it Matters

This dissertation contends that today's windpower represents a conservative addition to America's established utility system,[12] rather than a radical challenge to it. By comparing the FWEP of the 1970s and 1980s to the emergent entrepreneurial windpower industry in California, the analysis shows that the fortunes of windpower depended on two factors: the historical actors' abilities to insulate their version of windpower from the vagaries of economics and a changing political environment; and an ability to define goals that resonated with established institutions and larger historical movements. Because windpower ultimately represents a minor actor in a larger play, its survival has hinged largely on defining a version of success compatible with its environment. The Federal program failed to do this, while the entrepreneurs have so far succeeded. This "success"

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[10]U.S. Congress, Committee of Conference, *Energy Policy Act of 1992: Conference Report to accompany H.R. 776*, 102d Congress, 2d Session, Serial No. 102-1018 (Washington, DC: U.S. Government Printing Office, 1992), p. 259.

[11]Al Kaman, "Change in the Wind at Energy," *The Washington Post* (14 April 1993), p. A8.

[12]This analysis uses the term "system" developed by Hughes in his historical portrait of the electric utility industry. Hughes' most important insight has been that the generation, transmission and distribution of electricity occur within a technological *system*. For the system to thrive, system-builders knit into a "seamless web" considerations that an outside observer might label economic, educational, legal, administrative or technical. Large modern systems bind these elements into a whole, and the study of such systems must partially abandon conventional analytic categories. The American electric "system" of the mid-twentieth century included utilities and their residential and industrial customers, regulators, equipment manufacturers and fuel suppliers, augmented by hardware, use patterns, and management practices, and countless other elements. For decades, the system succeeded by drawing these elements into a "consensus," allowing utility managers to act as spokesmen for a coalition including--they maintained--all relevant parties. Thomas P. Hughes, *Networks of Power: Electrification in Western Society 1880-1930* (Baltimore: The Johns Hopkins Press, 1983).

consists of conservative adaptation to the existing electric system, rather than its forced change.

The story deserves telling for two reasons. First, the history of windpower forms an facet of *energy* history. Energy use remains a vital but underexamined determinant of modern life. As the developed world tinkers with a profligate and polluting scheme of energy production and use, and as the developing world industrializes, the attraction of "renewable" sources of power increases. The more we know of how such sources can fit into a modern society, the better.

Second, the story of windpower concerns *innovation.* It questions policy-makers' ability to induce meaningful technological change through the exercise of governmental will. In contrast to textbook examples of *laissez-faire*, market-driven technological development, Federal managers tried--and failed--to knit giant wind turbines into the existing electric supply system for political and social reasons. An alternate--and hitherto successful--"entrepreneurial" approach to windpower depended equally strongly on governmental intervention in the electrical system, which had formerly operated as a natural monopoly. But the set of policies that encouraged entrepreneurial windpower comprises a bewildering mix of unintended consequences, purported economic inefficiencies, and value-laden trade-offs. It is hard to see how this melange offers a recipe for inducing innovation. Yet, the very complexity calls us to examine the episode carefully. All arenas of human activity constitute complex systems, and we inevitably desire to intervene in them for social or political reasons. Recounting the story of windpower offers an invaluable chance to explore the limits of human intentionality in changing such a system.

## PART III: Who Will Be Interested

The work presented here embodies two tensions. First, it contrasts and combines analyses offered by participants in the history of windpower with the perspective of an outsider. The structure of the dissertation denies the common distinction between "actors" and "analysts." By taking seriously the accounts offered by actors in interviews, government documents and periodicals, this research shows that all people constantly act as historians; that is, they use narratives to appraise hypotheses of causality and change. Due to training and culture they often do so with limited tools, and unlike most professional historians, they use their historical judgements as the basis of worldly actions.[13] But they share the act of historical analysis with professional historians. Yet, the dissertation makes assessments and draws conclusions not found in the historical actors' own accounts, and thus contains the tension of an outsider writing about insiders, common to many studies of science, technology and policy. Ultimately, the dissertation represents a multi-stranded account that exceeds the varieties of causality and breadth of conclusions found in the historical subjects' discourse.

The dissertation locates a second tension between factors identified by many of the actors as internal and external. Building off the actors' contention that the history of windpower cannot be understood as a self-contained story, it argues that the history of windpower implicates the history of the electric utility industry, energy history, and ultimately American history as a whole. (Naturally, glimpses of these stories appear here through secondary and periodical literature.) But the dissertation tries to distinguish the various causal factors in a rigorous way, and show how the factors cast by actors as "internal" often embody "external" considerations. For example, the analysis shows that "technological" decisions often incorporate positions and agendas dismissed by the actors as "political." In sum, this dissertation tells a yet untold story, while maintaining that an adequate explanation of historical causality demands the relation of much larger stories at the same time.

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[13]This perspective resembles that of Michel Callon, who asserts that all engineers involved in technological design, development and diffusion "constantly construct hypotheses and forms of argument that pull these participants into the field of sociological analysis." Callon argues that technologists inevitably and naturally act as sociologists. Michel Callon, "Society in the Making: The Study of Technology as a Tool for Sociological Analysis," in Bijker, Hughes and Pinch (eds.), *The Social Construction of Technological Systems*, p. 83.

Historians

At a finer level, the story of windpower involves concerns important to various audiences. Historians of technology will be interested to re-consider an issue outlined by Hughes, the purported distinction between conservative and radical innovation. The former, Hughes believes, preserves technological systems, and frequently originates with scientists or engineers with a stake in the *status quo*. A radical innovation, on the other hand, often comes from independent inventors. The existing system cannot incorporate the new technology, which may form the cornerstone of a new system. Hughes seems to distinguish between the two quite sharply.[14]

The windpower story draws historiographical significance and dramatic tension from questioning that distinction. Hughes implies that negotiations concerning acceptance of a new technology hang on whether the innovation is *essentially* radical or conservative, but in the story of windpower those attributes *result* from negotiations. Some actors lobbied for utilities to adopt windpower as simply another supply option into the grid that they owned and managed. Others pushed for privately-owned windfarms, mostly outside the utilities' control. Still other actors envisioned windpower as a household or community-based energy option able to provide a radical alternative to the established electric system. The conservative or radical nature of windpower today remains a contentious issue, rather than an uncomplicated characteristic that we may use to explain historical events.

Sociologists

Sociologists concerned with technology will find in this analysis further food for the continuing discussion over micro- and macro-level analysis. Pinch and Bijker,[15] in well-

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[14]Hughes, *American Genesis: A Century of Invention and Technological Enthusiasm 1870-1970* (New York: Penguin Books, 1989), pp. 53-54; Hughes, "The Evolution of Large Technological Systems," in Wiebe E. Bijker, Hughes and Trevor J. Pinch (eds.), *The Social Construction of Technological Systems: New Directions in the Sociology and History of Technology* (Cambridge, MA: The MIT Press, 1987), pp. 57-59.

[15]Pinch and Bijker, "The Social Construction of Facts and Artifacts: Or How the Sociology of Science and the Sociology of Technology Might Benefit each Other" in Bijker, Hughes and Pinch (eds.), *The Social Construction of Technological Systems*, pp. 17-50.

known work on the social construction of technology, consider invention not as an event but as a process in which a number of relevant social groups negotiate the form an envisioned technology will take. They direct our attention to the "alternation of variation and selection" in a technology's emergence, asking who took part in the negotiation, and how they pursued their ends. Russell and Winner,[16] in separate responses, add that analysts should not unquestioningly accept the presence of "relevant groups" without asking also who was absent from the negotiations, either because they were excluded, because they lacked necessary information, or because they considered themselves irrelevant.

The combination of Pinch and Bijker's original queries with Russell's and Winner's caveats helps unpack the negotiations that defined windpower. Consider the role of NASA in the Federal wind initiative. At first glance incongruous, NASA's active participation indicates (in addition to other factors) its managers' aspiration to re-define the maligned agency in the post-Apollo era as an arbiter of energy technology. Thus, NASA's vision of windpower reflected its management and design culture, as well as its political agenda. In contrast, consider the nation's electric utilities, most of whom remained aloof from negotiations over windpower. In some cases, they judged the debate irrelevant, underestimating the pressure that regulators would bring to bear on them to adopt renewable-resources. In others, they declared themselves *temporarily* uninterested, preferring to get involved only after--and if--some other entity had borne the financial risks of developing the dubious technology. In the case of both NASA and the utilities, an attention to the micro-level negotiations can supply valuable understanding of historically causal factors.

Yet, it is a mistake to conceive of windpower only as the center of a web of negotiations. Windpower often benefitted serendipitously or suffered from powerful but

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[16]Stewart Russell, "The Social Construction of Artefacts: A Response to Pinch and Bijker," *Social Studies of Science* 16 (1986), pp. 331-46; Langdon Winner, "Upon Opening the Black Box and Finding it Empty: Social Constructivism and the Philosophy of Technology" in Joseph C. Pitt and Elena Lugo (eds.), *The Technology of Discovery and the Discovery of Technology* (Blacksburg, VA: The Society for Philosophy and Technology, 1991), pp. 503-519.

unrelated events. For example, while the Public Utility Regulatory Policies Act of 1978, passed largely as a rate-reform measure to encourage conservation, unexpectedly opened the door to entrepreneurial electricity generation, President Ronald Reagan's conviction that environmental protection dampened economic vigor squelched almost all Federal support for renewable energy. Such causally significant institutional factors do not represent "negotiations," and they do not easily fit Pinch and Bijker's micro-level schema of technological development.

We can augment Pinch and Bijker's perspective by considering Russell's treatment of British cogeneration (the use of excess steam from electricity generation for heating). "Somehow," Russell writes, this alternative energy technology "seems to have found only a limited role and precarious existence in very specific circumstances in the interstices of the sector--or simply fallen in between the gaps separating the existing institutions."[17] Russell's insight helps understand the story of windpower, which owes its success as much to *un*intended social action in other areas, as to tense negotiations between parties interested in it for its own sake.

Another area of sociological significance in the windpower story concerns the ability of human managers to bend a complex technological system to their will, for example by forcing it to accept a new type of hardware. Both Law and Latour,[18] for instance, extensively consider the extent to which human managers and engineers can cajole technology into cooperating with their plans. Callon, in appraising the development of the electric vehicle in France, concludes that the state lacks the resources to substitute for public demand in making technological or industrial decisions.[19] Hughes, on the other hand, gives

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[17]Russell, "Writing energy history: explaining the neglect of CHP/DH in Britain," *British Journal of the History of Science* 26 (1993), p. 34.

[18]Bruno Latour, "*The Prince* for Machines as Well as for Machinations" in Brian Elliot (ed.), *Technology and Social Process* (Edinburgh: Edinburgh University Press, 1988), pp. 20-43; John Law, "The Anatomy of a Socio-technical Struggle: The Design of the TSR2" in Elliot (ed.), *Technology and Social Process*, pp. 44-69.

[19]Michel Callon, "the state and technical innovation: a case study of the electrical vehicle in france," *Research Policy* 9 (1980), pp. 358-376.

slightly more importance to human actors in a technological system because they "have degrees of freedom not possessed by artefacts." Although modern systems tend to minimize the role of human elements, Hughes believes that humans still construct and destroy the alternative configurations of technology.[20] All these analysts enjoin us to explore specific cases of human intervention into technological systems, as a way to mark the limits of human agency.

This continuing theoretical discussion can benefit from considering windpower. Federal managers failed to substitute their will, grounded in political and social considerations, for a market-based demand for wind-generated electricity. On the other hand, entrepreneurial windpower succeeded partly because California regulators required state utilities to sign standardized long-term contracts for power purchases from alternative energy entrepreneurs. When first promulgated, these contracts specified purchase prices that seemed unexciting to windpower developers, but the unexpected oil glut of the mid-1980s made them quite attractive compared to the utilities' own falling cost of generating power. As the gap between the rates guaranteed by the standard contracts and the short-term market price of power widened, windpower developers rushed to sign up. By requiring these contracts and then forcing the utilities to honor them, California regulators succeeded in substituting their desire to propagate renewable energy sources for true market demand. Yet, their success depended on an unforeseen and uncontrolled shift in the energy market. The lesson seems to be simply that imposition of political will on a technological system is difficult, and that success may depend more on luck than machiavellian skill.

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[20]Hughes, "The Evolution of Large Technological Systems" in Bijker,Pinch and Hughes (eds.), *The Social Construction of Technological Systems*, p. 54. In this stance, Hughes approaches a Marxian view of the role of humans in technological society; Mackenzie, for example, interprets Marx as arguing that "the inclusion of labor power as a force of production... admits human conscious agency as a determinant of history; it is people, as much as or more than the machine, that make history." Donald MacKenzie, "Marx and the Machine," *Technology and Culture* 25 (July 1984), p. 477.

Policy makers and energy managers

To government policy makers and utility managers, the windpower story raises important questions concerning the flexibility of energy technologies with regard to the systems into which they are knit. In the 1960s and early 1970s, many supporters of windpower presented it as an alternative to the established energy system, taking part of its appeal from the ideological value of unplugging oneself from the utility grid. In 1976, Amory Lovins garnered attention for relating America's energy system to its social structure; Lovins suggested that switching to alternative energy sources such as windpower could bring desirable social change. In addition to the cleanliness and infinite supply of wind power, advocates predicted that its penetration into our society could decentralize power generation, erode the power of giant corporations, and encourage individuals and communities to make--and take responsibility for--their own energy decisions.[21]

The "counter-culture" took seriously calls such as that issued by Lovins. An indicative account describes an attempt by the staff of *Mother Earth News* to refurbish an early household-size turbine. The crew never compares the cost of the turbine to the price of utility power; the observation by the partisan author that "the power that is produced by the wind on the hill above will spin *no* meters, and will be accompanied by *no* bills" proclaims not efficiency but independence.[22] Yet, the energy option offered by companies such as Kenetech Windpower makes windpower's ideological value secondary to economic considerations.

In the mid-1990s, windpower has grown to fit the conventional centralized generation pattern. Although entrepreneurial windpower lessens the financial control formerly exerted by the utilities, the adaptation by windpower to the ideological structure of the conventional utility industry implies that windpower may not represent such a sweeping change after all. Moreover, utilities show increasing interest in windpower, in some cases

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[21]Amory B. Lovins, "Energy Strategy: The Road Not Taken," *Foreign Affairs* 55 (October 1976), p. 81.

[22]"Wind Power Comes to Mother's Land," *Mother Earth News* 69 (May-June 1981), p. 181.

beginning to install their own wind facilities. Often, they are aided by access to capital cheaper than that available to the entrepreneurs.[23] Thus, even if entrepreneurs represent a significant alteration of the electric system, they may not persist for very long. The windpower story offers clues to whether recent structural shifts in the electric utility industry presage lasting change, or whether that important American institution will limit its concessions to deregulation while maintaining its essential political and economic power. Policy-makers and energy managers will be interested in this research project as they seek information to position themselves for coming changes.

Counter-culture

To those who initially championed windpower for the ideological reasons described above, the story told here presents tough value questions. On one hand, for every wind turbine in use, no matter who owns it, the nation has less of a commitment to defend access to foreign oil. As a cartoon in *New Scientist* asks, referring to the political power of the Organization of Petroleum Exporting Countries, "can you imagine an Organisation [sic] of Wind-Exporting Nations?"[24] In addition, windpower of any stripe reduces both particulate pollution and the necessity for politically-unpopular energy options such as nuclear power. Yet, the community-based electricity generation desired by some supporters of windpower never occurred. Furthermore, windpower itself has impacts deplored by environmentalists, such as bird kills and a conspicuous presence in scenic areas. Those who support windpower for ideological reasons will find in this analysis data on which to base their assessments of the trade-offs it presents.

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[23]See Hamrin and Rader, *Investing in the Future*," p. 59. But note that utility managers often complain of independent power producers' freedom to use financing techniques prohibited to utilities by state regulators. For a refutation of this charge, see Roger F. Naill and William C. Dudley, "IPP Leveraged Financing: Unfair Advantage?" *Public Utilities Fortnightly* 129 (15 January 1992), pp. 15-18.

[24]David Austin, "Observer," next to Susan Watts, "Fresh threat to renewable energy sources," *New Scientist* 127 (18 August 1990), p. 13.

Science and Technology Studies

Members of the interdisciplinary community involved in Science and Technology Studies may find some or all of these issues stimulating. Indeed, I hope that this type of analysis and its set of questions prove interesting to STS. As a new field, STS today seeks legitimacy, which may account for our tendency to concentrate on "sexy" new issues, and to identify STS with problem-areas whose importance and visibility will increase in the coming decades. Unfortunately, we have sometimes neglected the boring, the big, and the powerful. Rather than *only* trying to position ourselves for the important debates of the next century, we ought *also* to direct our attention to the current loci of power. By focussing on the electric utility industry, this dissertation shares a "traditional" STS interest in change, but takes up the challenge of examining a huge, pervasive part of American life.

The most important "STS" issue underlying this dissertation ought to receive more attention in our field than it does: the tension between actors' and analysts' accounts of historical action. Like many STS works, it borrows analytic techniques from the fields of sociology, history, economics, literary theory--the list goes on. Yet, by applying these techniques to a contemporary episode, STS studies of the twentieth century face a dilemma perhaps unknown to some of its source disciplines: while this analysis should constitute a tool useful to other scholars, it also takes the actors themselves as part of its audience. The dissertation aims to produce an account that will feed back into the episodes it describes, and does not have the option of dismissing its subjects as statistical aggregates, fictional protagonists, or dead generals. Rather, they are alive, and their reaction to the analysis matters very much.

Yet, their approval cannot form the only criterion of success. Actors' accounts, like those of analysts, reify agendas, but an STS analysis cannot merely confirm its sources' agendas. Rather, the author's job is to unpack the basis of the actors' accounts, to offer the energy field a multi-stranded account based on scholarly perspectives not present in its everyday discourse, and ultimately to produce a tool that will shape future action in the arena it describes.

## PART IV: Sources, Structure and Scope

The first part of this study introduces the background to the story of windpower. Chapter One uses newspaper and periodical articles, government reports, court cases, and secondary literature to describe the stresses on the electric utility system in the 1970s that sparked the search for new generating sources. The work of two historians of the American electric utility industry, Hughes and Hirsh, plays a significant role in this chapter. Chapter Two summarizes the history of windpower up to its "rediscovery" in the 1970s. This chapter relies almost completely on secondary sources. Broad historical studies by Gimpel, Braudel and Hunter illustrate that windpower, in its many incarnations, inevitably lost ground to centralized power, until the "energy crisis" called America's conventional model of electricity production into question. Ancillary goals of this chapter are to expose the reader to the basic technical issues and vocabulary of generating electric power with wind machines, and to briefly explore the development of the electric utility industry.

Following chapters describe the Federal Wind Energy Program. This analysis includes no secondary literature at all. While the 1970s saw the publication of several books on windpower, such as Jon Naar's *The New Wind Power* and Volta Torrey's *Wind-Catchers,* these treatments promote the technology. Similarly, Witold Rybczynski's *Paper Heroes* constitutes an ideological critique of alternative energy. Rather than scholarly or political analyses, such works represent a class of historical evidence.

The analysis builds an original story through a variety of sources. The accounts of the historical actors themselves provide one type of data, for example interviews with FWEP managers Divone, Ancona and Thresher. Often, their writings and speeches have proven invaluable. Proceedings of annual government-sponsored windpower conferences provide additional data. Another source of "official" account consists of technical reports available on microfiche from the National Technical Information Service and NASA.

To counterbalance these sources, however, the analysis uses Congressional material, such as debates recorded in the *Congressional Record*, hearings over annual budgets, and special hearings such as those concerning the Wind Energy Systems Act of 1980 and Congress's oversight hearing on the FWEP in the same year. Sources outside the Federal windpower community, such as publications of the American Wind Energy Association, provide critiques of the FWEP not found in the program's own fora. Finally, the discussion uses recollections of participants outside the FWEP itself. These include members of the utility community, such as Ayers and Bumgarner, whose company hosted a Federal turbine; Weinberg and Iannucci, who managed windpower projects while at the Pacific Gas and Electric Company; and DeMeo, who managed the Electric Power Research Institute's solar and wind programs. In all cases, accounts from these sources are considered in view of their context; we wish to avoid letting "winners" write their own history, but simply letting the losers write theirs' is no solution either.

Chapter Three discusses the beginnings of the FWEP, including the role played by the National Science Foundation and NASA. Chapter Four uses the windpower studies performed by firms such as General Electric and Kaman Aerospace under contract to the FWEP, to lay out the FWEP managers' understanding of the issues confronting them the statement of mission that they articulated in response. Chapter Five explores the FWEP's various activities, showing that multi-megawatt machines constituted only one activity out of many. But it also demonstrates that the large-turbine effort had a coherency not shared by other program elements. Chapter Six discusses the problems experienced by the FWEP, including primary research on the MOD-1 machine, erected by the FWEP in Boone, NC. Chapter Seven discusses the "Reagan Revolution," and the end of the FWEP as a technology-producing entity (although not as an administrative entity).

The analysis then moves to the emergence of entrepreneurial windpower in California. Chapter Eight uses newspaper articles, the Rand Corporation's studies of the state's electric industry in the 1970s, and some secondary sources such as Barkovich's *Regulatory Interventionism* and Anderson's *Regulatory Politics* to depict California's energy dilemma in the 1970s. Chapters Nine through Eleven describe the three regulatory initiatives that enabled the growth of windpower. First, Chapter Nine tracks the confusing story of PURPA, the law that effectively deregulated the electric generating sector, through Congressional debates, Supreme Court rulings, and utility and renewable energy industry journals. The chapter concludes that we must classify the huge effect of PURPA on windpower as an unintended consequence. Chapter Ten examines the operation and effect of tax credits for renewable energy technology, drawing largely on personal interviews. Valuable insight is also drawn from an article by Starrs, taken from his Master's thesis. Chapter Eleven uses interviews to unpack the story of the standardized long-term contracts that guaranteed favorable prices for windpower through the oil glut of the mid-1980s. The chapter concludes by critically reviewing the history of a successful entrepreneurial firm, Kenetech Windpower, through a series of interviews and a plethora of newspaper and periodical articles. Finally, Chapter Twelve balances actors' accounts of the FWEP and the California windpower movement against an outside analyst's perspective.

As boundaries, the dissertation takes the years between 1970 and 1990. This period opens with the "renaissance" of American windpower, encompasses the troubled times of the Reagan administration, and ends with the reemergence of environmentalism as a political force during the Bush years. These endpoints are flexible; coherent treatment of many themes implicates events long past or quite recent. The dissertation also limits its scope to American windpower. European windpower represents an equally interesting story, but appears here only to emphasize that American windpower reflects a unique milieu of circumstance, culture and human decisions.

# CHAPTER ONE
# "Unusual Stresses"
# on the Electric Utility Industry

## Introduction: A Changing Cast

At first glance, the American electric utility system in the late 1960s and early 1970s displays a changing cast of actors, with each arrival applying additional stress to the system. Yet, that metaphor only partly captures the truth. Some important "new" actors had always been present, but had remained silent. In some cases, weakness had muted their attempts to be heard. In others, actors had ceded their voice to other participants, requiring in return the representation of their interests (as they perceived them at the time). Rather than actors entering and departing the stage, the story consists of changing relationships between actors as they redefined themselves and their agendas.

During the middle decades of the twentieth century, the national system for producing and delivering electric power symbolized American progress. Shortly thereafter, however, the system faded from public consciousness, chiefly because it functioned so well. Soothed by cheap, dependable service available for negligible effort on their part, residential customers ceased to play an active role in the system. Instead, the "public" allowed Federal and state regulators to represent its interests, presumably by maintaining the *status quo*. At the same time, industrial customers received with approval rate packages designed to boost consumption and thereby permit utilities to attain increasing economies of scale. Government regulators rarely meddled in utility procedure; after all, utilities apparently fulfilled quite well their pledge to provide reasonably-priced electricity to all members of society desiring it. During these golden years, all actors shared the goals of growth, dependability, and falling costs and prices--at least, all the actors that had succeeded in defining themselves as relevant.

In the tableau of the late 1960s, the participants in the electric utility system *seem* to have achieved consensus. At least, their rhetoric proclaimed that they had done so, claims often accepted by later analysts. In fact, this tableau draws its appearance of consensus from its success in relegating dissenting voices to the wings. For instance, oil-producing nations' early attempts to share in petroleum profits seemed irrelevant to American electric companies. In those years, utilities burned little imported oil, and the huge domestic petroleum industry easily absorbed attempts by foreign producers to lower production and raise prices. Another group of actors, conservationists, often opposed powerplant pollutants and utility construction plans, but most Americans dismissed them as misguided pastoralists, or worse, as fanatical obstructionists.

Sometime in the mid-1960s, however, the relationships within the cast began to change, as previously powerless actors accrued increasing influence and moved inward from the periphery. The stresses resulting from these dislocations impelled the system in new directions. Both established and "new" players in the electric utility system cast about for solutions to the problems they perceived constricting them. Some actors, as we will see in later chapters of this study, advocated adoption of renewable resource generating technologies such as wind turbines. First, however, the following chapter depicts the build-up of stress itself. After providing contrasting snapshots of the industry in 1964 and 1970, we explore three strains on the system: the end of progressive economies of scale and improving thermal efficiency, dubbed "technological stasis" by one historian; the "energy crisis" of 1973-1974, and; the emergence of a new type of environmentalism, exemplified by the Environmental Defense Fund (EDF).

## PART I: "The threshold of a new era"

In 1964, the Federal Power Commission (FPC) released its second-ever *National Power Survey* of the American electric industry. The opening of the comprehensive report indicates the bright confidence with which the government and the utilities themselves regarded the electric industry:

> The electric utility system of the United States stands on the threshold of a new era of low-cost power for all sections of our country... Larger and larger machines are being built which can generate electricity at progressively lower costs. These huge power plants burning fossil fuels present a moving target for nuclear power plants which nevertheless are rapidly becoming more and more competitive.[1]

The FPC noted that demand for electricity had doubled every decade during the past eighty years (nearly twice as fast as the economy as a whole), and suggested optimistically that consumption might triple in coming years. It attributed such "phenomenal" growth to the fact that "the industry's technological progress has made electricity one of the best bargains available." To extend the downward trend in real power prices, the FPC advocated continued expansion of generating capacity and power consumption, and, most emphatically, interconnection and coordinated planning between the nation's 3600 separate power networks.

Twenty-eight years had elapsed between the first and second *National Power Surveys*, but the third followed in 1970, six tumultuous years later. Its grim opening tone contrasted with that of its predecessor:

> Mounting demand, sharply rising costs and changing social values have combined to place unusual stresses on the U.S. electric power industry. This is evident from the strained power supply conditions in many parts of the country and from numerous current proposals for increased rates. The Federal Power Commission believes that these developments, serious in their own right, may be merely a prologue to future events.[2]

The survey complained that challenges to vital construction projects based on environmental concerns had prevented utilities from responding to rising demand, forcing them to "shed load" when voltages dropped too severely (*i.e.*, to initiate temporary local blackouts). Environmental challenges directly affected prices, as utilities had to "spend ever larger sums on environmental protection and appearance-improving features of power installations." The survey advised improving powerplant siting procedures to include disclosure of utility plans

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[1]Federal Power Commission, *National Power Survey* (Washington, DC: U.S. Government Printing Office, 1964), pp. 1, 3.

[2]Federal Power Commission, *The 1970 National Power Survey* (Washington, DC: U.S. Government Printing Office, 1971), p. 1/1.

and opportunity for public participation. Other recommendations included formulation of a national energy policy, which would assess environmental impacts, intensive pursuit of new technology, notably breeder reactors, and policies to help private utilities raise investment capital. The FPC found "little likelihood that the rate of growth in electricity use will slow appreciably in the two decades immediately ahead," but in contrast to the 1964 report, the agency painted growth as perilous and warned that only coordinated planning and timely action might avoid imminent disaster.

## PART II: Technological Stasis

The stresses on the electric system in the late 1960s and 1970s derived from diverse quarters. In his study of the electric utility industry, historian Richard Hirsh argues that one often-neglected source of strain consisted of utility managers' continued dependence on management strategies predicated on constantly improving technology. Most notably, rate structures encouraged ever-swelling electricity sales; the resulting growth in demand allowed managers to incorporate into the system generating sets of increasing size and featuring steadily improving thermal efficiencies. With time (but *before* the onset of exogenous factors such as the oil embargo to which "traditional" accounts frequently attribute the industry's troubles), technological improvements leveled off, and the growth-oriented strategies of the past became counter-productive. "Unfortunately," Hirsh writes, "most managers did not recognize (or did not want to believe) the severity of technological problems, and they dealt instead with financial and public relations issues that appeared more controllable."[3] Although utility executives of the day understood this process only poorly, it contributed to the malaise of the electric industry, and to its inability to provide cheap power. This section examines Hirsh's thesis in more detail.

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[3]Hirsh draws no conceptual distinction between "technological" factors internal to the electric utility industry and "social" factors outside it. Rather, he emphasizes the "social dimension of technological development (p. 3)." Among many stresses on the system, technological stasis deserves special mention not because of a unique causal role, but because in explaining the industry's troubles, both historical actors and historians often failed to appreciate it, focussing instead on exogenous factors such as the oil embargo. Richard F. Hirsh, *Technology and Transformation in the Electric Utility Industry* (Cambridge: Cambridge University Press, 1989), pp. ix, 2.

Samuel Insull

The early years of American electrification spawned numerous electric companies, each competing for the same customers. Occasionally, their crews even raced to string parallel lines along the same streets. Chicago, for example, boasted more than twenty electric lighting firms when a young Englishman named Samuel Insull, who had previously served as Thomas Edison's personal secretary, took over in 1892 as president of the Chicago Edison Company. Under the new name of the Commonwealth Edison Company, Insull's firm absorbed its competitors, and, until the collapse of his sprawling empire in the 1930s, Insull himself became fabulously wealthy and powerful. He was, according to biographer Forrest McDonald, the man "responsible for founding the business of centralized electric supply."[4]

Insull blended three insights. Formerly employed in Edison's electrical equipment manufacturing business, he saw that larger generators offered lower costs per unit of power. While his competitors marketed electricity as a luxury product for running elevators and lighting mansions and department stores, Insull encouraged wide demand, the steady growth of which allowed him to order from the General Electric Company (GE) turbine-generators two to four times the size of any in existence. Second, with regard to total social cost, he concluded that because of the capital-intensive nature of the business, one firm in any given area served the public more cheaply than two. Thus, he vigorously tried to eliminate competition and the costly duplication of facilities. Finally, Insull saw that, as McDonald puts it, "one of the principle mysteries of the business was that the total expenses of a central station seemed to be about the same no matter how much electricity it delivered." Insull attributed this apparent anomaly to utilities' need for power plants big enough to serve maximum load, although much of the plants' capacity stood idle most of the time. When capital equipment lay inactive, the utility earned no return on its investment. Beginning in 1894, Insull came to believe that the secret to profits lay in attracting a balance of customers

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[4]Hughes, *Networks of Power*, pp. 201-205; Forrest McDonald, *Insull* (Chicago: University of Chicago Press, 1962), p. vii.

whose demand peaks each occurred at different times of the day and year. The electric utility industry pursued a strategy based on these insights during the next seventy-five years.[5]

Insull's career ended ignominiously. Repudiated by the American public as a symbol of financial power gone amok, he faced trial for embezzlement, using the mails to defraud, and violation of bankruptcy laws. A jury acquitted Insull. However, the spectacular collapse of his empire, which at its height financially linked sixty-five utilities, contributed to the passage of the Public Utility Holding Company Act of 1935 (PUHCA), designed to thwart centralized control of electric companies. Yet, in addition to other achievements, Insull articulated a rationale for the principle of natural monopoly. Regulators and the American public came to accept that inter-firm competition in the electric utility industry resulted in higher, not lower, costs for all concerned, and they permitted utilities to operate as monopolies in specified geographic regions, with corresponding exemption from antitrust prosecution. In return, utilities undertook to deliver reasonably-priced service to any citizen requesting it, and submitted to rate-of-return regulation limiting the percentage of revenues they retained as profits. To drive down prices, utility managers devised rate plans intended, in the words of one engineer, to "increase residential sales and thereby reduce unit costs of supplying electricity."[6]

Increasing efficiency, size, status and satisfaction

As the decades passed, utility managers cooperated with manufacturers to improve and enlarge boilers, turbines, generators and auxiliary equipment. GE, the Westinghouse Electric Corporation and the Allis-Chalmers Corporation competed to produce generating sets of steadily expanding capacities. In 1903 Samuel Insull shocked the industry by insisting on five-megawatt (MW) turbine-generators for his Fisk Street Station in Chicago,

[5]McDonald, *Insull*, pp. 57-58, 63-69; Hirsh, *Technology and Transformation*, pp. 19-21; Hughes, *Networks of Power*, pp. 216-220.

[6]McDonald, *Insull*, p. vii; Hirsh, *Technology and Transformation*, p. 19; William F. Kennedy, *The Objective Rate Plan for Reducing the Price of Residential Electricity* (New York: Morningside Press, 1937), p. 1.

but seventy years later capacities had reached 1300 MW. New alloys and designs improved average thermal efficiencies more gradually, from 4% in 1900 to about 32% in the late 1960s, with the best--though not necessarily the most economical--plants attaining close to 40% fuel conversion.[7] Manufacturers achieved much of this progress without benefit of a rigorous design theory. Instead, they conservatively over-engineered their machines to cover unforeseen problems, and built in the field experience of their customers with previous models.[8]

The emerging system seemed to benefit all participants. Utility investors received comfortable and dependable returns, and customers received reliable and inexpensive service. As the real price per kWh of electricity declined from about $3.00 in 1895 to about seven cents in the late 1960s (in 1986 dollars), the status of utility managers and engineers rose correspondingly high. Popular culture portrayed electricity and the men who managed it as, in one historian's phrase, agents of "efficiency, rationality and progress."[9] After the doldrums of World War II, utility managers exuberantly constructed new plants to meet rising industrial demand for power. Celebrities such as movie actor Ronald Reagan appeared in advertising campaigns to endorse all-electric homes featuring new appliances such as air conditioners and refrigerators. Giant steps in consumption and construction, combined with falling prices, encouraged utility managers, regulators, and the public they served to associate electric power with burgeoning industrial might, rising standards of living, and above all, American security.

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[7]Thermal efficiency denotes the amount of energy squeezed by a generating set from a given unit of fuel. A thermally efficient unit may be economically *in*efficient if it costs more to build than warranted by the fuel saved.

[8]Hirsh, *Technology and Transformation*, pp. 4-6, 37-40; Hughes, *Networks of Power*, pp. 209, 211.

[9]David Nye, *Electrifying America: Social Meanings of a New Technology 1880-1940* (Cambridge, MA: The MIT Press, 1990), pp. 157-161.

Signs of trouble

By 1964, however, average thermal efficiencies leveled off in the low thirty-percent range. Some generating sets attained higher levels by further boosting boiler temperatures and pressures, but the cost of vessels able to contain the hot and corrosive steam negated the enhancements to thermal efficiency. New technology and materials brought unfamiliar operating problems, and the cantankerous machines spent increased time undergoing repairs.[10]

The 1964 *National Power Survey* reported that the amount of fuel necessary to generate one kWh of electricity, in decline for decades, had reached a valley, "illustrating the decreasing opportunities for significant improvements in the conventional steam electric cycle." To offset this trend, the *Survey* hopefully anticipated dropping fuel prices and recommended redoubled efforts to develop larger generating sets, forecasting giant units of 1500 MW by 1980. However, the *Survey* also hinted at trouble to come by noting the poor reliability of larger plants. The report warned that design-by-experience had given way to design-by-extrapolation, as manufacturers designed the ever-larger units requested by utilities without the benefit of experience operating earlier machines.[11]

The capacities of the largest units rose throughout the 1960s, and peaked at 1300 MW in 1973. Hirsh suggests that managers shied away from larger generating sets due to their low reliability, stemming from their complex designs and extensive maintenance requirements. He emphasizes that design-by-extrapolation had produced a generation of machines manifesting operating problems that managers neither understood nor proved capable of solving.

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[10]In fact, 1980 registered average thermal efficiencies slightly under the 1965 figure of 32.5%. Hirsh, *Technology and Transformation*, pp. 56-63, 90.

[11]*National Power Survey*, 1964, pp. 63-75. At the time, generators had reached 1100 MW.

Conclusion: "Grow and build" outlived its rationale

To summarize, during the twentieth century the electric utility industry developed a structure of technology, design strategies, business principles, and cultural values that intersected and reinforced each other. The problem described by Hirsh comprises not only a business strategy, but also a cultural value shared by the brotherhood of utility engineers and managers, and, perhaps in a more implicit fashion, by the public they served. Americans (or those who considered the matter) linked increasing scale, lower prices, rising standards of living, more productive industries, and national pride. Unfortunately, cultural values and social institutions tend to persist after the conditions producing them have changed, and growth, as a cultural value, outlived the economic "rationale" that had justified it in Insull's day. The arrival of technological stasis, after which managers could no longer count on constantly improving thermal efficiencies and decreasing unit-costs, shook the entire structure.

## PART III: The Oil Embargo

The *National Power Survey* of 1964 reported that in the previous year the utility industry had drawn on the mix of fuels noted in Table 1. Barring unforseen external stresses, the report predicted that by 1980 use of each conventional fuel would fall, with nuclear power supplying the remaining 19%. In a very brief section on oil, the report recommended easing import restrictions in order to increase supplies of cheap petroleum, but suggested that oil's share of the national energy mix would decrease as coal and nuclear power became cheaper. At the time, crude oil cost $2.10 per barrel.[12]

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[12]*National Power Survey*, 1964, pp. 53, 58.

| TABLE 1: Fuel Mix in the Electric Utility Industry by percent of total | | | | |
|---|---|---|---|---|
| **FUEL** | **Actual 1963** | **1964 projection of 1980** | **Actual 1970** | **1972 projection of 1980** |
| **Coal** | 54.0% | 47.1 | 46.8 | 43.4 |
| **Gas** | 21.0 | 17.1 | 23.8 | 11.8 |
| **Hydro** | 19.2 | 12.7 | 16.1 | 9.8 |
| **Nuclear** | 0.3 | 19.2 | 1.4 | 22.7 |
| **Oil** | 5.5 | 4.0 | 12.3 | 12.3 |

Data in Columns I and II from: National Petroleum Council, *U.S. Energy Outlook: A Summary Report* (Washington, DC: 1972), p. 20. Data in Columns III and IV from: Federal Power Commission, *National Power Survey* (Washington, DC: Government Printing Office, 1964), p. 53.

By 1970, the use of coal had declined more quickly than foreseen, due primarily to new laws limiting sulphur dioxide emissions from coal plants, and the use of natural gas had unexpectedly increased. The big surprises appeared in the categories of nuclear power, which still supplied under 2% of utility energy, and oil, which had increased to 12.3%. This change resulted partly from the price of crude oil, which fell throughout the 1960s to an all-time low of $1.21 per barrel in 1970. But utilities particularly prized low-sulphur Libyan and Nigerian oil, which they could burn in compliance with new emission standards. Newly constructed oil-burning plants coming on line, and the increased use of oil in dual-fuel plants in the Northeast, spurred a rise in annual American crude oil consumption from 548.7 million barrels in 1961 to 804.2 million in 1970, a 31.8% increase. During that period, annual imports rose from 243 to 558 million barrels, an increase of 56.3%. Although *The 1970 National Power Survey* noted that oil constituted a minor portion of American energy supply, the authors fretted that "fuel oil users, including electric utilities, are becoming increasingly dependent on foreign sources of supply."[13]

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[13]1970 utility energy mix and revised projections for 1980 from National Petroleum Council, *U.S. Energy Outlook: A Summary Report* (Washington, DC: NPC, 1972), p. 20. The NPC describes its projections for 1980 as the "most feasible" scenario "from the point of view of electric utilities... the mix that would probably evolve if the utility industry were not subjected to severe constraints on its decisions (p. 21)." Oil imports from *The*

(continued...)

In 1968, James Akins of the State Department informed America's Western European and Japanese allies that America, the world's most prolific oil producer, had neared full production capacity. For those who grasped the import of Akins' announcement, it signified the end of an era. Excess production capacity had long insulated America and its allies from attempts by other oil-producing nations to use oil as a weapon. During the 1967 war between Israel and its Arab neighbors, for example, when Arab members of OPEC withheld their oil to punish Israel's Western allies, increased American production made up the shortfall. In that episode, the oil weapon most hurt the nations wielding it, who lost substantial revenues. Akins' notice that America could no longer stabilize world supplies made the "oil weapon," long pondered by OPEC, a real threat.[14]

## The Organization of Petroleum Exporting Countries

OPEC began in 1960 as a collaboration of three Arab nations plus Iran and Venezuela, who had long cavilled at what they perceived as the highhanded behavior of Western oil companies in setting purchase prices. Although membership grew, the organization lacked power. Members helplessly watched the price of oil--in many cases, their only export--ebb throughout the decade. Western oil companies and politicians insisted that free-market competition limited only by the cost of production should determine oil prices. OPEC negotiators responded that, in the case of an irreplaceable commodity such as oil, producing countries should receive enough revenue to develop an economy that might sustain them when the oil had gone. These "artificial" prices would also benefit oil consumers, the argument ran, by encouraging wise use and stimulating development of alternative fuels. Such pleas failed to move the oil companies. Price "negotiations" generally consisted of the companies setting prices and subsequently informing the producing nations of their decision.

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[13](...continued)
*1970 National Power Survey*, pp. 4/17-4/19. Low price of oil from M.A. Adelman, "OPEC at Thirty Years: What Have We Learned?" *Annual Review of Energy* 15 (1990), p. 1.

[14]"The End of Easy Oil" by Robert Stobaugh and Daniel Yergin in Stobaugh and Yergin (eds.), *Energy Future: Report of the Energy Project at the Harvard Business School* (New York: Ballantine Books, 1979), p. 1.

In 1970, however, as oil reached its all-time low price, only Iran and Saudi Arabia among world producers retained excess production capacity, and some OPEC members renewed calls to unsheathe the oil weapon. In 1971, a pipeline fracture and the ongoing closure of the Suez Canal due to the 1967 war temporarily forced oil-consuming nations to rely on Libyan oil. The Libyan leader, Muammar el-Qaddafi, took advantage of his position to squeeze the Western oil companies. One by one, they capitulated, and Qaddafi won a fifty-cent-per-barrel price increase, the first in history.[15]

Saudi Arabia's King Faisal, leader of the world's third-largest oil producer (after America and the Soviet Union) and of OPEC's "moderate" wing, looked to the United States to protect the Middle East against communism and domestic radicals. Nevertheless, he warned America in May of 1973 that he would not condone his nation's further estrangement within the Arab world, and that Western interests would suffer unless they respected the agendas of their Arab allies. Among those heeding such danger signals, the State Department's Akins published an article in April of 1973 entitled "The Oil Crisis: This Time the Wolf Is Here." In it, he expressed doubt that Faisal's moderate tendencies could carry the day, and warned that "the vulnerability of the advanced countries is too great and too plainly evident." He urged consuming nations to cooperate in seeking new sources of hydrocarbons and in developing new forms of energy, and recommended formation of an international council of oil-consuming nations to allocate supplies in times of shortage, so as to avoid cutthroat competition which might drive up prices.[16] Even as petroleum imports continued to rise--3.2 million barrels per day in 1970, 4.5 in 1972, 6.2 in the summer of

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[15]Robert Stobaugh, "After the Peak: the Threat of Hostile Oil" in Stobaugh and Yergin, *Energy Future*, pp. 15-34; James E. Akins, "The Oil Crisis: This Time the Wolf Is Here," *Foreign Affairs* 51 (April 1973), p. 470; S. Fred Singer, "The Price of World Oil," *Annual Review of Energy* 8 (1983), p. 464. While post-colonial Arab rhetoric emphasized a common ethnic identity, many Arab countries of the late 1960s and 1970s sought *national* identity as well. In addition, rapid population growth increased revenue needs. These two factors undercut OPEC's efforts to coordinate Arab politics. After 1982, when OPEC became a true cartel, Arab members often accused their neighbors of flouting production quotas in order to make quick profits at the expense of their fellows. Arab unity suffered substantial fractures, greatly reducing OPEC's effectiveness, but to observers in the West, the united Arab front of the mid-1970s seemed daunting.

[16]Akins, "The Oil Crisis," pp. 467-469, 487.

1973--John Erhrlichman, President Nixon's chief domestic advisor, told Akins that "conservation is not the Republican ethic."[17]

Ehrlichman was not the only skeptic. Industry expert M.A. Adelman, an economist at the Massachusetts Institute of Technology, stated flatly in a 1972 article that "the world 'energy crisis' or 'energy shortage' is a fiction. But belief in the fiction is a fact. It makes people accept higher oil prices as imposed by nature, when they are really fixed by collusion." He attributed supply problems to the poorly informed and disorganized State Department, and to nefarious manipulations by the oil companies. He painted those firms as "the agents of a foreign power" using OPEC price hikes as a smokescreen for increasing their own share of domestic fuel prices, and willing to pass any price increase on to their customers as long as they could assure a steady stream of profits for themselves.[18]

The crisis: war, price increases, and embargo

On October 6, 1973, as Israeli Jews closeted themselves for Yom Kipper, a hushed day of prayer and atonement, Egyptian and Syrian jets and artillery opened fire on Israeli positions along the Suez Canal, in the Sinai, and on Israel's northern border. The unprepared Israelis fought back. As the world learned of the Soviet Union's massive effort to resupply the Arab armies, President Nixon proclaimed that Communist "satellites" must not defeat an American ally, and he authorized a similar effort in support of the beleaguered

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[17]Ehrlichman's remark quoted in Daniel Yergin, *The Prize: The Epic Quest for Oil, Money, and Power* (New York: Simon & Schuster, 1991), p. 591. Daily imports refer not only to the crude oil burned by utilities, but also to refined products such as gasoline.

[18]M.A. Adelman, "Is the Oil Shortage Real? Oil Companies as OPEC Tax Collectors," *Foreign Policy* 9 (Winter 1972-1973), pp. 69-107. In early 1974, during the embargo, Senator Henry "Scoop" Jackson (D-WA), chairman of the Interior Committee, held hearings to determine whether the major oil companies had devised the energy "crisis" to squeeze small independent firms out of business, and eliminate environmental laws. He accused executives of the seven largest companies of making "obscene profits" even as the embargo continued, pointing as evidence to Exxon's 1973 earnings, up 59% over the previous year. Yergin, *The Prize*, p. 657. Whether one attributes the crisis to an assertion of power by producing nations, or a conspiratorial grab for profits by Western oil companies, the effect on the electric utility system was the same--fuel shortages, higher bills, and consumer outrage.

Israelis. Nixon's decision, once it became public, embarrassed Faisal and his moderate allies, forcing them closer to their more militant neighbors.

On October 12, as the war raged, representatives of the Western oil companies met OPEC oil ministers in Vienna to negotiate oil prices. The oil companies proposed a 30% increase; the producing nations countered by offering a 100% increase. From that impasse, the Westerners returned home. Americans heard from an Interior Department spokesperson that "the odds are ten to one that we will have cold homes, we will have cold hospitals, we will have factories forced to close down." Presidential advisor Melvin Laird suggested that they buy sweaters and prepare for fuel rationing.[19]

On October 15, after stopping the Egyptian army in the Sinai Pass, the Israelis launched their first successful counter-offensive. The next day, the OPEC representatives of Iran, Iraq, Saudi Arabia, Kuwait, Qatar and Abu Dhabi reconvened in Kuwait City, where they set the posted price of crude oil at $5.11 per barrel, an increase of 70%. Just as the oil companies had formerly called the tune, from this point on the producers abandoned pretense that prices resulted from bilateral negotiations. The bland observation by one OPEC representative that higher crude prices benefitted America--"We are helping you find new energy sources more quickly"--did not soften the truth: the oil weapon had arrived.[20]

On October 17, the Iranian representative left Kuwait City. The remaining five representatives, now all Arabs, agreed to cut production by 5%, and an additional 5% each subsequent month "until an Israeli withdrawal is completed and until the restoration of the rights of the Palestinian people." (The demanded withdrawal concerned lands taken by

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[19]Interior Department spokesperson and Laird quoted in "Cold War: Reduced Arab Oil Flow Promises to Make Life Difficult for Americans," *The Wall Street Journal* (17 October 1973), pp. 1, 19. See Yergin, *The Prize*, pp. 588-632, for more on the embargo.

[20]"Six Oil Countries Raise Price 17%," *The New York Times* (17 October 1973), p. 16; "Cold War," *The Wall Street Journal*, p. 19; "Arabs Cut Oil Exports 5% a Month," *The New York Times* (18 October 1973), pp. 1, 18. The price of $5.11 refers to the *posted* price, used by producing nations as a standard from which to set an excise tax on the oil companies, regardless of the actual market price.

Israeli in the 1967 war.) On October 19, Congress approved a package of $2.2 billion in military aid for Israel. The following day, as a distracted Nixon struggled to maintain control of the Watergate tapes, the Saudis halted oil deliveries to the United States. Other Arab members of OPEC soon joined the embargo. Non-Arab members, including Venezuela, Nigeria and especially Iran, took advantage of the West's predicament by boosting prices, and, where possible, production. Crude oil reached $11.65 per barrel in December 1973, and spot market bidding hit $17 before the embargo ended in mid-March of 1974.[21]

Effects of the crisis: calls for a managed energy economy

Throughout the frigid winter of 1973-1974, Americans suffered gasoline shortages, cold houses, and rising fuel and electric bills. Equally damaging, perhaps, they brooded over the chilling effect on their comfortable lifestyle of a group of small nations, which many Americans had hitherto contemptuously ignored. Particularly irksome came the pedantry of America's patrician ally, the Shah of Iran:

> Really, oil is almost a noble product. We were... careless to use oil for heating houses and even generating electricity, when this could so easily be done by coal. Why finish this noble product in, say, thirty years' time, when thousands of billions of tons of coal remain in the ground? [The industrial nations will] have to tighten their belts; eventually all those children of well-to-do families who have plenty to eat at every meal, who have their cars... will have to rethink all these aspects of the advanced industrial world. And they will have to work harder... Your young boys and young girls who receive so much money from their fathers will also have to think that they must earn their living somehow.[22]

[21]"Arab Countries Reduce Their Petroleum Production 5% As Latest Protest Against Western Support for Israel," *The Wall Street Journal* (18 October 1973), p. 3; "Oil Flow to U.S. Halted by Saudis," *The New York Times* (21 October 1973), p. 28; "4 More Arab Governments Bar Oil Supplies for U.S.," *The New York Times* (22 October 1973), p. 1; "Venezuela Sets Oil-Price Boost; Nigeria to Follow," *The Wall Street Journal* (29 October 1973), p. 3. OPEC took organizational responsibility for the price increases, which they explained as natural results of the evolving structure of the petroleum business. In contrast, the embargo was an *Arab* response to Western support of Israel. In the present analysis, however, both acts taken together demonstrate the vulnerability of the electric utility industry to an actor it had customarily ignored.

[22]Reza Pahlevi, quoted in Yergin, *The Prize*, p. 626.

Taken with the concurrent problems of inflation, Watergate, and the continuing war in Viet Nam, the oil price hikes and embargo added to the sense of national impotence and to the pervasive longing for bold action.

The sharp lesson of the oil embargo received reinforcement in 1979, when the Shah's government fell to a fundamentalist Islamic revolution, occasioning a second energy crisis. The two oil shocks provoked a spate of policy reflections and recommendations on the part of politicians and scholars. Many of these pundits argued that only Federal takeover of the "energy economy" could prevent imminent disaster. Thus, apart from the fuel-supply "crisis," the utility industry suffered additional stress[23] as many Americans came to believe that the entire apparatus required radical restructuring.[24]

Analysts disagreed on the causes of, and solutions to, America's energy problem, but most found the situation grave. One author predicted in an article titled "Oil and the Decline of the West" that the world would prove incapable of managing petroleum reserves. "Instead," he opined glumly, "we will probably be confronted by a series of major oil crises... The world, as we know it now, will probably not be able to maintain its cohesion."[25] In another example, a 1979 report by the Energy Project of the Harvard

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[23]Higher oil prices applied less of a *direct* stress on utilities than one might think. By 1960, many state regulatory commissions incorporated a "fuel adjustment clause" in industrial and commercial electricity rates, allowing utilities to pass changes in the price of fuel directly to their customers. In the 1970s, as oil prices rose rapidly, such adjustments became common in residential rates as well. Thus, the stress on utilities came from outraged customers, some of whom objected that fuel-adjustment clauses removed utilities' incentive to use fuel efficiently. (Utilities complained of a "regulatory lag" between rises in fuel prices and the authorization of ratepayer compensation by their public utility commission.) See "Energy Cost Adjustment Clause" in *Resource: An Encyclopedia of Energy Utility Terms*, 2nd ed. (San Francisco: Pacific Gas & Electric Co., 1991), pp. 192-193. Fuel clauses and their critics persist. See Richard E. Morgan, "Time to Face FACs: How Fuel Clauses Undermine Energy Efficiency," *The Electricity Journal* 6 (October 1993), pp. 34-41.

[24]Current analysts generally call the second oil shock a distribution problem. Saudi production boosts almost completely made up for the oil withdrawn from the market by the Iranian revolutionaries. However, panicked Western nations seeking to inflate their reserves refused to cooperate by limiting bid prices, or by allocating available supplies. In the fracas, prices rose over 150%, showing again the vulnerability of domestic oil users. See E.W. Colglazier and David A. Deese, "Energy and Security in the 1980s," *Annual Review of Energy* 8 (1983), pp. 415-420.

[25]Walter J. Levy, "Oil and the Decline of the West," *Foreign Affairs* 58 (Summer 1980), p. 1015.

Business School found that the crisis "constituted a turning point in postwar history... It interrupted or perhaps even permanently slowed postwar economic growth. And it set in motion a drastic shift in world power." While many developing nations read the "crisis" as a long-awaited sign that the world had reached a more equitable balance of power, and although some Americans hopefully dismissed it as a freak occurrence, the Harvard scholars interpreted it as "a warning of a fundamental and dangerous disorder."[26]

The need for a national energy policy provided a common theme to many studies performed at the time. The Energy Policy Project, funded by the Ford Foundation and headed by S. David Freeman, a former White House energy advisor, spoke for many Americans in calling for incisive action, and warning that "drift is surely the worst of the alternatives before us." The report questioned conventional utility operating strategies aimed at increasing demand, noting that new, larger generating facilities did not exhibit the economies of scale anticipated by their designers. While acknowledging the importance of energy supply, Freeman's team argued that America could maintain an acceptable rate of economic growth (about 2%) while pursuing a "carefully planned long-term energy conservation program." For instance, the report recommended amending local building codes so as to encourage energy efficiency, instituting national minimum fuel efficiency standards for automobiles, and utilizing cogeneration wherever possible. In addition, the Energy Policy Project blasted the Federal research and development (R&D) priorities that earmarked 74%--some $475 million--of the energy R&D budget for Fiscal Year (FY) 1973 to nuclear technology, and under $10 million to technologies using renewable resources such as solar and wind energy.[27]

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[26]Stobaugh and Yergin, "The End of Easy Oil," in Stobaugh and Yergin (eds.), *Energy Future*, p. 2.

[27]Energy Policy Project, *A Time to Choose: America's Energy Future*, Final report to the Ford Foundation (Cambridge, MA: Ballinger Publishing Co., 1974), pp. 2, 150, 256, 258, 306-308.

Amory Lovins and the two energy paths

The most provocative challenge to existing energy policy came from physicist Amory Lovins. In a 1976 article published by *Foreign Affairs*, Lovins outlined two possible paths that America might take in its energy future. The first path, he wrote,

> ...resembles present federal policy and is essentially an extrapolation of the recent past. It relies on rapid expansion of centralized high technology to increase energy supplies, especially electricity. The second path combines a prompt and serious commitment to efficient use of energy, rapid development of renewable energy sources matched in scale and energy quality to end-use needs, and special transitional fossil fuel technologies.

Lovins contended that the alternatives, which he dubbed the hard and soft paths, demanded an exclusive choice.[28]

Lovins suggested that technological fixes--that is, devices for using energy more productively--could by themselves increase efficiency by a factor of three or four, without requiring any momentous changes in lifestyle. However, he appeared equally interested in the "technical and sociopolitical *structure* of the energy system [original emphasis]." Progress along either energy path entails distinct social changes, Lovins explained, but

> ...the kinds of social change needed for a hard path are apt to be much less pleasant, less plausible, less compatible with diversity and personal freedom of choice, and less consistent with traditional values than are the social changes that could make a soft path work.

Lovins encouraged his readers to select the energy regime matching the type of society they would rather inhabit.[29]

In addition to shifts in the demand side (*i.e.*, the way Americans used energy), Lovins proposed adopting household- and community-scale energy supply technology, such as wind turbines, solar water heaters, and waste-to-methanol conversion processes for central generating plants. He argued particularly against nuclear power, which, he claimed,

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[28]Lovins, "Energy Strategy," p. 65.

[29]*Ibid.*, pp. 72, 91.

empowered a technical elite, discouraged individual responsibility for energy decisions, and alienated energy users from the infrastructure of their world.

Lovins' article provoked enthusiastic responses as well as vituperative condemnation. Of the latter set, physicists Aden and Marjorie Meinel, known for advocating the construction of huge solar collectors in the Southwestern desert,[30] professed themselves "chilled" that a fellow scientist could so "distort physical reality." They interpreted Lovins as advising Americans to "abandon high-technology and large-scale cooperative organization [which represented] a step toward making mankind once more a slave to the dictates of a dispassionate environment and his own furies." The Meinels objected that small-scale energy production ran "contrary to the way society has gone for centuries," and called it "inconvenient, unreliable and costly" besides. They advised relying on established utilities and the "true option" of nuclear fusion, because a "bird in the hand is worth two in the bush." Other critics entered into detailed wrangles with Lovins over both his overall vision and his specific claims, such as the assertion that America's energy efficiency could be increased by a factor of three or four. Lovins' critics reviled him for attacking the *status quo* with nothing better to replace it with than, to use one respondent's contemptuous phrase, "the soft path, the yellow brick road and pie in the sky."[31]

Conclusion: two linked stresses

To summarize, the "energy crisis" of the early 1970s did not represent a completely exogenous stress on the electric utility system. The utilities' own growth-oriented strategies made the "crisis" possible. However, new restrictions on burning high-sulphur coal, natural limits on domestic oil production, and, most of all, a slow buildup of geopolitical forces

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[30]Aden B. Meinel and Marjorie P. Meinel, *Power for the People* (Tucson, AZ: by the authors, 1970).

[31]Aden and Marjorie Meinel, "'Soft' Energy Paths--Reality and Illusion" in Charles B. Yulish (ed.), *Soft vs Hard Energy Paths: 10 Critical Essays on Amory Lovins' "Energy Strategy: The Road Not Taken?"* (New York: Charles B. Yulish Associates, 1977), pp. 70-76; Peter J. Brennan, "The Soft Path, the Yellow Brick Road and Pie in the Sky" in Yulish (ed.), *10 Critical Essays*, pp. 7-15. For more on the issues raised by Lovins, see U.S. Congress, House of Representatives, Committee on Interstate and Foreign Commerce, *Centralized vs. Decentralized Energy Systems: Diverging or Parallel Roads?*, report prepared by the Congressional Research Service for the 96th Congress, 1st Session (May 1979), Committee Print 96-IFC 17.

contributed to the crisis; these factors remained well beyond the control of the utility industry. In terms of its effects, the event produced two linked stresses on the system. In addition to an immediate impact on costs and prices, the "crisis" also hurled energy into the consciousness of citizens and policy-makers, creating demand for national energy plans, policies and strategies.

## PART IV: Litigious Environmentalism

In the early twentieth century, American concern for the physical world took the form of "conservationism," a movement typified by President Theodore Roosevelt's initiative to preserve America's natural resources for efficient exploitation by future generations. By the 1960s, however, conservationism mutated into "environmentalism," a view of an interconnected physical world, including human beings, which sought "balance" for its own sake, and because this balance contributed to human "quality of life." Just as earlier Americans had dismissed conservationists as elitist bird-watchers in khaki shorts, so popular culture of a later day stereotyped their successors as naive liberals, yearning for an imaginary lost world, or worse, as obstructionists impeding national progress.[32]

By the late 1960s, the strategy of public education pursued by environmentalists had lost effectiveness. Too often, private firms suspected of polluting the land, water and air succeeded in denying public access to relevant information by declaring it a trade secret. Equally troublesome, the Federal government turned away from articulating general policies in favor of ruling on specific cases, requiring cash-poor environmental groups to battle simultaneously on multiple fronts. For these reasons, Victor Yannacone, a Long Island, NY, lawyer and Charles Wurster, a biologist, launched the Environmental Defense Fund in 1967 to challenge the use of the pesticide DDT by state agencies.[33]

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[32]Samuel P. Hayes, *Beauty, Health and Permanence: Environmental Politics in the United States, 1955-1985* (Cambridge: Cambridge University Press, 1987), pp. 13-39.

[33]"A New Say in Court," *Time* 94 (24 October 1969), p. 54; Luther J. Carter, "DDT: The Critics Attempt To Ban Its Use in Wisconsin," *Science* 163 (7 February 1969), pp. 548-551.

The EDF represented a dramatic evolution of environmentalist strategy. Yannacone and Wurster aimed to lay scientific evidence before the courts and bypass, in one historian's words, "an unresponsive bureaucracy and a lethargic public." The founders disagreed over the relative importance of getting immediate results and of establishing a body of case law. Still, they agreed that litigation provided an alternative "for those who had lost patience" with public education.[34]

The EDF relied on a reserve of over two-hundred scientists, ready to volunteer their testimony at any moment, and a pugnacious flair for drama. Numerous articles gleefully reported the slogan Yannacone scrawled on the blackboard at his lectures: "SUE THE BASTARDS!" Under Yannacone's leadership, the self-styled legal guerrillas of the EDF fought to establish that the Constitution guarantees Americans a clean environment. In addition to this controversial claim, the new environmentalists also maintained that private and public landowners hold their property in trust, and cannot use it contrary to the public interest. Other organizations soon followed the EDF's lead, including the Sierra Club's Legal Defense Fund and the Natural Resources Defence Council, founded by members of the Yale Law class of 1969.[35]

Support from the courts

Yannacone described the EDF's use of litigation as a democratization of public policy, allowing any citizen backed by sufficient scientific evidence to take industry or government to court. Yet, the effectiveness of this new tool depended on judicial sympathy. Although the courts rejected large portions of the environmentalists' agenda, they also acceded to significant aspects of it. Most important, the courts revised their criteria for

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[34]The historian quoted is Thomas R. Dunlap, *DDT: Scientists, Citizens and Public Policy* (Princeton, NJ: Princeton University Press, 1081), pp. 4, 147. See also Luther J. Carter, "Environmental Law (I): Maturing Field for Lawyers and Scientists," *Science* 179 (23 March 1973), pp. 1205-1209.

[35]Creighton Peet, "The Effluent of the Affluent," *American Forests* (May 1969), pp. 16-19, 37-38. Yannacone and the EDF eventually parted ways, perhaps due to what David Brower of the Sierra Club suggested was a need for some people "who are older and stuffier (Peet, p. 37)." See Carter, "Environmental Defense Fund: Yannacone Out as Ringmaster," *Science* 166 (December 1969), p. 1603.

deciding which actors in a given situation deserve a legal hearing. Previously, the law had required demonstration of specific injury (or, at best, potential injury) before granting "standing," without which an actor remains invisible before the law. In the late 1960s and early 1970s, however, a body of case law emerged greatly liberalizing the definition of relevant injury, opening the door to cases concerning potential environmental damage.

One such case concerned a vast pumped storage facility planned by New York City's electric utility, the Consolidated Edison Company ("Con Ed"), at Storm King Mountain on the picturesque banks of the Hudson River. This project provoked opposition from two groups. Nature lovers, who organized into the Scenic Hudson Preservation Conference, regarded the facility as a desecration of a treasured area. Meanwhile, villages and counties through which transmission lines would run objected that their property values and tax revenues would fall. In 1965, an alliance of the two interest groups argued before the Second Court of Appeals that neither Con Ed nor the FPC had considered the impact of the planned construction on the aesthetic beauty of the region.

The Court agreed. In overturning the FPC's decision to license the facility, Judge Hays noted that the Federal Power Act required the FPC to consider "recreational purposes" in developing national waterways. He also questioned whether, in issuing Con Ed a license, the FPC had faithfully discharged its duty to protect the public interest. Most ominous for Con Ed and other utilities, Hays set a precedent by granting "standing" to an environmental group, recognizing it as a party to the proceedings even though it had not claimed specific potential economic injury. Con Ed soon re-initiated proceedings to build a reservoir at Storm King, and in the mid-1970s the legal battle still raged.[36]

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[36]"Scenic Hudson Preservation Conference *et al.*, v. Federal Power Commission" (354 F.2d 608). In 1981, Con Ed agreed to halt construction on the Storm King project and donate the site for a park. In return, its environmentalist opponents agreed not to press for closed-cycle cooling systems in three other plants. See: David Andelman, "Con Ed's Growth Plan Facing Big Obstacles," *The New York Times* (1 April 1974), pp. 1, 51; Carter, "Environmental Law (I), pp. 1205-1206; David Loth and Morris L. Ernst, T*he Taming of Technology* (New York: Simon and Schuster, 1972), pp. 79-83, and; Thomas M. Haban and Richard O. Brooks, *Green Justice: Environment and the Courts* (Boulder, CO: Westview Press, 1987), pp. 75-85. Haban and Brooks give excerpts of Hays' 1965 decision.

(continued...)

A similar judicial initiative concerned the role of Federal agencies, pushed by some courts into redefining their constituencies. Judge Hays, in explaining his Storm King decision, charged that although the FPC had claimed to represent the public, it had limited itself to "blandly calling balls and strikes for adversaries appearing before it," one of whom, Con Ed, wielded far more power than the other, the Scenic Hudson Preservation Conference. Rather, Hays ordered, the Commission must take an "active and affirmative" role in protecting the public interest.[37]

Equally important support came from Congress, which in 1969 passed Sen. Jackson's National Environmental Policy Act (NEPA). Signed into law by President Nixon on January 1, 1970, as his first act of the decade, NEPA imposed environmental responsibilities on all branches of the Federal government. Most significant, Section 102 required agencies to prepare an environmental impact statement (EIS) for all Federally supported or regulated activities.

Here, again, the judicial arm of government supported the new environmentalism. NEPA received teeth in a Court of Appeals case concerning an license from the Atomic Energy Commission (AEC) for a proposed atomic power plant. Judge Skelly Wright began his decision by noting that in the past, agencies such as the AEC had demurred from considering the environmental impacts of their policies, claiming that they lacked authority to do so. Given NEPA's directives, Wright dryly observed, the AEC's "hands are no longer tied." He then blasted the AEC's "crabbed interpretation" of NEPA. The rules devised by the agency seemed to allow it merely to prepare an EIS and submit it to its hearing board, which would then be free to ignore it in reaching a decision. Judge Wright opined that, in

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[36](...continued)

See also "Sierra Club v. Morton, Secretary of the Interior, *et al.*" (405 U.S. 727), in which the Sierra Club challenged the Interior Department's approval of a proposal by Walt Disney Enterprises to build a resort in the Sierra Nevada Mountains. The Supreme Court ruled in 1972 that the Sierra Club could apply for standing based on possible non-economic injury, for example on "aesthetic or environmental well-being." Frank Graham, Jr., "Taking Polluters to Court," *New Republic* 158 (13 January 1968), pp. 8-9; Haban and Brooks, *Green Justice*, pp. 144-145; Carter, "Environmental Law (I)," p. 1207.

[37]Carter, "Environmental Law (I)," p. 1205; Hoban and Brooks, *Green Justice*, pp. 63, 81.

writing NEPA, legislators had intended federal agencies truly to justify their actions in light of the EIS, showing that all alternatives had been considered, and ensuring that obvious public benefits outweighed potential environmental damage. NEPA's directives halted very few projects, but developers either abandoned or never began many other environmentally unjustified efforts. The law acted, in Judge Wright's phrase, as a brake on "the destructive engine of material 'progress.'" By forcing into the open the criteria used in making decisions, NEPA provided a tool for controlling entrenched technology and interests.[38]

To charge agencies such as the FPC and the AEC with ignoring the public interest misses the point. During the long consensus over how to manage electricity, Federal regulators, like residential electricity users, identified utility managers as spokesmen for the entire system, including the "public." In the 1960s, the "public" fractured into distinct, adversarial groups, and the concept of public interest began a conceptual redefinition. Some groups identified new interests in addition to cheap, dependable electricity, for example cleaner air, fewer powerplants, and access to beautiful land for recreation. Other actors asserted their right to speak for a completely new kind of right-bearing non-human actor, the "environment." The judicial decisions discussed above can be interpreted as instructing Federal agencies to identify certain groups as the *relevant* public, for example because those actors lacked the economic power of others.

Popular support

Although organizations such as the EDF partially abandoned the orientation toward public education held by their predecessors, litigious environmentalism encouraged and received encouragement from growing popular interest in environmental issues. For example, in response to a casual suggestion by Senator Gaylord Nelson (D-WI) that Americans set aside April 22, 1970, for discussion of environmental issues, 1500 college campuses, 10,000 schools and millions of citizens observed Earth Day with lectures, clean-

[38]"Calvert Cliffs' Coordinating Committee, Inc., v. United States Atomic Energy Commission" 449 F.2d 1109 (D.C.Cir.1971); Haban and Brooks, *Green Justice*, pp. 60-72; "Environmental Programs," *Congress and the Nation: Vol. 3--1969-1972* (Washington, DC: CQ Almanac, 1973), pp. 748-749.

ups and rallies. A group called Environmental Action, formed in the aftermath of Earth Day, identified twelve members of Congress as "bad guys on the environment;" after Environmental Action publicized their voting records, seven of the "dirty dozen" lost their re-election bids.[39]

Not all Americans joined the clamor for environmental action. While predominantly white, middle-class college students and faculty conscientiously attended "teach-ins," many members of disenfranchised minorities remained indifferent to the "movement," or feared that it would distract attention and funding from their own pressing needs for acceptable jobs, education and housing. On the other end of the social spectrum, conservatives such as economist Milton Friedman considered environmentalism a fad, and they blamed most pollution on consumers rather than producers. Though the environmental coalition contained significant gaps, and although interest in environmentalism fluctuated in the following years, national and community activism remained a potent and unpredictable threat to institutions identified as environmental transgressors, including the electric utility industry.[40]

Worldly Environmentalism: The EDF and electric ratemaking

As we have seen, the new environmentalism included a new litigious strategy, aided by new legal conceptions of the public interest, the right of access to environmental information, and the role of government agencies. However, to cement its new role as a relevant actor in the American energy system, the EDF went one step farther, redefining "environmental" issues to embrace popular concerns such as electric rates. This alliance of environmentalism and consumer advocacy can best be seen in the EDF's role in California's utility planning procedures.

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[39]"The Dawning of Earth Day," *Time* 95 (27 April 1970), p. 46; "The ecology fans show their muscle," *Business Week* (14 November 1970), pp. 26-27; George C. Wilson, "Environmentalists Claim 8 Wins in Battles Against 'Dirty Dozen,'" *The Washington Post* (7 November 1974), p. A6.

[40]Carter, "Environmental Teach-In: A New Round of Student Activism?" *Science* 167 (16 January 1970); "To blacks, ecology is irrelevant," *Business Week* (14 November 1970), p. 49. Claims that the environmental coalition lacked minority support, while largely true, also served the interests of the movement's critics, by casting it as the concern of dilettantes who could "afford" to worry about such things.

In the early 1970s, the EDF fought to eliminate rate structures such as discounts for bulk-power sales that led, they believed, to profligate growth and environmental degradation. Unfortunately, eliminating such deals resulted, at least in the short term, in higher electric rates. By the mid-1970s, the EDF had retreated from positions that tied environmentalism to higher bills in the mind of a public already incensed over the oil embargo. As an alternative, two EDF staff members, economist Zach Willey and attorney Tom Graff, articulated a new strategy.

As a colleague described their insight, Willey and Graff intended to

> ...show that coal and nuclear powerplants were an inferior choice, on [the utilities'] own terms. A moment's pause was necessary to appreciate that, despite enormous environmental implications, this argument about future power development would not mention the environment at all.[41]

Specifically, the EDF staffers argued that utilities could meet demand more cheaply by using a mix of energy conservation and small-scale, renewable-resource technologies such as wind turbines than by constructing conventional powerplants. To make this case, the EDF participated in 1975 as an "intervenor" in a rate-case before the California Public Utility Commission (CPUC), concerning the Pacific Gas & Electric Company's (PG&E) application to raise rates in the coming year.

In September of 1975, Leonard Ross, a commissioner recently appointed by Governor Jerry Brown, had written for the CPUC that "we regard conservation [as] the most important task facing utilities today,"[42] and demanded that utilities pursue alternatives to conventional powerplant construction. In the hearing over 1976 rates, Willey and Graff pointed out that PG&E had apparently ignored Ross's injunction by planning to spend $13 billion on construction in the coming decade, but nothing on conservation. They then called

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[41]The following account of the EDF's activities in utility regulation draws on David Roe, *Dynamos and Virgins* (New York: Random House, 1984). See also Douglas D. Anderson, *Regulatory Politics and Electric Utilities: A case study in political economy* (Boston: Auburn House Publishing Co., 1981), pp. 110-113.

[42]78 CPUC, d.84902 (16 September 1975), p. 746. See Barbara Barkovich, *Regulatory Interventionism in the Utility Industry: Fairness, efficiency and the pursuit of energy conservation* (New York: Quorom Books, 1989), pp. 76-77.

witnesses, including physicist Arthur Rosenfeld of the Lawrence Berkeley Laboratory, who questioned the magnitude of PG&E's estimates of future electricity demand. Willey went on to present computer-generated scenarios based on different growth strategies, using PG&E's own forecasting methods. The comparisons showed, he claimed, that EDF's alternative development plan would lead to not only lower rates but higher returns for investors. His contention that conservation and alternative energy constituted smart business, and his defense of the utility's right to earn a profit, represented a break by EDF from the predominantly "anti-utility" stance of its environmentalist colleagues.

A new regulatory philosophy

The Willey-Graff approach resonated with emerging state regulatory philosophies to step up the stress on American utilities. In the mid-1970s, regulators across the nation began to experiment with "marginal cost pricing," a theory advocated most cogently by Alfred E. Kahn, appointed chairman of the New York Public Service Commission in 1974. Formerly a professor of economics at Cornell University, Kahn had argued in his influential 1970 study, *The Economics of Regulation*, that regulation often impedes competition, that government officials often misunderstand the consequences of their actions, and that market forces, rather than government policy, ought to allocate resources. Most important, Kahn advocated prices reflecting marginal costs, rather than traditional rate structures which had been designed to stimulate demand.[43]

At the time, most utilities still offered "declining block rates," which charged less per unit of electricity as customers' total consumption of power increased. These stimulants to use made apparent economic sense when burgeoning utilities regularly achieved

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[43]Marginal pricing theory dictates that a customer purchasing an additional unit of power pay the cost of producing *that* unit. Utilities use their most efficient "baseload" units most of the time; these burn cheap coal or nuclear fuel, or use hydropower, whose "fuel" costs nothing. Utilities only call on line "peaking" units when high demand requires it; these units burn expensive oil and natural gas. Thus, generating each "extra" increment of power costs substantially more than previous increments. A pricing system that reflects this difference, the theory contends, sends consumers appropriate messages concerning the real cost of the commodity, and allows correct allocation of society's resources. See Alfred E. Kahn, *The Economics of Regulation: Principles and Institutions*, Vol. 1 (New York: Wiley and Sons, 1970), pp. 65-66, and; Thomas K. McCraw, *Prophets of Regulation* (Cambridge, MA: Belknap Press, 1984), pp. 233-256.

economies of scale; rising demand allowed utilities to build bigger, more efficient late-model plants and divide the fixed costs of operation over more units of energy sold. However, the 1960s brought climbing marginal cost curves--each subsequent unit of electricity cost a smidgen more, rather than less, to produce. In the altered environment, Kahn argued, declining block rates sent precisely the wrong message.

Kahn's new rate plan included "peak-load pricing," by which customers paid more during the times of day and year of highest demand, when generation costs ran highest. Kahn also eliminated declining block rates. By introducing marginal pricing, Kahn intended to slow price increases, but he found additional support from environmental advocates, such as the EDF,[44] who opposed powerplant construction. His success encouraged other state and Federal policy-makers to recommend rate reform. In 1976, the FPC advised that "utilities should accelerate their efforts to test the potential benefits of peak-load pricing as a means of controlling load growth,"[45] and in the following year the Carter administration began a push in Congress for rate reform legislation.

In addition to cooperating with Kahn in New York, the EDF took their show on the road to other states, including Arkansas, after Attorney General Bill Clinton invited them to intervene in a rate case. However, the EDF saw more long-term promise in teaching other environmental activists and local governments the Willey-Graff approach, which rephrased environmentalism in a manner amenable to utility interests. In hindsight, this collaborative strategy seems an important evolution of Yannacone's confrontational "sue-the-bastards" philosophy. Yet, utilities fought it tooth and nail.[46] One executive warned his colleagues

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[44]McCraw, *Prophets of Regulation*, pp. 249-252.

[45]Federal Power Commission, *National Power Survey: The Adequacy of Future Electric Power Supply. Problems and Policies: The Report and Recommendations of the Technical Advisory Committee on the Impact of Inadequate Electric Power Supply* (Washington, DC: U.S. Government Printing Office, 1976), p. viii.

[46]Roe gives a hint of the institutional barriers to change when he recounts his remarks to Willey as they drove past PG&E's headquarters: "You're telling these guys that they can do just what they're supposed to do, and keep on growing just the way they want, and look fifteen to twenty percent better on the bottom line while (continued...)

that the issue confronting them was "environmental protection versus electric power production," and that America "can be destroyed just as quickly by ruining its economy as by polluting its environment."[47] Even PG&E, which later gained a reputation as one of the nation's progressive utilities, resisted the CPUC's push toward new energy strategies, and in 1979 the company received a $7-million fine for failing to pursue promising cogeneration opportunities.[48]

Conclusion

The late 1960s and 1970s saw a radical transformation of environmentalism. From a public education effort aimed at showing the importance and difficulty of preserving the balance of the natural world, environmentalism became a militant effort based on legal intervention. Buttressed by important shifts in judicial philosophy, organizations such as the EDF fought the stereotype of environmentalists as crackpots by enrolling the scientific community. At the same time, they countered public perceptions of elitism by enlarging their definition of the human "environment" to endorse "worldly" goals such as lower electricity bills and higher investor returns. These pragmatic shifts greatly enlarged the appeal of environmentalism. They also increased its ability to apply stress to the institutions it identified as environmental transgressors, including the electric utility industry.

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[46](...continued)
they're doing it. And when they ask how, Dr. Willey tells them that all they have to do is turn around one-hundred and eighty degrees, and find a lot of people who know a lot about things like refrigerator efficiencies and cogeneration, and then take that building over there and a few thousand of those coal and nuclear engineers sitting in it, and throw them into the bay." Willey responds, "Yeah, I suppose there are a few nuclear designers around who don't want to be retrained to do attic insulation (pp. 89-90)."

[47]John Dolinger, President of the National Rural Electric Cooperatives Association, quoted in "Nuclear developments," *Electrical World* 185 (15 March 1976), p. 83.

[48]The impact of the precedent-setting fine was diluted by its inclusion in a CPUC decision granting PG&E rate increases totaling $430 million per year for electricity and gas sales. Tom Redburn, "Utility Penalized for Slow Action on Energy Plan," *The Los Angeles Times* (19 December 1979), pp. I/1, I/27.

## Conclusion: Searching for New Solutions

In the late 1960s and early 1970s stress on the electric utility system increased rapidly. The slowing rate of technological improvement and increasing dependence on an increasingly scarce fuel combined with a powerful alliance of opponents of utility growth policies and customers distraught over rising prices. This congeries of factors called into question conventional assumptions of how to manage electricity. While many managers held fast to the values and practices of the past, voters and activists pushed policy-makers to play a larger role in guiding the nation's energy decisions. An important part of this new role involved seeking new generating technologies, ranging from the liquid metal fast breeder reactor to the photovoltaic panel. "New" incarnations of a very ancient technology, the windmill, provided another alternative.

One cannot tell the history of twentieth-century windpower by focussing exclusively on the technology itself. Such an "internal" account misses a vital dimension of the story. Rather, windpower rode the tides of larger institutional movements, in particular the three stresses described in this chapter. In effect, while windpower provides an interesting and often dramatic story, it more often performed a bit part in a much larger play. Different actors frequently negotiated intensely over the form windpower was to take, but more often, windpower's future was determined by larger tectonic movements of American or even global history. Windpower represents just one manifestations of the "unusual stresses" on American society. It flourished (and continues to flourish) largely because of realignments of the players and interests in the American energy system.

# CHAPTER TWO
# Retreat and Reappearance: Windpower Through History

## Introduction: An Old Answer

As the stresses of the early 1970s mounted, many participants in the American electric utility system cast about for solutions to the problems they perceived plaguing them. Factions advocated political activism, changes in consumer behavior, and the development of new supply technologies, among other responses. "Renewable" sources of energy represented a particularly intriguing solution. To both counter-culture people and many engineers, the sun, wind, oceans and earth seemed to promise bountiful cheap energy, while posing few environmental risks. Most of these technologies, in particular photovoltaics, required substantial breakthroughs before practical exploitation, but windmills had a long, distinguished history, and needed--it seemed--only a touch of twentieth-century high-tech polish to become a useful component of the nation's energy mix.

Before their reappearance in the twentieth-century as electricity generators, wind machines had played significant roles in numerous societies. In each era, centralized facilities such as steam mills, central water systems, and electric utilities combined economies of scale with greater dependability, relegating wind machines to back roads and museums. But in the depths of the energy crisis, many people gave the familiar windmill a second look.

By examining secondary sources, this chapter summarizes the distinguished pedigree of wind machines and shows the role played by windmills at selected moments. Where possible, the synopsis describes the technical problems confronting wind innovators, and the solutions they devised. Because understanding modern windpower requires understanding the management culture and structure of the electric utility industry, this chapter also exposes the development of the American electric utility system.

## PART I: Early Exploitation

Today's wind-driven electricity generators belong to the family of *turbines*, machines that convert the energy of steam, water or air as it strikes blades or sails mounted on a wheel. Most people, however, refer to any spinning wind machine as a windmill. Indeed, for centuries millers used windpower to grind grain. But innovators often set wind machines to other tasks. Modern wind devices which produce alternating electric current for use by utilities bear many names, including wind turbine generators (WTG), wind energy conversion systems (WECS) and vertical- or horizontal-axis[1] wind turbines (VAWT and HAWT). Still, many people imprecisely label them all windmills, a fitting tribute to the original aim of human exploitation of the wind.

Millers probably first exploited wind energy to grind grain into flour in tenth-century Seistan, a dry, sandy region near present-day Iran and Afghanistan. The strong winds, which blow from one direction during long periods each year, powered gristmills resembling modern merry-go-rounds. Encircling walls directed the wind through a chute onto cloth sails. The flat rotor spun about a vertical axle, which projected through the ceiling to the millhouse above. There, a crossbar drove grindstones around a circle. Later Seistani mills situated the sails above the grindstones, showing early millers' awareness of stronger winds at greater heights off the ground.[2] From Seistan, windmill technology spread east to China, where sailmakers enhanced the concept with nautical rigging techniques.[3]

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[1]In modern terminology, horizontal-axis machines "fly" a rotor on a shaft parallel to the ground; vertical-axis machines feature an upright shaft. Older accounts use the opposite terminology, taking the plane of rotation as the point of reference. This dissertation follows modern usage, even where anachronistic.

[2]Volta Torrey, *Wind-Catchers: American Windmills of Yesterday and Tomorrow* (Brattleboro, VT: The Stephen Greene Press, 1976), pp. 17-18; Walter Minchinton, "Wind Power," *History Today* 30 (March 1980), p. 32; David Inglis, *Wind Power and Other Energy Options* (Ann Arbor, MI: The University of Michigan Press), p. 3.

[3]Joseph Needham, *Science and Civilisation in China; Volume IV: Physics and Physical Technology; Part 2: Mechanical Engineering* (Cambridge: Cambridge University Press, 1965), pp. 556-558, 566.

Most authors call the horizontal windmill a European device. Minchinton, in a brief overview of wind history, acknowledges the legend that the first Crusaders trickling back from the Holy Land in the eleventh century brought windmill technology with them, along with other Muslim curiosities as sugar and the stirrup. But he observes that despite circumstantial evidence, the horizontal European machine resembles water wheels more than vertical Seistani windmills. He concludes that the "sudden appearance of windmills in France and England remains a mystery." Torrey, in one of the better wind "popularization" books of the 1970s, points out logically that Seistan lies off the Crusaders' main route. White's classic survey of medieval technology lists references to Lincolnshire windmills as early as 1170, and calls the European machine "a separate and ...far more effective invention." Gimpel, in his own well-known work on medieval technology, asserts that the European windmill "owes no debt" to vertical machines.[4] Needham, in his encyclopedic study of science and technology in China, calls the medieval European windmill "a distinct advance on any other form" because the whole area of the rotor surface received the wind, in contrast to Seistani mills in which each sail moved against the wind for half its revolution. While Europeans probably received some stimulus from the east, Needham hypothesizes that this might have been simply the information that "over there people found wind-wheels possible and useful."[5]

Whatever the windmill's origin, Europeans rapidly adopted the concept. Braudel, in his wide survey of "everyday life" in the medieval world, sees the increasing popularity of windmills as "a standard measure of the energy supply in pre-industrial Europe," and evidence of slowly building demographic pressure that eventually allowed the birth of modern capitalism. White interprets windmills as symbols of equally important changes in the human spirit and worldview. He argues that multiplying windmills, like growing interest

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[4]Minchinton, "Wind Power," p. 33; Lynn White, Jr., "Dynamo and Virgin Reconsidered" in *Dynamo and Virgin Reconsidered: Essays in the Dynamism of Western Culture* (Cambridge, MA: The MIT Press, 1968), p. 67; White, *Medieval Technology and Social Change* (London: Oxford University Press, 1962), pp. 87-88, 162; R.J. de Little, *The Windmill: yesterday and today* (London: John Baker, Ltd., 1972), p. 9; Jean Gimpel, *The Medieval Machine: The Industrial Revolution of the Middle Ages* (London: Penguin Books, 1976), pp. 24-25.

[5]Needham, *Science and Civilisation*, pp. 564-565, 567.

in perpetual motion machines, magnetism and falling objects, show medieval Europe's emerging view of "the cosmos as a vast reservoir of energies to be tapped and used according to human intentions."[6]

European windmills: innovation and prosperity

The heavy gusts of Northern Europe evoked a new technology, the post mill. These squat house-like structures featured a rotor with wooden sails on a horizontal axis tilted slightly up into the wind to account for "wind shear," the tendency of the wind to blow at a slight angle toward the ground. To avoid a "wind shadow" cast by the mill housing on the rotor, post mills flew "upwind" rotors, which faced into the wind. This orientation required millers physically to turn the mill housing, which balanced on a center piling, whenever the wind changed. Unlike direct-drive vertical-axis mills, post mills incorporated wooden cog-and-ring gearwheels to transfer force from the horizontal windshaft to the stones.[7]

One extremely important difference between vertical- and horizontal-axis machines receives scant attention. In modern terms, early vertical-axis windmills represented "drag" devices. The wind pushed the sails around their axis, and windspeed provided an upper limit on speed of rotation. By contrast, horizontal-axis mills used the principle of "lift," in which the passage of air over the surface of the sail provides a force perpendicular to the wind, causing the rotor to turn at speeds that may exceed the windspeed. Lift, which causes airplanes to rise as their wings cut through the air, remains difficult to explain in intuitive terms. Shephard, in a well-researched but narrow essay published in a handbook for wind engineers, observes that even in the nineteenth century, writers incorrectly described the phenomenon of lift in terms of drag, indicating that in this case theory lagged behind innovation by many centuries.[8]

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[6]Fernand Braudel, *The Structures of Everyday Life: The Limits of the Possible*, trans. Sian Reynolds (New York: Harper & Row, 1979), p. 357; White, *Medieval Technology*, p. 134.

[7]Torrey, *Wind Catchers*, pp. 19-20, 35-37; de Little, *Yesterday and Today*, pp. 12-18.

[8]Dennis G. Shephard, "Historical Development of the Windmill" in David A. Spera, *Wind Turbine Technology: Fundamental Concepts of Wind Turbine Engineering* (New York: AMSE Press, 1994), p. 15.

Over the centuries, millers and builders introduced many innovations. To reach stronger winds, they mounted their machines on wooden towers; the "smock mill" took its name from the resemblance of its squat wooden tower to the profile of a flaring peasant smock. To capture shifting winds, millers used ropes to turn the upper cap, which contained the rotor, rather than the entire structure. Later, to increase strength and height (up to 122 feet!), and to resist fire and rot, builders used brick and stone. Metal gears and wheels replaced machinery carved from hard woods such as apple, hornbeam and holly; the noisy new works cost more, but lasted longer.[9]

Millers paid close attention to the direction of the wind. A tail wind could destroy a post or smock mill in seconds. To guard against this threat, and to take maximum advantage of less severe variations in wind direction, Edmund Lee, an English blacksmith, introduced the fantail in 1745. Lee placed a small rotor on a slender spar behind the mill, with its axis perpendicular to that of the main rotor. When the main rotor faced directly into the wind, the fantail remained still. Slight changes in the wind rotated the fantail slightly; its low gearing pulled a rope that turned the housing back into the wind. Although fantails protected mills from tailwinds, millers disliked climbing out onto the support strut to lubricate the wheel as the housing trembled from the motion of the main rotor.[10]

Braking provided another problem. Millers could not easily slow or stop their mills, adding to the danger of servicing the machine. Worse, querns rubbing together without grain to grind might throw a spark into the chaff; fire could destroy a wooden mill as rapidly as a tailwind. To slow the rotor, some millers threw sand into the works, and Leonardo da Vinci's notebooks included imaginary braking schemes, but for centuries millers stopped their mills by physically quarter-turning them into the wind.

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[9]Torrey, *Wind-Catchers*, pp. 58; de Little, *Yesterday and Today*, pp. 19-28.

[10]De Little, *Yesterday and Today*, pp. 37-41; Minchinton, "Wind Power," p. 34.

Experimenters found a solution in feedback devices. In 1772, Andrew Meickle, a Scot, fitted windmill sails with spring-loaded shutters similar to modern Venetian blinds. Strong winds forced open the shutters, thus reducing the sails' surface area and slowing the rotation. Later feedback systems incorporated "fly-ball governors" like those that regulated the speed of steam engines. This device placed two spherical weights diametrically across from each other on the main shaft, near the rotor's hub. As rotation increased, centrifugal force separated the balls, activating a braking mechanism, such as opening the shutters or changing the pitch of the blades.[11]

In the Age of Reason, experimenters quantified the behavior of many technologies, including the windmill. In 1759, John Smeaton of Yorkshire published an influential study of "The Natural Powers of Wind and Water to Turn Mills." He reported the velocity of the tip of a windmill's sail as almost directly proportional to the speed of the wind, the maximum load on the sail as almost proportional to the square of the wind's speed, and the maximum power as nearly proportional to the cube of the wind's speed. The Royal Society later awarded Smeaton a medal for his demonstration that horizontal-axis wind machines converted energy more efficiently than the vertical-axis variety.[12]

A socially significant technology

Europeans used wind machines to grind grain in areas lacking sites for watermills. Innovators found other uses, however. In Holland, a flat windy country with few other resources, wind "mills" ground snuff, spices, lime and chalk, sawed wood, and pumped water from wells. Most famously, Dutch inventor Jan Adriaenszoon gained the sobriquet "Empty Water" in the early seventeenth century by draining the country's numerous fens with portable post mills. These machines drove long augers that lifted water through hollow

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[11]De Little, *Yesterday and Today*, pp. 30-34; Minchinton, "Wind Power," p. 34.

[12]Torrey, *Wind-Catchers*, p. 60; Minchinton, "Wind Power," p. 34; Louis C. Hunter, *A History of Industrial Power in the United States, 1780-1930; Volume One: Waterpower in the Century of the Steam Engine* (Charlottesville, VA: University Press of Virginia, 1979), p. 93.

tubes or bucket chains to lift seawater into rivers and canals, which carried it down to the sea; dikes protected the reclaimed land.[13]

Windmills and watermills often coexisted, and occasionally competed. As early as 1191, the Abbot of an English monastery ordered a windmill torn down in order to protect the fees he earned on grain ground at local watermills. But windmills never matched the success of watermills, nor did they join watermills in making the transition from village to factory use. Rivers rise and ebb with the seasons, but they flow predictably compared to the wind, which may vary from hour to hour--and rivers always flow in the same direction. Eighteenth-century industrialists pursuing economies of scale in ever-larger production facilities, notably in New England, found that a line of water wheels spanning a river on a single shaft could power a large plant, with different machines connected to the central shaft by oiled leather belts. Hunter's survey of industrial power in early America suggests that millers wrangling with upstream users over water rights used windmills as a source of backup power. But the windmill, which must be reoriented into shifting winds, proved less adaptable to the factories of the Industrial Revolution.[14]

Nevertheless, windmills proliferated for centuries. Holland used between 6000 and 8000 windmills in 1750, and 9000 by the middle of the next century, but only 2500 by 1900, after the introduction of steam-powered mills. English millers may have operated 10,000 windmills in 1840, while Germany boasted 18,232 windmills in 1895, and 17,000 in 1907. As many as 200,000 "German grinders" may have turned in pre-Revolutionary Russia. Throughout Europe, thousands of millers enjoyed high status. Often, their fellow citizens addressed them as 'Master,' and local governments excused them from military service. Torrey tells us that windmills "might serve a thousand persons, and its operator was

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[13]Torrey, *Wind-Catchers*, pp. 46-49.

[14]Braudel, *Everyday Life*, p. 354; Torrey, *Wind-Catchers*, p. 19; Hunter, *Industrial Power*, p. 157.

a middleman between them and nature, a private citizen performing a public service." In short, windmills formed a common element of the pre-twentieth-century landscape.[15]

De Little, in a small antiquarian volume on the restoration of British mills, asserts that the "absolute pinnacle of [windmill] design was probably reached in England" just as steam-driven roller mills gained popularity in the 1840s. Reliant on a less capricious fuel and more flexible with regard to siting, the new mills also produced white flour that previously only the very rich could afford. By 1895, as farmers came to rely on the cheaper, centrally-located steam-mills, British windmills had started to disappear. Their demise hastened after World War I, although they persisted until the mid-twentieth century in the developing world. In America, however, a new kind of wind machine emerged to play a notable historical role.[16]

## PART II: Ancient Technology in the New World

Colonists of each nation invading the New World built windmills. The Spanish may have erected wind-driven pumps on the Yucatan peninsula in the late 1500s. Governor George Yardley of Virginia probably built the first windmill in what became the United States in 1620. By the late seventeenth century, Danes arriving in the Virgin Islands with African slaves to grow sugar erected windmills to grind it. Windmills followed French settlers down the St. Lawrence River, to the cities of Detroit and St. Louis, and in the eighteenth century they appeared in the Mississippi River delta. Dutch windmills lined New Amsterdam's Broadway, but Native Americans burned some Dutch machines further up the Hudson River. Patriotic English settlers on nearby Long Island built their own mills and

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[15]Minchinton, "Wind Power," p. 35; Torrey, *Wind-Catchers*, pp. 42-43; Frank R. Eldridge, *Wind Machines*, 2nd edition (New York: Van Nostrand Reinhold Company, 1980), p. 19; Ye. M. Fateyev, "Wind Power Installations: Present Conditions and Possible Lines of Development," trans.: original Russian 1959, NASA fiche N75-21796 (1975), p. iii. Hunter gives different data in *Industrial Power*, mentioning 5,000 English windmills "as late as 1820," 8,700 French windmills in 1847, and 16,200 German *grist*mills in 1875 (p. 44).

[16]De Little, *Yesterday and Today*, pp. 9-10; Minchinton, "Wind Power," p. 35; Braudel, *Everyday Life*, p. 137; Needham, *Science and Civilisation*, p. 560. For a recent treatment of the demise of industrial windpower, see Richard H. Hills, *Power from wind: A history of windmill technology* (Cambridge: Cambridge University Press, 1994), pp. 215-231.

forbade Dutch millers from practicing there. American wind machines ground grain, sawed lumber, filled salt pans, signalled ships and honed harpoons. While less reliable than water power, windmills occupied a secure niche in the diverse process of colonization--for a time.[17]

Although the steam revolution occurred more slowly in America with its abundant wood and hydropower than in crowded, depleted Britain, American water- and windmills soon fell victim to progressing industrialization and improved transportation. Nineteenth-century capitalists seeking economies of scale concentrated production in ever-larger establishments, and the spreading rail system carried their products to isolated markets that had previously relied on local water- or windpower. The vicissitudes of the older forms of power seemed unacceptable in the age of steam. Wind machines--no longer true mills--next appeared on the American horizon in a different form.[18]

<u>Revolvers, barbed wire, and cheap windmills</u>

Frontier historian Walter Prescott Webb, considering a Westerner's casual remark that "barbed wire and windmills made the settlement of the West possible,"[19] agreed, after adding the Colt's revolver to the list. Revolvers disposed of Western badmen and Native Americans, and barbed wire solved the riddle of how to build fences without wood, thus shutting free range cattle out of farmlands. But wind machines conjured water.

Back East, shovel-wielding welldiggers could strike water between eight and thirty feet down. The hard, dry Plains required drilled wells up to three-hundred feet deep and a pump to raise the water. Farmers, who had flocked to the Plains during the rainy years of

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[17]Torrey, *Wind-Catchers*, pp. 71-84.

[18]Torrey, *Wind-Catchers*, pp. 63-64, 71; Edwin T. Layton, Jr., "The Industrial Evolution in America: Energy in the Age of Water and Wood," *Materials and Society* 8 (1983), pp. 249-263. Layton notes that steam did not replace hydropower in America until 1870, well after its rise in Britain (p. 250). Much of Hunter's analysis on the demise of waterpower in *Industrial Power* holds for windpower as well (pp. 481-485).

[19]Walter P. Webb, *The Great Plains* (Boston: Ginn and Co., 1931), pp. v, 270.

the 1880s, suffered tragically during the droughts that followed. A windpump, even one of the numerous homemade varieties, enabled industrious homesteaders to survive when parched neighbors returned home. It might mean, in Webb's phrase, "the difference between starvation and livelihood." From the Civil War to World War I, tens of thousands of windpumps watered cattle, filled locomotives at lonely supply stations, and pumped drinking water.[20]

American windpumps featured many small blades or slats attached to a "bicycle" wheel between eight and thirty feet in diameter, mounted on a tower twenty to forty feet high. Collectively, the blades presented a large cross-section to the wind, thus supplying necessary power. Due to aerodynamic interference of each blade on its neighbors, however, the wheel turned rather slowly. A crank transformed the rotary motion of the shaft to reciprocating motion, raising and forcing down a vertical rod connected to a pump at the bottom of the tower. A windpump with a twelve-foot wheel could pump ten gallons of water per minute in a 15-mph wind, lifting the water about 100 feet. Because of the danger of climbing the frequently flimsy towers to lubricate the works, manufacturers developed enclosed oil baths. Fantails or rudders sported the manufacturer's name, and advertisers often paid farmers for the privilege of painting their own slogans over the original label.[21]

Following the ranchers and farmers came the townsfolk, and each family required water. In 1904, a *Kansas City Star* correspondent reported that:

> A stranger journeying by rail in northwestern Kansas is struck by the many windmills he sees from the car windows. The prairie land is fairly alive with them. The windmill has taken the place of the old town pump... In the town of Colby, Kansas, on the Chicago, Rock Island and Pacific railway, 125 private windmills

[20]*Ibid.*, pp. 342-347. Soviet historians claimed that engineer V.P. Davydov invented windpumps to water Russian locomotives. See Fateyev, "Wind Power Installations," p. iii.

[21]Minchinton, "Wind Power," p. 35; Torrey, *Wind-Catchers*, pp. 107-110; Inglis, *Wind Power*, pp. 24-25; Eldridge, *Wind Machines*, p. 22.

> bring water to the top for domestic consumption. The home of the humblest citizen of the town is not complete without its windmill.[22]

Mail order catalogs advertised gizmos to convert pumping action to rotary motion, allowing farmers to adapt their windpumps to "shelling, grinding, cutting feed, sawing wood, churning, etc." In the 1860s an inventor even patented a fan-driven magneto that lit an incandescent bulb.[23]

In fact, the vibrant windpump industry inspired thousands of patents. By 1889, seventy-seven factories shipped their wares across the Midwest from Batavia, Waukegan, Kalamazoo, and other small cities on the eastern rim of the Plains. Entrepreneurs accomplished this success with little increase in scientific understanding; in 1890, an engineer bemoaned the lack of rigorous investigation into the economics and behavior of wind machines since Smeaton's experiments over a century before.[24] In accounting for the success of windpumps, Webb points instead to mass production, minimal use of materials, interchangability of parts, and simple designs that allowed easy erection by ordinary mechanics with basic tools. In 1893, 21 million visitors to the World's Columbia Exhibition saw the notable inventions of the age, including Edison's phonograph, Pullman's sleeping car, and a glorious congregation of windpumps. Photographs of that thicket of wind machines still astonish the eye.[25]

By 1930, some six million windpumps dependably supplied the midwest with water. Ranchers, especially, relied on them to water stock. Unfortunately, the windpumps' very reliability meant that farmers hardly ever replaced them. Coupled with the availability of cheap electric pumps requiring even less attention than wind machines, the machines'

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[22]Quoted in Torrey, *Wind-Catchers*, pp. 102-103.

[23]Webb, *Great Plains*, p. 348; Paul J. Israel (reprint ed.), *1897 Sears Roebuck Catalog* (New York: Chelsea House Publishers, 1976), no pagination; Torrey, *Wind-Catchers*, p. 97.

[24]Alfred R. Wolff, *The Windmill as a Prime Mover* (New York: John Wiley and Sons, 1890), pp. 122-131.

[25]Webb, *Great Plains*, pp. 337, 340; Torrey, *Wind-Catchers*, pp. 90-91.

reliability helped kill the industry. In 1919, only thirty-one American windpump manufacturers remained. In the early 1970s, New Mexico State University reported as many as 175,000 survivors watering the prairies, but only a handful of firms producing windpumps.[26]

## PART III: Windpower and Electrification

In the early twentieth century, electric power spread across the nation, edging out a diverse set of resources. Electricity, when generated by a central plant burning coal or exploiting hydropower and delivered over a complex web of transmission lines, provided advantages that windpower lacked. Utility power proved reliable, cheap, and versatile. Best of all, it required little or no effort from users. For a brief moment, wind-driven electricity generators survived in the interstices of the rising tide of central power. Yet, Americans scarcely debated the merits of central versus free-standing power; rather, the great debate of the day concerned private and public power. The following section explores early American electrification, paying special attention to its ideological and political dimensions, which underlie the great sea-changes in the electric system of the 1960s and 1970s.

Electricity first entered American homes as a luxury good, in the form of novelties, doorbells and light. Wealthy homeowners in the last quarter of the nineteenth century found the attractive new illuminant cleaner than gas, with no risk of asphyxiation or explosion, and they framed the bulbs in special chandeliers or Tiffany cut-glass shades. Entrepreneurs, feminists and utopian thinkers, however, saw almost immediately the potential for electricity to improve daily life on a large scale. As the first decades of the century passed, newly-wired homes sported not only electric bulbs, but machines for washing and wringing clothes, cooking, sewing and cleaning.[27]

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[26]Torrey, *Wind-Catchers*, p. 88; Tom Kovarik, Charles Pipher and John Hurst, *Wind Energy* (Chicago: Domus Books, 1979), p. 11; David Lee, "Wind Power," *National Wildlife* 13 (August 1975), p 32.

[27]Nye, *Electrifying America*, pp. 238-286.

Observers of the day and later historians noted the profound changes effected by home electrification, and characterized it as a typical case of modernization. They agreed less on how to evaluate it. For example, the iconoclast Thorstein Veblen argued in 1899 that cultures inevitably develop a wealthy "leisure class" which distinguishes itself by rejecting productive work and the productive use of surplus capital in favor of "conspicuous consumption." The middle classes aspire to the status of the leisure class, and ape their habits of dress, drinking and diversion. Women, in particular, come to function solely as consumers engaged in "non-productive labor for the sake of household reputability." The transfiguration of the American home by electric power seemed to corroborate Veblen's thesis, and most sociologists, while not necessarily sharing his sardonic perspective, agreed that electrification had transformed the role of the home from production to consumption.[28]

Among modern historians, Ruth Cowan challenges Veblen's "production to consumption model," by expanding her definition of production. While "industrialized" households no longer produce goods for sale or home use, they continue to produce "meals, clean laundry, healthy children and well-fed adults." Cowan concedes that electricity made women's work less strenuous and multiplied women's productivity fourfold from 1850 to 1950. However, the hours spent by women at "productive" housework remained constant, as standards of cleanliness increased and as women took sole responsibility for tasks previously shared by servants, men and children. Still, Cowan accepts the striking impact of "nonhuman energy sources" on modern housework.[29]

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[28]Thorstein Veblen, *The Theory of the Leisure Class: An Economic Study of Institutions* (New York: Modern Library, 1934), pp. 35-101 and 353-366, esp. pp. 68, 111.

[29]Ruth Schwartz Cowan, *More Work for Mother: The Ironies of Household Technology from the Open Hearth to the Microwave* (New York, Basic Books, Inc., 1983), pp. 69-71, 99-101. In some passages, Cowan and Veblen agree. Compare Veblen: "the duties performed by the lady, or by the household... are frequently arduous enough... But much of the services classified as household cares in modern everyday life... are of a ceremonial character... They may be ...imperatively necessary from the point of view of decent existence; they may be... requisite for personal comfort even... But ...they are imperative and requisite because we have been taught to require them under pain of ceremonial uncleanness or unworthiness (58)." And Cowan: "These rules were passed down to us by members of an earlier generation (our parents) and sprang from a fear of the deprivations that poverty engenders and from a desire either to rise above those deprivations or stave them off (214)."

David Nye, in a penetrating history of electrification in daily life, depicts virtually all Americans welcoming electricity, which seemed to herald a dawning age of ease and progress. But Nye also suggests the alienating nature of modern technology, writing that electric work was "no longer entirely comprehensible." Nye suggests that women in particular, who once understood all aspects of homemaking, witnessed the increasing mystification of their lives.[30]

Electrification changed the households it entered. Almost without exception, those who benefitted pronounced it a good thing. However, the tide of electrification, with its social changes and trade-offs, rose unevenly across America. In 1907, twenty-five years after Thomas Edison opened his first central generating station on New York City's Pearl Street, 8.0% of urban homes and a minuscule but uncounted fraction of American farms enjoyed utility-generated electricity. By 1920, the relative numbers rose to 47.4 of urban homes and 1.6% of farms; by 1930, to 84.8% and 10.4%. Adding to the disparity, electric companies might charge rural customers double the rate for urban service, and, as one historian put it in a dissertation on rural electrification, the number of electrified farms climbed "only with agonizing slowness."[31]

For a number of reasons, the burgeoning American electric utility industry ignored the rural market. Popular culture portrayed--or caricatured--rural America as unsophisticated, conservative, and resistant to new technology. At the same time, many Americans retained Thomas Jefferson's faith that America's farms safeguarded the nation's moral center, in isolation from the dangers of "progress." Although experimenters first applied electric power to farm labor in the 1890s, some Americans doubted that even

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[30]Nye, *Electrifying America*, p. 280.

[31]Hughes, *Networks of Power*, pp. 40-45; Mark C. Stauter, "The Rural Electrification Administration, 1935-1945: A New Deal Case Study," (Ph.D. diss., Duke University, 1973), p. 5; Nye, *Electrifying America*, pp. 287, 261, 239; U.S. Bureau of the Census, *Historical Statistics of the United States: Colonial Times to 1970, Part 2* (Washington, DC: U.S. Government Printing Office, 1973), S/109-S/111.

electrification could rationalize the farm, while others felt that farms should remain "morally pure."[32]

Economic and demographic factors further discouraged utilities from extending service to rural districts. Building a long transmission line and an extensive distribution network to serve lonely farms earned utilities less profit than urban electrification, where large numbers of closely grouped customers shared fixed distribution costs. Rather than sell to scattered farmers--whom they considered too poor to buy large amounts of electricity anyhow--the electric industry pursued obvious economies of scale by selling to dense population centers. And, as historian Thomas Hughes points out in his classic study of the construction of the American power network, utility engineers and managers justified their stance by appealing to pervasive business ideology; they considered the extension of service to those unable to pay "a matter of social reform, not the business of private enterprise." In any case, with less than half of city homes served in 1920, utilities had hardly saturated the urban market. The farmers would have to wait.[33]

Farmers craving electric service had few choices. They might pay the utilities' stiff installation charge, and high rates thereafter. Or, they might form cooperatives; by 1923, thirty-one groups of farmers in nine states had pooled resources to buy power from local utilities and distribute it through their own network of lines. In a few cases, cooperatives even built their own generating facilities.[34] Or, the farmer might continue to rise with the sun, depending on kerosene for light. A significant number, however, turned to wind, water and gasoline generators to produce their own electricity.

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[32]Abram J. Foster, *The Coming of the Electrical Age to the United States* (New York: Arno Press, 1979 [from 1952 dissertation]), pp. 318-322; Nye, *Electrifying America*, pp. 287-291.

[33]Stauter, "Rural Electrification," pp. 2-3; Bureau of the Census, *Historical Statistics*, S/111; Hughes, *Networks of Power*, p. 464. Utilities also sought balanced demand throughout the day and year. In the cities, public lighting and evening transportation reduced the time which generating equipment, used during the day to supply factories and homes, sat idle. Nye, *Electrifying America*, pp. 292-294.

[34]Stauter, "Rural Electrification," p. 4.

Windmills for Electricity

In the early 1920s, rural America emerged from its isolation, due partly to the influence of returning doughboys who had seen "Gay Paree" in the European war. Farm families wanted electricity for light and to operate radio receivers, which connected them to nearby cities. Where central station service proved out of reach, the pervasive windpumps provided a clue; perhaps one could transform their rotary power to electric power.

In fact, the windpumps' multi-bladed wheels turned too slowly to generate electricity. Experimenters replaced the wheels with airplane propellers, which turned more swiftly. If they could not get a real propeller, a carved wooden one did the trick. Thus equipped, the shaft could turn either a generator, rotating the armature inside a set of coils to produce direct current, or an alternator, rotating the field to produce alternating current. Wind tinkerers also found that electricity production required a battery storage system, unlike their old water pumps, which raised water to a tank for use when the wind died down. (Unfortunately, they also found the batteries of the day expensive and incapable of holding a charge for long periods.) Parts cost five dollars or so, and in some states the local extension office published instructions.[35]

In response to growing interest, entrepreneurs marketed "aerogenerators." Marcellus Jacobs manufactured the most famous, a 2.5-kilowatt[36] (kW) model with a rotor diameter

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[35]Kovarik, Pipher and Hurst, *Wind Energy* p. 11; Inglis, *Wind Power*, pp. 24-25; Jon Naar, *The New Wind Power: A timely firsthand report on how business, government, and independent research are creating a new energy industry* (Hammondsworth: Penguin Books, 1982), p. 48.

[36]Physicists measure electric power in units called watts, after James Watt, inventor of the steam engine. A kilowatt (kW) equals one thousand watts; a megawatt (MW), one million watts; a gigawatt (GW), one billion. Engineers consider a wind turbine rated at two kW in winds of a given strength *capable* of producing two kW of electric power at any instant, although *real* power production depends on the instantaneous speed of the wind, and may be less or even more than two kW.

To measure the energy (work) produced by a turbine, multiply the real power by a unit of time. Kilowatt-hours (kWh) typically express the energy produced by wind and other types of generators. Thus, a turbine rated to produce two kW in a given wind produces four kWh of energy if it operates in the same steady wind for two hours.

Power ratings can deceive. One can increase the rating of a wind turbine by substituting a larger generator, but this will not necessarily boost energy production. In general, the energy captured and converted to electricity depends on wind strength, rotor diameter, and aerodynamic and mechanical efficiency.

of fifteen feet. A novice pilot, Jacobs devised a spruce propeller-style rotor, turning at 125-225 revolutions per minute (rpm). In high winds, a flyball governor automatically feathered (*i.e.*, changed the pitch of) the blades. In a feathered position, they exposed less surface area to the wind, and rotation slowed, preventing damage due to overspeed. Jacobs also found that two-bladed rotors tended to yaw[37] in a series of jerks; he explained later that this configuration, when in a horizontal position, presents centrifugal resistance to the yaw motion, causing serious structural vibration. By 1927, he settled on a three-bladed rotor, which he promoted ever after.[38]

Jacobs' machines cost $490 apiece, plus $365 for a unique glass-cell lead-acid battery, and $175 for a steel tower. Jacobs estimated maintenance costs at under five dollars per year, plus about $36 per year toward replacing the battery. From 1928 to 1957, his Minneapolis factory marketed aerogenerators worldwide, generating over $75 million in sales. The remarkable machines seemed indestructible; one erected by the Byrd Expedition at the South Pole operated for twenty-two years with no maintenance at all. Jacobs retired in 1957 due to ebbing demand for his product, which he attributed to the success of the Rural Electrification Administration (REA) in delivering cheap, dependable central power. In the 1970s, eager neophytes refurbished old Jacobs machines, which might sell for $3000 (not including tower and batteries). In response to such enthusiasm, Jacobs re-entered the market.[39]

Still, Carol Lee's recent dissertation on decentralized power generation on American farms contends that few wind plants were ever installed. "Wind-generated electricity," she writes, "never fulfilled the emerging expectations of the 1910s and 1920s for farm power.

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[37]Yaw, an aviation term, refers to rotation in the plane parallel to the ground.

[38]Eldridge, *Wind Machines*, pp. 22-24; Marcellus L. Jacobs, "Experience with Jacobs Wind-Driven Electric Generating Plant, 1931-1957" in Joseph M. Savino (ed.), *Wind Energy Conversion Systems: Workshop Proceedings Held at Washington, DC, on 11-13 June 1973*, NTIS NSF-RA-W-73-006, sponsored by the NSF, RANN and NASA, pp. 155-159.

[39]Wilson Clark, *Energy for Survival: The Alternative to Extinction* (Garden City, NY: Anchor Books, 1975), pp. 539-541; Torrey, *Wind-Catchers*, pp. 122-126.

In the end, both water- and wind-powered plants generated more emotion than electricity." While the secondary literature leaves unclear the pervasiveness or significance of aerogenerators, it seems that they briefly filled a niche in the absence of central station service, but soon disappeared. Torrey found only one aerogenerator, the Wincharger, produced and sold in America in the 1970s.[40]

Why did aerogenerators disappear?

A joint report prepared in 1929 by electric utilities, the Farm Bureau and the Department of Agriculture noted that half of America's electrified farms made their own electricity from hydropower, gasoline engines, and wind turbines. These technologies failed to persist for clear reasons. Utility service, when it finally arrived, proved cheaper, more reliable, less troublesome, and needed no storage. Even if the cost of central power had not decreased, Lee points out, Americans found utility service more convenient. The spread of central power across America "relegated [individual generating sets] to the status of an alternative technology... increasingly acceptable only in the absence of central station lines." Finally, Lee notes that large-scale, central station generation seized the imagination of engineers, businessmen and politicians, becoming a symbol of American progress.[41]

The issue of centralization, so important today, seemed less controversial a century ago. Lee notes that the 1929 study "stresses that rural electrification went beyond the political scope of public power and beyond the technical range of central station service." That is, some farmers electrified their farms without the political support of centralized government, or the technology developed by centralized utilities. But America in the early twentieth century treated decentralized power as obviously inferior to central service, an

[40]Torrey, *Wind-Catchers*, pp. 126-129; Carol Lee, "Wired Help for the Farm: Individual Electric Generating Sets for Farms, 1880-1930," (Ph.D. diss., The Pennsylvania State University, 1989), pp. 121, 123.

[41]Lee, "Wired Help," pp. 215-222.

option that one would only exploit in the absence of utility service. Rather than increasing centralization, the main debate of the day set private against public power.[42]

In 1928, Governor Gifford Pinchot of Pennsylvania published evidence that six financial empires--those of Samuel Insull, General Electric, J.P. Morgan, A.W. Mellon, H.M. Byllesby, and Henry Dougherty--controlled two-thirds of the nation's generating capacity. Together, he charged, they constituted "a power monopoly organized and financed to secure the profits of extortion by the arrogant abuse of unregulated, unrestrained privilege." Worried that America would enter "the great electric era of world competition" handicapped by excessively expensive electricity, Pinchot supported government-coordinated development of American electric capacity, especially in rural areas. His stand echoed presidential candidate Robert M. La Follette's "Progressive" campaign of 1924, which advocated seizing power from unregulated business interests and putting it in the hands of government for safekeeping.[43] In the hands of Pinchot and others, rural electrification became a tool by which social reformers enlisted government in the fight against the monopolies.[44]

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[42]Lee, "Wired Help," pp. 3-4. U.S. Census figures list 9.2% of American farms as electrified in 1929. The column heading, "Percentage of dwelling units with electric *service* [my emphasis]," implies that individual generating sets are not counted. Bureau of the Census, *Historical Statistics*, S/110.

[43]Significantly, La Follette's polled only 17% of the vote in 1924, the year in which pro-business candidate Calvin Coolidge won the presidency. By 1928, the Progressive Party was tottering toward oblivion. See Maldwyn A. Jones, *The Limits of Liberty: American History 1607-1980* (Oxford: Oxford University Press, 1983), p. 444.

[44]Gifford Pinchot, *The Power Monopoly: Its Make-Up and its Menace* (Milford, PA: By the author, 1928), pp. 1-6; Hughes, *Networks of Power*, pp. 297-305; "Wired Help," Lee, p. 222. Concern over possible abuse by private electric companies, and the spectacular collapse of Insull's empire in 1932, eventually brought about the Public Utility Holding Company Act of 1935, which subjects companies owning electricity-generating facilities to strict Federal oversight. Some analysts, however, partly attribute the collapse of the holding companies and the resentment caused by the disaster to exogenous factors such as investor naivete and unexpected drops in demand for electricity during the Depression. See Leonard S. Hyman, *America's Electric Utilities: Past, Present and Future* (Arlington, VA: Public Utilities Reports, Inc., 1983), pp. 75-85.

Utility managers and engineers generally dismissed Pinchot's imputation of a Power Trust as "political necromancy."[45] Instead, they attributed the success of their industry to "the initiative of progressive and far-seeing men and the employment of courageous private capital."[46] Like most American businessmen of the day, they doubted that government-managed industry could match the technological progress fostered by the American market. As one utility executive declared pugnaciously, "no communist experiment or socialist plan produced the first incandescent lamp, the first practical dynamo, or the first system of electrical transportation."[47] Rather than government planning, utility managers placed their faith in private institutions, and assured the public that, in *Electrical World*'s phrase, "the power companies made this country the leader of the world in electrification and are keeping it in the lead."[48]

Nevertheless, the farms remained dark. President Franklin Roosevelt viewed their lack of electric service as the denial of a basic right, and propounded two types of Federal intervention. First, the government commissioned Federal power marketing authorities such as the Tennessee Valley Authority (TVA), founded in 1933 to furnish cheap power and fertilizer for the Tennessee River Valley, and to make navigable the region's rivers. Second, as part of the Federal Emergency Relief Act of 1935, Congress formed the REA to encourage electrical cooperatives by distributing low-interest government loans.[49]

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[45]The Editorial Staff of *Electrical World*, *The Electric Power Industry: Past, Present and Future* (New York: McGraw-Hill Book Company, Inc., 1949), pp. 4-7.

[46]T.C. Martin and Stephen L. Coles, *The Story of Electricity, Volume I* (New York: The Story of Electricity Company, 1939), p. i.

[47]Arthur S. Huey, Vice President of H.M. Byllesby & Co., *The Regulation of Public Utilities* (Chicago: pamphlet's publisher not noted, 1911), p. 7.

[48]Editors of *Electrical World*, *The Electric Power Industry*, p. 7.

[49]Stauter, "Rural Electrification," pp. 12-14; Hughes, *Networks of Power*, p. 464. Note that rural electrification took a unique path in California, where utilities pursued rural markets on their own, long before Federal involvement. Due to sparce energy resources, high rural irrigation loads, a scarcity of urban industry, and the presence of long transmission lines from hydroelectric facilities which farm communities could tap *en route*, California utilities had electrified 60% of the state's farms by the mid-1930s, while the national figure

(continued...)

REA cooperatives encountered various obstacles. Many utility managers determined not to allow competitors to operate inside the geographic borders of their "natural monopoly." Some, on hearing that a cooperative had applied for a Federal loan, convinced state regulators that the utility had, in fact, been about to enter that area, and that the proposed cooperative would infringe on its territory. This tactic frequently prompted charges that the commissions had been captured by the utilities they were meant to regulate. In other cases, utilities learning of a proposed cooperative quickly ran a line through the prospective area, picking off the most promising customers. These "spite lines" often made the cooperative economically impractical and left the majority of farmers in the area without electricity.[50]

When all else failed, some utilities purchased established cooperatives. Buy-out offers often provoked controversy among co-op members. In 1948, for example, an official of the National Rural Electrification Cooperative Association, a Federally-supported agency, pleaded with farmers of Virginia's Craig and Botetourt counties not to sell their co-op to the Appalachian Power Company. He charged that Appalachian belonged to a large holding company, the American Gas and Electric Company, and exhorted his audience: "Don't sell out to the Wall Street interests... Word of what you do here will go out to millions of farm families throughout America, and to Congress... Don't surrender!" In this case, the farmers rejected the utility offer. In others, they did not.[51]

By 1959, the REA had extended loans at 2% interest to 1026 rural cooperatives serving 4.3 million consumers, and 95.9% of American farms enjoyed electric service.[52]

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[49](...continued)
hovered around 10%. See James C. Williams, "Otherwise a Mere Clod: California Rural Electrification," *IEEE Technology and Society Magazine* 7 (December 1988), pp. 13-19, 29.

[50]Marquis Childs, *The Farmer Takes a Hand: The Electric Power Revolution in Rural America* (Garden City, NY: Doubleday and Company, 1952), p. 76.

[51]*Ibid.*, p. 86.

[52]Bureau of the Census, *Historical Statistics*, S/110, S/149, S/151.

The Federal Power Commission reported that "the advantages of electricity in farm operations are well recognized and in many instances it can be demonstrated that electricity pays for itself by increased production, improved quality, and reduced labor costs--to say nothing of added convenience." Electrification brought not only electric lights, stoves and refrigerators, but also "milking machines, milk coolers, incubators, brooders, grinders, hoists, pumps (including irrigation pumps), hay driers cleaners, and many other devises [sic]."[53] Voices from the private sector denounced the early REA as a "folly... conceived in the hate of the 'Power Trust' bogey,"[54] but a supporter observed in 1952 that while utility "spokesmen speak of subsidies, socialism, or worse in costly propaganda," the cooperatives faithfully repaid their REA loans, often in advance.[55]

## Conclusion

Wind powered pumps and generators faded from the American scene for three reasons. First, they could not compete economically with cheap centrally-generated electricity. Second, the power they produced, at least in the case of generating sets, could not be adequately stored to provide consistent power. Third, the issue of centralized versus decentralized power production disappeared in the furor over a bigger debate, that between private enterprise--perhaps corrupt--versus government management--perhaps inefficient.

Our brief excursion into the early years of the electric utility industry lays the ground for a discussion of utility-scale windpower. Early in the century, investor-owned utilities won an incomplete but clear victory over the public power model; by 1985, government-owned facilities and cooperatives accounted for only about one quarter of the nation's generating capacity.[56] Convinced of its unique ability to facilitate progress and

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[53]Federal Power Commission, *Estimated Future Power Requirements of the United States By Regions, 1955-1980* (Washington, DC: Federal Power Commission, 1955), p. 9.

[54]"Rural Electrification," *Electrical World* 131 (21 May 1949), p. 507.

[55]Childs, *Farmer*, pp. 15-16.

[56]*Statistical Yearbook of the Electric Utility Industry\1985* 53 (Washington, DC: Edison Electric Institute, 1986), p. 7.

improve the quality of life, the private utility industry maintained a wary suspicion of government meddling in the power sector. Federal efforts to encourage alternative energy technologies such as windpower in the 1970s met the same rancor as had earlier attempts to break up the holding companies and push rural electrification.

With the gradual extension of the national electric grid, windpower retreated. According to the Bureau of the Census, wind machines supplied the country with 14,000 horsepower (hp) in 1849, 120,000 hp in 1900, and 200,000 hp in 1930. Just twenty years later, in 1950, windpower's contribution had fallen to 59,000 hp,[57] and close to forty long years passed before it again made a stir on the national scene. Before that happened, however, one notable attempt to generate electricity from the wind deserves mention, not least because of the importance given it by developers of the "wind renaissance" of the 1970s.

## PART IV: The Vermont Giant

"In 1934 I had built a house... and found both the winds and the electric rates surprisingly high."[58] With those words Palmer Putnam introduces the story of his experimental 1250-kW Smith-Putnam wind turbine, constructed in 1941 and unsurpassed in size until the mid-1970s. Windpower historians and participants alike identify Putnam's project as seminal, foreshadowing numerous issues addressed by future engineers and managers. Beauchamp Smith, former vice-president of the firm that constructed the turbine, told participants at the first Federal wind-energy workshop in 1973 that the attempt to generate electricity from wind power succeeded technologically; "What it did not prove," he cautioned, "is that this can be done on an economically feasible basis!"[59] Both Smith and

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[57]Bureau of the Census, *Historical Statistics*, S/12. These figures do not specify the application of the wind machines.

[58]Palmer C. Putnam, *Power From the Wind* (New York: Van Nostrand Reinhold Company, 1948), p. 3.

[59]Beauchamp E. Smith, "Smith-Putnam Wind Turbine Experiment" in Savino (ed.), *Workshop Proceedings*, pp. 5-10.

Putnam himself called the project a failure, indicating their true goal: not to create simply a machine, but to integrate a generation technology into the existing utility system.[60]

In the late 1930s, the S. Morgan Smith Company, manufacturers of hydro-electric equipment, became concerned over the increasing scarcity of good hydropower sites. As an experiment in diversification, they agreed to build Putnam's turbine. Putnam and the Smith Company believed that, due to the variability of the wind, turbines required storage or backup power. Free-standing aerogenerator-battery sets offered expensive, inefficient and temporary storage; Putnam and the Smith Company saw more potential in the pumped-water storage systems used by utilities. In such systems, electric pumps fill elevated reservoirs during periods of cheap or available power; the utility then releases the water to pass through hydroelectric generators when electricity costs more to produce or when demand exceeds available generating capacity. The Central Vermont Public Utility Corporation, forced by insufficient generating capacity to buy wholesale power, agreed in 1939 to purchase the turbine's output.

Putnam assembled a high-profile team of experts to select a site, carry out design-cost studies, and operate a pre-production prototype. Because the energy available from the wind varies with the cube of the windspeed, economic operation of wind turbines demands highly accurate placement. When the team turned its attention to the task of site selection, however, they found only meager theoretical knowledge of wind behavior, and few detailed studies of possible locations. Previous investigators had mapped wind conditions only near airports, located at sites chosen precisely for their calmness. The team eventually assembled their own measurement devices and procedures, including "ecological" techniques, which deduced past wind conditions by examining plant formations and topography. They settled on Grandpa's Knob, near Rutland, VT, where neighboring mountains acted as natural airfoils to focus the wind onto the turbine.

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[60]See, for example: Inglis, *Wind Power*, pp. 7-8; Eldridge, *Wind Machines*, p. 24; Torrey, *Wind-Catchers*, pp. 130-140; Kovarik, Pipher and Hurst, *Wind Energy*, pp. 13-15; Minchinton, "Wind Power," p. 36. My account draws on these pieces, as well as Smith's talk and Putnam's report, later published as a book, cited above.

Because electricity too high in frequency could damage utility equipment, the turbine had to maintain a constant speed of rotation. To accomplish this feat, Putnam first considered blade flaps similar to those on airplane wings; in high winds, the flaps would open, creating a less efficient airfoil and slowing rotation. Researchers knew little about the use of such flaps on turbines, so Putnam selected a technology pioneered by Hamilton Standard Propellers for hydraulic turbines and used in early aerogenerators. A fly-ball governor adjusted the blades' pitch in high winds, thereby reducing rotational, torque on the generator, and power frequency. During gales, the blades feathered completely, turning parallel to the wind.

The team made countless other design decisions. The turbine flew only two blades; the minimal increase in power offered by a third did not justify the extra material cost. Putnam built the turbine as an "upwind" unit, with the rotor receiving the wind before the tower. This avoided aerodynamic interference from the tower on the rotor, but made necessary a "yaw" motor to head the rotor into the wind. (Downwind machines automatically follow the wind, like a sailing ship.) The yaw motor also alleviated the vibration observed by Jacobs in two-bladed with free downwind yaw. The blades coned; that is, they reacted independently to changes in wind shear, allowing for differences in the wind angle at the trough and peak of the rotation. While aircraft engineers had abandoned this technique in favor of propellers with blades fixed at a built-in coning angle, Putnam felt true coning necessary in a rotor so huge. The axis of the rotor tilted 12.5 degrees into the winds blowing down off the nearby mountains; this generous angle also ensured that the blades, when coning, would clear the tower. Finally, the team selected a synchronous generator, turning at a constant speed to produce electricity at 60 cycles per second, in phase with the electricity in most utility grids. They placed the generator aloft in the rotor housing; although this necessitated a stronger, more expensive tower, it avoided the greater expense of a complex drive-train connected to a stable generator located on the ground.

Among the design variables considered, turbine size proved crucial to economic performance. Earlier wind machines had completely met users' needs for grinding, water, or power, and thus users purchased machines large enough to meet their greatest need at any given moment. But as a utility supply technology, the Smith-Putnam wind turbine produced an aggregate commodity, pooled in the Central Vermont grid. Thus, Putnam had to identify the unit size capable of generating the cheapest energy. He chose to optimize cost per kilowatt of installed generating capacity ($/kW). Putnam's initial study, which hypothesized a run of 100 units, indicated as the most economical turbine one with a rotor diameter of 226 feet and a capacity of 600 kW. Later investigations commissioned by the Smith Company led to production of a 1250-kW test unit with a 175-foot rotor on a 150-foot tower, the smallest turbine considered dynamically representative of the ultimate production unit. Operation of this pre-production unit led to recommendations that future rotor diameters lie between 175 and 225 feet, tower heights between 150 and 175 feet, and capacities between 1500 and 2500 kW--a thousand times the capacity of the Jacobs' 2.5-kW aerogenerator!

The Putnam-Smith turbine went "on line" in October of 1941. It performed well, exceeding its rated capacity of 1250 kW by generating up to 1500 kW in winds up to 70 mph. In February 1943, a bearing failed. Due to wartime shortages of materials for non-military applications, it took two years to replace. In the interim, the team discovered stress fractures at one blade root, but they impatiently decided to continue the testing. For a time all went well, but in March of 1945, the turbine "threw a blade," which landed 750 feet away.

Following the disaster, Putnam estimated that a block of six new test units would cost $190/kW. After Central Vermont announced that they would pay only $125/kW, the cost of comparable conventional power, S. Morgan Smith declined to invest further in the project. Beauchamp Smith recalled that "the test unit was dismantled and removed from the site, the patents and patent applications were dedicated to the public domain, and the investment written off to experience."[61] Meanwhile, Putnam suggested in his final report

[61]Smith, "Turbine Experiment" in Savino (ed.), *Workshop Proceedings*, p. 7.

ways in which future workers might bridge the gap of $65/kW. He noted that the pre-production unit had not benefitted from competitive bidding. He also hoped for economies of mass production, pointing out that while mass-produced steel box cars cost only six cents per pound to produce, the custom-made turbine blades cost almost eight times that.

Putnam and his team attributed the catastrophic failure to the shortcuts they had taken to avoid further delays. Putnam concluded that "the technical problems of the 1250-kW wind turbine are understood and have been solved. To solve the economic problems of putting this or a larger wind-turbine into low-cost production probably requires Government aid."[62] Whether or not Putnam was correct in his confident dismissal of remaining technical problems, the story of the turbine at Grandpa's Knob illustrated several important points:

>While wind turbines had previously failed to provide an decentralized alternative to utility power, they might possibly provide a *utility supply technology*;

>Engineers believed that wind, due to its variability, could only function in concert with *energy storage devices*;

>Windpower's success required not only extensive *mapping of wind resources* but also the development of new scientific tools for doing so, and;

>Most important, the experiment identified two variables on which successful development of wind turbines would depend. Developers would have to identify the *most economical turbine size* to lower energy cost, and they would have to pursue *economies of mass production* to lower initial cost.

These conclusions provided the starting point for the wind renaissance of the 1970s. As we will see, some proved more obdurate than others.

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[62]Putnam, *Power*, p. 218. Some commentators questioned the absolute technical success of the project, for instance pointing out that "the initial cause of the rupture was probably an inadequate estimate of the stresses exerted by the wind on a metallic structure exposed to the wind." G. Lacroix, "Wind Power," translation: original French 1949, NASA fiche N74-17792 (March 1974), p. 17.

## Conclusion: Centralized versus Decentralized Power

Although a handful of promoters continued to advocate the use of wind power for a variety of reasons,[63] they failed to prove its economic viability, and the years between Putnam's experiment and the 1973 Arab oil embargo saw no large-scale applications in America. Rather, the opposite occurred; wind became a counter-culture technology among those few who derived ideological satisfaction from unplugging themselves from the grid. Most Americans, by contrast, enjoyed not having to think too much about the cheap power they purchased from their local utility.

As for the utilities, for decades they successfully exploited economies of scale and extended service to virtually all of America. By 1956, 98.8% of all dwellings received service from central power plants. As the average inflation-adjusted price of residential service steadily dropped from over $3.00/kWh in 1890 to about seven cents/kWh in the late 1960s, utility managers came to look with pride on their accomplishments.[64]

Utility managers asked to assess windpower's potential to contribute to America's energy supply in 1970 might have replied that the concept made poor sense, just as it had in 1945, when Central Vermont backed out of the Smith-Putnam project; or in the 1930s, when the national grid reached rural America, squelching the growth of aerogenerators; or in the 1920s, when the windpump industry failed in the face of electric pumps, leaving scattered reminders on ranches and farms across the Midwest; or in the late nineteenth-century, when steam-driven roller mills replaced European-style windmills. One skeptical engineer argued in 1977 that providing electricity through the use of home windmills entailed "immense" costs. Considering a $10,000 system providing one home or two apartments with 600-700

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[63]For example, between 1945 and 1954 the FPC published four monographs by Percy Thomas advocating multi-megawatt wind installations of his own design, featuring multiple rotors on a single tower. See Charles W. Lines, "Percy Thomas Wind Generator Designs" in Savino (ed.), *Workshop Proceedings*, pp. 11-18.

[64]Bureau of the Census, *Historical Statistics*, S/109; Hirsh, *Technology and Transformation*, p. 9. Prices in 1986 dollars.

kWh per month, financed by a thirty-year, 8.75% loan, he calculated that windpower would cost 11.3 cents/kWh, over triple the cost of central station power.[65]

On the basis of this historical survey, at least, skepticism of windpower's potential contribution appears well placed. Wind machines in every era thrived only in the absence of competition from centrally-produced power, or in the interstices of the advancing central power regime. However, as we saw in Chapter One, the situation had begun to change by 1970, not because of changes in wind turbine technology, but because of the changing environment in which Americans produced and used electricity. The 1970s brought the controversial possibility that, suddenly, *de*centralized electricity generated from renewable resources might offer economic advantages.

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[65]Daniel W. Kane, "Comments on Article by Amory B. Lovins" in Yulish (ed.), *10 Critical Essays*, p. 54.

# CHAPTER THREE
# Consolidation and Diversification: The Beginnings of Federal Windpower

## Introduction: Two Trends

In the 1970s, American energy policy exhibited two simultaneous trends. On one hand, citizens and policy-makers convinced that they faced an "energy crisis" excoriated the inefficient and contradictory process by which the government instituted energy policy, at the time scattered among dozens of separate agencies. To consolidate energy decision-making into one giant apparatus, the Federal government created the Department of Energy (DOE) in 1977.

At the same time, engineers, environmentalists and counter-culture thinkers increased their pleas that the government diversify its energy research. They variously cast nuclear, solar, clean coal, or other technologies as the solution to the crisis. Such calls resulted in the early 1970s in modest budgets for alternative energy research and development. As in the case of policy consolidation, the events of 1973 rapidly increased the diversity and level of the Federal government's energy research and development.

Among many projects benefitting from these two trends, the Federal Wind Energy Program received increasing budgets and substantial attention from the DOE. As the FWEP grew throughout the 1970s, it encouraged the development of a wind technology industry, which knit "garage workshops" and huge diversified corporations into an uneasy alliance. This chapter explores the accretion of momentum behind Federal windpower, and outlines the roles of NASA, the National Science Foundation (NSF) and other early players.

## PART I: The Visionaries

After prolonged lack of interest among Americans concerning wind energy, the early 1970s brought scattered hints of change. In some cases, political and social visionaries discovered in wind power an alternative to what they perceived as unsustainable waste in

American life. For instance, in early 1971 Stewart Udall, former Secretary of the Interior under Presidents Kennedy and Johnson, published a widely reprinted essay in *The New York Times*. Udall evoked windmills as "symbols of sanity for a world increasingly hooked on machines with an inordinate hunger for fuel and a prodigious capacity to pollute." He believed that windmills had "zero environmental impact," and offered a way to heal Americans' corrupt relationship with their environment. Udall solemnly told readers that "the issue is nobler than survival. It is whether we can equip ourselves to live truly decent lives."[1]

"Counter-culture" thinkers, who sought alternatives to what they perceived as pervasive but pernicious trends in American society, identified windmills as a means of democratizing the nation's "energy economy."[2] These people enthusiastically cited Amory Lovins' argument that

> ...the energy problem should not be about how to expand energy supplies to meet the postulated extrapolative needs of a dynamic economy, but rather how to accomplish social goals elegantly with a minimum of energy.[3]

Another sage of the day, R. Buckminster Fuller, encouraged his student Hans Meyer to develop cheap windmill materials with which ordinary people could do their own windpower experimentation.[4] To Lovins, Fuller and their fans, the American energy system contained unnecessary complexity; they rallied citizens to streamline their lives and take direct responsibility for energy use at the family or community level.

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[1]Stewart Udall, "Turned On by Windmills," *The New York Times* (13 February 1971), p. 27.

[2]Even this phrase, common at the time, irked counter-culture advocates, who felt that it masked important non-economic questions of social value involved in energy decisions.

[3]Amory B. Lovins, *Soft Energy Paths: Toward a Durable Peace* (New York: Harper Colophon Books, 1977), pp. 13, 120-122.

[4]Naar, *The New Wind Power*, p. 218; Hans Meyer, "The Use of Paper Honeycomb for Prototype Blade Construction for Small to Medium-Sized Wind Driven Generators" in Savino (ed.), *Wind Energy Conversion Systems*, pp. 73-74.

William Heronemus: "soft" technology meets "big" technology

Some Americans sympathized with the counter-culture's paean to simplicity. The early 1970s saw an upturn in sales of "the glorious, simple, ugly windmill,"[5] and in 1971 one of two surviving American windpump firms reported its best year since the 1920s--375 sales--after receiving mention in the "back to the land" publication, *The Whole Earth Catalog*. But, while household wind machines appealed to a few people, the general public--or at least the press--seemed more captivated by the free-flying images painted by William Heronemus, a bold advocate of large-scale windpower. A professor of civil engineering at the University of Massachusetts, Heronemus had designed nuclear submarines for the U.S. Navy before retiring. He remained skeptical that engineers could construct safe nuclear reactors. Instead, he advocated capturing the wind on enormous scales.[6]

Heronemus stoutly declared that a combination of plants drawing on wind and ocean-thermal power "could satisfy *all* the projected energy requirements of the 21st century."[7] He attacked what he labelled misconceptions about windpower among those few who had considered it at all. To those who maintained that available winds contained little energy, Heronemus had two suggestions. One might place windmills in regions of high wind, such as Vermont's Green Mountains or the Hawaiian and Aleutian Islands. A better plan situated turbines on high towers. Heronemus calculated that even in regions of moderate wind, windspeeds would reach about 21 miles per hour (mph) at heights of 600 feet, and 23 mph at 1000 feet. (By contrast, the hub of the Smith-Putnam unit stood 120 feet off of Grandpa's Knob.) Each tall tower, Heronemus conjectured, might sport multiple rotors.

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[5]Jon Lowell, "Windmills Moving Again," *The Washington Post* (11 July 1971), p. G5.

[6]Clark, *Energy for Survival*, p. 524; Torrey, *Wind-Catchers*, pp. 166-173.

[7]Emphasis in original. This synopsis of Heronemus's position draws on his talk, "The United States' Energy Crisis: Some Proposed Gentle Solutions," published in U.S. Congress, House of Representatives, *The Congressional Record--Extensions of Remarks* 118, 92d Congress, 2d Session (9 February 1972), pp. 3587-3592.

In response to those who maintained that economical use of wind turbines required winds of at least 30 miles per hour, Heronemus considered the case of mass-produced turbines with rotor diameters of fifty feet, designed for moderate winds. He calculated that fabricated in batches of 100 units per year, manufacturers could make turbines at a cost of $350 per kilowatt ($/kW) of installed capacity; in batches of 20,000 per year, the cost should drop to $100/kW.[8] Such prices, he claimed, made wind plants economically attractive even for moderate wind regimes.

Finally, Heronemus addressed concerns that wind power provided an undependable resource, and that the nation would have to back up each wind plant with conventional facilities, whose power utility managers could reliably dispatch during periods of calm. Instead, Heronemus proposed development of energy storage technologies. Utilities might use wind energy to compress air, or the Federal government might devise a national pumped hydraulic storage system using Lake Superior as the upper reservoir. Heronemus particularly recommended using wind turbines to produce current to electrolyze water; the resulting hydrogen gas could serve as fuel for direct combustion, or as an ingredient in fuel cells, or for the gasification of coal.

Heronemus came to prominence in 1972 after arguing the position outlined above before a combined meeting of professional engineers. He concluded his address by asking why knowledgeable policy-makers devoted hundreds of millions of dollars annually to exotic nuclear research, while docketing only a few million dollars for solar energy. That challenge might have died in obscurity, had it not come to the attention of Sen. Mike Gravel (D-AK), who inserted the text of Heronemus' talk into the *Congressional Record.*

Heronemus received extensive attention as a leading prophet of the "alternative energy" movement. Students at the University of Massachusetts and the public at large

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[8]For purposes of comparison, open-cycle gas turbine-generators, widely used in the electric utility industry as peaking or emergency units, cost a low $80-100/kW in 1970. On the other hand, such units had high fuel costs. Generators using cheaper fuel cost much more. Federal Power Commission, *The 1970 National Power Survey,* p. 8/2.

grew familiar with his creativity, which ranged from plans to meet all of Vermont's electricity needs by covering the state's mountains with wind machines, to stringing a long line of turbines from the Texas coast to the Canadian border. By 1974, perhaps as a result of exposure to Heronemus' ideas, even NASA confidently discussed turbines with 200-foot rotors on 1000-foot towers.[9]

Few of Heronemus' proposals received serious funding. He derives his historical significance from the breadth of his influential imagination. Heronemus awed his audience with a vision of wind turbines on a huge scale: enormous in size, produced by an intensive industrial effort, and erected in such numbers as to radically transform portions of the national landscape. Equally important, he helped wrestle narrow technical discussions of energy policy onto issues of environmental sustainability and long-range goals.

Of course, Heronemus' ideas did not challenge social values and the existing political structure in the same way as, for example, Amory Lovins' "soft path." No doubt, Lovins would have rejected Heronemus' vision of mammoth turbines tied to the electrical grid as an "ingenious high-technology way to supply energy in a form and at a scale inappropriate to most end-use needs."[10] But Heronemus perturbed utility executives and policy-makers by advising them to invest huge sums of money in an untried technology, while questioning the advisability of their nuclear dream.

At the same time, he provoked advocates of wind energy to "think big." He inspired engineers to conceive of wind machines not as the clunky windpumps of the Great Plains, but as challenging high-technology powerplants requiring intense industrial and academic effort. As the years passed, Heronemus received progressively less mention in the dry

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[9]"Windmills Advocated for Power," *The Washington Post* (18 August 1973), p. D10; Lee, "Wind Power," p. 33; Marvin Miles, "There's Energy in the Air, NASA Points Out," *The Los Angeles Times* (10 March 1974), pp. 3, 19.

[10]Lovins refers here to "the schemes that dominate ERDA's solar research budget--such as making electricity from huge collectors in the desert, or from temperature differences in the oceans, or from Brooklyn-Bridge-like satellites in outer space." Lovins, *Soft Energy Paths*, p. 42.

reports of the Federal wind program. Yet, he surely deserves some of the credit for allowing bureaucrats and engineers to hope--against the wisdom of the day--that they could resolve a daunting social problem in a technologically interesting, economically efficient way, by combining "soft" technology and "big" technology.

## PART II: Federal Mobilization

The fancies of Udall, Fuller and Heronemus had a negligible impact on the Federal government. On June 4, 1971, President Nixon addressed Congress on the subject of clean energy resources. Nixon called for accelerated development of the liquid metal fast breeder reactor, new equipment to control sulphur oxide emissions, and techniques to convert coal into a clean-burning gaseous fuel. He gave solar energy only a cursory nod.[11] In the same year, the Federal Power Commission dubiously suggested that solar stations orbiting the Earth might someday transmit energy to the planet's surface via microwaves, but the FPC stressed that the "ultimate solution" to the world's electricity needs lay in controlled fusion reactors.[12]

Still, Washington made a small commitment to solar research, including wind programs. Soon after Nixon's speech to Congress, the Office of Science and Technology organized eleven panels to set R&D goals for various energy technologies. Lacking other options, responsibility for assembling a solar panel fell by default to the NSF and NASA; the latter agency had recently accepted an invitation by the government of Puerto Rico to assess the oil-dependent island's wind resources. In December 1972, an NSF/NASA panel of forty academics, industrial engineers and policy-makers recommended that the Federal government initiate efforts to develop alternatives to conventional energy technologies. The panel found promise in solar thermal, photovoltaic, ocean thermal, biomass conversion, and wind energy systems. In fact, the report estimated that wind energy could conceivably

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[11]Richard M. Nixon, "Special Message to the Congress on Energy Resources, June 4, 1971," *Public Papers of the Presidents: Richard Nixon, 1971* (Washington, DC: U.S. Government Printing Office, 1972), pp. 703-714.

[12]Federal Power Commission, *The 1970 National Power Survey*, pp. 1/28, 9/14 and 21/2.

satisfy 19% of the nation's energy needs by 2000.[13] After submitting a proposal to Congress for establishing a five-year research program, the NSF received authority--and a small budget--for managing the entire Federal solar effort.[14]

## Pure Science versus Applied Research

The NSF's decision to enter solar energy research resulted in part from growing concern among American policy-makers that the nation's scientific institutions, in allowing theoretical interest to determine research priorities, had ignored issues of social significance. Many critics of "pure" science believed that the problems confronting the nation demanded large-scale, government-directed responses, rather than *laissez-faire*, piecemeal research. In 1969, the NSF launched a program which eventually took the name Research Applied to National Needs (RANN). By supporting applied research into problems of the environment, productivity and energy--including the potential of windpower--RANN provided a counterpoint to NSF's traditional focus on pure, scientist-managed science. Previously, NSF research had taken place almost exclusively in universities, but RANN attempted to integrate academic efforts with industry and the Federal government's National Laboratories.

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[13]National Science Foundation/National Aeronautics and Space Administration Solar Energy Panel, "Solar Energy as a National Resource" (1972).

Solar thermal systems concentrate sunlight to heat fluid in a closed system, which in turn boils water to turn a turbine. By contrast, photovoltaic systems convert light directly into electricity. Biomass conversion systems transform organic matter into fuels. Geothermal systems tap underground reservoirs of hot steam or water, while ocean thermal systems exploit temperature differences between layers of the oceans.

Energy analysts often group the above technologies with wind and hydroelectric power to form a vague but accepted category. At best, however, they possess only a family resemblance, and no adequate label. The term "alternative" often implies a historical or ideological option to conventional fossil and nuclear fuel systems. Yet, American utilities have long exploited hydroelectric resources, and may absorb wind and geothermal and other resources into their operations. Advocates often refer to the group as "renewable resource technologies," implying infinicy of supply. Utilities have found, unfortunately, that some geothermal systems deplete the energy they exploit; underground heat deposits may "renew" themselves only on very long time scales. In addition, a finite number of hydroelectric and geothermal sites exist for exploitation, thus limiting the supply of energy available for human use. In the early 1970s, policy-makers often classified all such technologies as "solar," noting that global winds arise from insolation, and that biomass crops store solar energy. On those grounds, however, one might also consider fossil fuels as stores of solar energy. And, of course, one has to stretch the solar concept to include hydropower and geothermal systems. Nor does the concept of "environmental sustainability" provide a guide; President Nixon considered nuclear fusion a "clean" technology. Hydroelectric plants have profound environmental effects, and as we will see, even windpower has an impact.

[14]Savino, "Forward" in Savino (ed.), *Workshop Proceedings*, p. iii; Frederick H. Morse, "NSF Presentation" in Savino (ed.), *Workshop Proceedings*, pp. 40-243.

Administrators evaluated these projects not only on the quality of the science, but on whether policy-makers could assimilate the results. While supporters of RANN praised it for knocking down obsolete barriers between industry, academia and government, and making American R&D more efficient and less haphazard, some scientists worried that second-rate work with obvious practical applications would receive funding while high-quality research with less predictable results languished. In addition, some representatives of industry scoffed at RANN as an expensive re-education program for sheltered eggheads. While all three points of view contained some validity, RANN continued. By 1973, RANN had disbursed more than $200 million to over 1200 projects, including the wind component of the NSF/NASA solar program, which in Fiscal Year (FY)[15] 1973 received $200,000.[16]

First Steps

The most important of the handful of wind projects funded by the NSF in 1973 consisted of a June workshop organized by Joseph Savino of NASA, which gathered together surviving windpower pioneers, young enthusiasts, utility and industry representatives, and government policy-makers. The workshop, Savino announced, would find out where wind development had left off, assess current work, and determine research priorities for the new program.[17]

Conferees heard first an exhortation in the spirit of RANN from the NSF's Alfred Eggers, a former NASA administrator. "The name of the game is utilization," he admonished them. "This is not just another opportunity to do our technical thing. Think

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[15]Before 1977, Federal fiscal years began on July 1 of the preceding year, and ran to June 30. Starting in 1977, they began on October 1 of the previous year, and continued to September 30. The government inserted a "transitional quarter" between the FY 1976 and FY 1977 budgets.

[16]Guyford Stever, "Forward" in *Energy, Environment, Productivity: Proceedings of the First Symposium on RANN: Research Applied to National Needs*, sponsored by the NSF in Washington, DC (18-20 November 1973), p. iii; Alfred J. Eggers Jr., "Perspective on Research Applied to National Needs," in *Energy, Environment, Productivity*, pp. vii-xi; Harvey Brooks, "Knowledge and Action: The Dilemma of Science Policy in the '70s," *Daedelus* 102 (Spring 1973), pp. 130-132.

[17]The following description draws on Savino (ed.), *Workshop Proceedings*, *passim.*

megawatts on line and all the things that have to be done before they will be on line. In other words, think total systems."[18] Following Eggers, participants viewed a film of the Smith-Putnam turbine and heard from a succession of wind pioneers, including Beauchamp Smith, Marcellus Jacobs and William Heronemus.

Participants learned that while wind development had ceased in America following the Smith-Putnam experiment, a number of European countries had used Marshall Plan funds to explore the potential of wind power. Ulrich Hutter had done some of the best work during World War II, while directing a wind development program for Germany's National Socialist government. The Americans found Hutter's design philosophy exciting. By using low-weight, aerodynamically-efficient designs, the Austrian had pared the capital costs of his machines and increased energy capture. He had also explored a number of innovative concepts. Hutter's fiberglass rotors delivered their rated power of 10- and 100-kW at windspeeds of 18 mph, notably less than required by Danish, Russian, British and French turbines.[19] Hutter himself addressed the conference, reporting that the Europeans had abandoned their efforts by the 1960s, and that no large turbine remained in operation.[20]

Other papers described more recent windpower research. Fuller's protege, Hans Meyer, described the use of paper honeycomb material for turbine blade construction. A

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[18]Alfred J. Eggers, Jr., "Opening Address" in Savino (ed.), *Workshop Proceedings*, p. 3.

[19]Matthias Heymann, "Why were the Danes the best? Wind turbines in Denmark, West Germany and the USA, 1945-1985," presented at Annual Meeting of the Society for the History of Technology Annual in Cleveland, OH (18-21 October 1990), p. 7. NASA later translated some European studies, including: V.R. Sektorov, "Using the Energy of the Wind for Electrification," translation: original Russian 1953, NASA fiche N74-16801 (February 1974); H. Witte, "The Economy and Practicality of Large Scale Wind Generation Stations (Conclusions)," translation: original German 1938, NASA fiche N74-16802 (February 1974).

[20]Shortly, the Americans learned of a 200-kW Danish machine, built in 1956 by Johannes Juul, still standing near Gedser on the island of Falster. ERDA and the Danish government split the $85,000 cost of refurbishing the Gedser unit, and used it to test early computer models of turbine behavior. Unlike Hutter's racy efforts, the Gedser machine featured slow rotation, heavy construction, and spars linking the blades for added stability. Instead of pitch control, Juul's conservative design used "stall control;" its airfoils automatically maintained constant rotor speeds and stable current frequency without moving parts, by creating turbulence in higher winds. The Gedser turbine later inspired the active Danish wind development program. Heymann, "Why were the Danes the best?" pp. 3-6; Marshall Merriam, "The Gedser Mill Re-vitalized," *Wind Power Digest* (Winter 1977-1978), pp. 32-34; Eldridge, "Wind Machines," pp. 14-17.

report on an NSF-funded project investigating the possibility of constructing a 5-to 10-MW system utilizing wheeled-airfoils sailing around a ten-mile track fell flat, as the presenter conceded ignorance of a similar project in New Jersey in 1933. In addition, some members of the audience bemoaned the researchers' focus on the interesting engineering aspects of the project to the comparative exclusion of its economic efficiency. The audience received with better grace a report from the other end of the spectrum by innovator Henry Clews, who described his wind-powered Maine home, and his effort to import small units from Switzerland and Australia for domestic sale.

Representatives of industry related their ideas as well. A spokesman for the Boeing Vertol Company described how his firm's new computer model applied concepts used in helicopter analysis to the design of windmill rotors. A speaker from a U.S. Army laboratory declared that wind turbine designers could adapt a good deal of helicopter rotor technology, but he acknowledged some differences due to slower rotation and different gravitational forces in the case of wind machines. Another paper described a Grumman Aerospace Corporation concept, the diffuser-augmented turbine, which used a large funnel to channel the wind onto the rotor of a conventional turbine.

Participants may have gained the most from periods of freewheeling audience discussion and committee reports. It often seemed difficult to separate "technical" and "non-technical" issues. For example, how might utilities assess the value of wind power? Certainly, operation of wind plants would permit utilities to burn less fuel, but could wind power completely relieve utilities of the need to build reliable conventional powerplants? And how might one put a price on reduced environmental degradation? Some participants warned against assuming that wind turbines truly posed "zero environmental cost," and raised concerns of visual pollution and land-use controversies.

The group also discussed the wind resource itself. Many participants suggested that the government compile a national wind atlas. Other conferees inquired about the effect of turbulence caused by the "wind shadow" of a tower on a downwind rotor, the possibility of using fiberglass rotor blades, and the natural vibratory frequency of turbine towers.[21] Still others tried to assess the state of the industry. Could one purchase a 50-kW wind turbine anywhere? No-one built turbines of that size, came the reply, but for those interested in old 10-kW units, there existed "a fine market, like for used cars." Finally, NSF and NASA representatives reassured suspicious participants that NASA would contribute manpower and laboratory facilities from its own funds, rather than draining the slim NSF solar research budget to pay for project overhead.

On the last day of the three-day conference, Savino broached a critical subject, the nature of the market for wind turbines and the energy they generated. He urged the representatives of industry and government in attendance to admit once and for all the gravity of the energy supply problem, and to take responsibility for exploring alternative technologies:

> ...among certain government agencies, such as the Rural Electrification [sic], the FPC, and the power utilities, the attitude seems to be one of business as usual... Isn't it time the public utilities, as well as the agencies, tell it to the public like it is? We are going to have to start paying higher prices... We must stop chasing the demand curve. Shouldn't your companies and agencies also start getting involved in supporting alternative systems? ...We, the proponents of wind power, can never create the environment necessary to move forward until you people who have the influence get involved instead of sitting back and waiting for someone to come forward and say here's a package that works--would you like to use it?[22]

Nevertheless, while the conference helped organize and set priorities for the wind program, Savino's challenge remained unaddressed: how might a government program encourage a preliminary market demand among the ultimate customers of wind systems--particularly where many of those potential users held alternative energy in suspicion, if not outright contempt? In 1973, at least, it seemed easier to push windpower technology from behind through funding R&D than to stimulate a market to pull the technology forward.

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[21]Dynamic structures vibrate at a frequency determined largely by the length of their longest axis. Turbine design requires tuning the tower, the rotor and components such as the yaw motor to ensure that no sub-system's natural frequency be a multiple of that of any other. Should that happen, the resulting resonance increases the amplitude of the vibrations, producing dangerous structural loads.

[22]Savino, "Panel Discussion," in Savino (ed.), *Workshop Proceedings*, p. 235.

NASA's preliminary assessment

NSF and Congressional policy-makers chose NASA to carry out their wind technology program. While the aeronautics and space agency, with its experience in well-funded, centrally-directed, high-priority, high-technology projects, may seem an odd choice to design wind turbines, NASA personnel indeed had extensive experience in two crucial areas--designing airfoils and measuring weather conditions. But the selection of NASA as a major player in American windpower owed as much to political horse-trading as it did to "rational" policy-making.

By the early 1970s, NASA badly needed an infusion of popular and governmental support. After growing through the early 1960s, the agency's budget authorizations had steadily deflated (with one minor hiccup) from a high of $5.25 billion in FY 1965 to a low of $3.04 billion in FY 1974 (nominal dollars). By then, some members of Congress suspected that they had received exaggerated accounts of the Soviet space threat, and spoke bitterly of the NASA "moondoggle." As legislators voted escalating funds for the war in Viet Nam and for ambitious domestic programs, they niggled over NASA's budget requests, reducing the number of Apollo missions, scratching plans for a manned expedition to Mars, and slowing the pace of the space shuttle program.[23]

In response, NASA administrators pursued a "spinoff" strategy. They attempted to convince legislators and the public that the national space enterprise, often presented as a noble quest, produced knowledge and products that benefitted American society in immediate, concrete ways. The possibility of transforming NASA into a lead energy agency constituted an intriguing possibility for the organization as it scrambled to redefine its mission.

Unlike analysts such as Amory Lovins, who cast the energy crisis as a demand problem concerning the inefficient ways in which Americans consumed energy, NASA

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[23]Linda N. Ezell, *NASA Historical Data Book, Volume III: Programs and Projects 1968-1978* (Washington, DC: NASA, 1988), p. 8 and table 1/2.

administrators argued that they could help solve it by devising advanced technological fixes for the supply side. The energy dilemma, one agency spokesperson told the House Subcommittee on Science and Astronautics, "required strong and sustained government leadership and a massive technological effort" similar to the Manhattan Project and the Apollo program.[24] He strongly suggested that Congress use NASA's laboratories and expertise to coordinate a massive joint government-industry program of energy R&D, including the windpower portion of the NSF solar energy program.

After the oil embargo of 1973, many legislators received NASA's pitch enthusiastically. For instance, one member of the House told his colleagues that:

> I see no reason why we cannot use space scientists for energy research today. NASA as an organization and its scientists and engineers as individuals can help push back the technical frontiers just as effectively as they did in space.[25]

Bolstered by such support, NASA in FY 1974 established an Office of Energy Programs "to focus the application of its aerospace technology to energy needs."[26] In that year, NASA received $2 million for energy projects. In addition to windpower, NASA explored clean, high-efficiency combustion engines and streamlined vehicles, the conversion of crops into clean fuels, and long-range research into satellite collection of solar energy for microwave transmission down to earth. NASA delivered the windpower project to its Lewis Research Center, an R&D facility primarily involved in space power generation and advanced propulsion technology. Within the giant Lewis complex, the wind project found a home at

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[24]Testimony of Bruce T. Lundin, Director of NASA's Lewis Research Center, in U.S. Congress, House of Representatives, Committee on Science and Astronautics, Subcommittee on Aeronautics and Space Technology, *1975 NASA Authorization*, No. 25, Part 4, 93th Congress, 2d Session (13 March 1974), p. 396.

[25]Rep. Roy A. Taylor (D-NC), in U.S. Congress, House of Representatives, *Congressional Record* 120, 93d Congress, 2d Session (13 February 1974), p. 2940. Note here and henceforth that the *Congressional Record* permits members of Congress to edit their remarks before publication.

[26]Nancy L. Brun, *Astronautics and Aeronautics, 1974: A Chronology* (Washington, DC: NASA, 1977), p. 226.

the Plum Brook Station, located in Sandusky, OH, and known chiefly for its space environment simulation chamber.[27]

This arrangement apparently resulted from Congressional favor-brokering. As part of its attempt to trim NASA's budget, the Office of Management and Budget (OMB) had pressured the agency to shut down various facilities, including Plum Brook. Although the budget process required NASA administrators publicly to accede to OMB's decision, behind the scenes they tried desperately to find new "clients" for the facility among other government agencies, before Civil Service layoffs forced Plum Brook's closure, scheduled for June of 1974.[28] They received valuable help in this hunt from sympathetic members of Congress.

Rep. Charles A. Mosher (R-OH), ranking minority member of the Subcommittee on Science and Astronautics, expressed special concern over the prospect of NASA laying off up to 357 members of the Lewis and Plum Brook work forces over two years. (No surprise, Plum Brook lay in Mosher's Thirteenth District.[29]) The Ohio Republican assured the House that "I am very familiar with the nature of Plum Brook--its land, facilities, equipment, and manpower," and he arranged special testimony on the issue by NASA personnel. In the end, Mosher convinced his subcommittee to side with NASA against OMB and oppose the shutdown of what he praised as a "modern and unique installation."[30] Still, while one Federal wind administrator now frankly concedes that the selection of these facilities

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[27]Jane Van Nimmen and Leonard C. Bruno, *NASA Historical Data Book, Volume I* (Washington, DC: NASA, 1988), p. 375.

[28]Testimony of NASA Acting Associate Administrator Edwin C. Kilgore before the House Subcommittee on Aeronautics and Space Technology (20 March 1974), cited in Brun, *Astronautics and Aeronautics*, 1974, p. 66.

[29]"Charles Mosher," *Congressional Directory, 93rd Congress, 1st Session* (Washington, DC: U.S. Government Printing Office, 1973), p. 146. For Mosher's efforts to protect Plum Brook and assist NASA in finding new projects for the installation, see testimony of Kilgore in U.S. Congress, *1975 NASA Authorization*, pp. 643-660.

[30]Rep. Charles A. Mosher (R-OH), in U.S. Congress, House of Representatives, *Congressional Record* 120, 93d Congress, 2d Session (25 April 1974), p. 11,889.

smacked of local politics, he maintains that NASA's work in low-speed aerodynamics and other areas made Lewis "a pretty good fit."[31]

In 1976, William "Red" Robbins, a mechanical engineer who had notched successes in the development of jet engines, nuclear rockets and communications satellites, took over as NASA's Wind Energy Project Manager. He chose engineer Ronald Thomas, who had served on the NSF/NASA solar energy panel, to manage the Wind Energy Project Office at Lewis. A third key player at NASA, Darrell Baldwin, had previously worked on outfitting Plum Brook's space facilities; Baldwin brought to the wind effort his extensive experience in program management, construction, and the logistics of large equipment projects.

By autumn of 1973, NASA completed a preliminary assessment of windpower's potential. The primary unknowns, NASA argued, concerned economic viability. Thomas explained at a RANN conference that while the wind provided a "free, non-depleting resource," the machines themselves cost money. To compete with other forms of energy, engineers would have to bring the cost of building, operating and maintaining a wind turbine (including relevant taxes and interest charges on borrowed capital) below the cost of building, operating, maintaining and fueling conventional power plants.

The wind's variability implied to NASA that wind systems, whether connected to a utility grid or used as a free-standing power source, required access to energy storage. To smooth out fluctuations in the wind, turbines might operate in parallel with small diesel engines, make use of flywheel or pumped water storage, or utilities might disperse a large number of units geographically so that some fraction would always capture the wind. On the other hand, the variability problem might matter less than anticipated; while winds shifted on an hourly or daily basis, they seemed quite predictable on a monthly or yearly basis.

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[31]Telephone interview with Daniel Ancona, Senior Project Manager for the DOE's Division of Wind, Hydro and Ocean Power (26 June 1994).

NASA recommended that the NSF program also attend to wind resource mapping, and explore potential legal, environmental and institutional barriers to windpower development. Still, while some NASA insiders such as Joe Savino fretted over how to stimulate a "market pull" for windpower, the agency focussed its program on designing elegant, theoretically economical machines, and gave less thought to how to move those machines into general use. Worse, according to one of NASA's DOE overseers, "NASA sort of tended to live up to their reputation of lavish budgets and unconstrained development work... You know, get the job done at all costs. Gold-plate everything." But, he recalls, NASA eventually became fairly responsible at setting quantitative goals and sticking to project budgets. For example, they brought in the important MOD-2 turbine project essentially on cost and on time.[32]

## PART III: The Oil Shock

The American wind effort started out quite small. To help lay out the NSF's energy programs, including renewable resource technologies, the California Institute of Technology's Jet Propulsion Laboratory in Pasadena loaned the services of MIT-trained engineer Louis Divone. After the NSF received its small wind budget for FY 1973, Divone accepted an invitation to stay on for six months. He eventually served for five years as the branch manager of the DOE's Wind Energy Division, before moving on to direct all solar electric programs (including wind, photovoltaic and ocean thermal). But in 1973, when his small rag-tag team of Savino from NASA-Lewis and a few others drew up a five-year proposal for the NSF, Divone viewed its chances pessimistically.[33]

In October of 1973, however, OPEC raised the posted price of petroleum by 70%. Just days afterward, Arab members of OPEC placed an embargo on sales of petroleum to the United States. The ensuing price and supply shocks quickened the sluggish debate over

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[32]Telephone interview with Ancona.

[33]Interview with Louis V. Divone, Associate Deputy Assistant Secretary for Buildings Technologies, U.S. Department of Energy (14 October 1993).

national energy policy. Many of those who had downplayed the situation as a short-term energy "crunch" rather than a full-blown crisis joined the general clamor for action on all fronts.

Particularly after the oil shock, proponents of windpower spoke of its potential not only in terms of megawatts, or as a percentage of total national generating capacity, but as barrels of oil saved. For example, an influential early assessment of windpower stated that

> By substituting wind energy for fossil fuel energy, an equivalent of 2.1 billion barrels of oil could be saved in 1995 if fuel prices rise 7% or more each year, or 0.5 billion barrels if fuel prices do not increase. Such a significant reduction in fuel consumption would reduce oil imports and the off-shore oil dollar drain on our economy.[34]

Other assessments calculated windpower's potential in terms of quadrillion British thermal units (Btu; one "quad" equals $10^{15}$ Btu), a measure that allowed comparison with other forms of energy. Estimates varied; in 1979 a FWEP manager suggested that by 2000 windpower might supply two quads nationally, but in the same year an official of the American Wind Energy Association (AWEA), the wind industry trade group, put windpower's practical potential at seven quads by the turn of the century.[35]

The sudden increase in perceived need for energy R&D swept all skepticism before it, and windpower development benefitted immediately. As Divone recalls,

> we laid out a plan, not expecting too many people to pay too much attention to it, and then the Arab oil embargo hit. Anything that had the word *energy* in it--it didn't matter what the adjective in front was--got funded.[36]

A study on the nation's energy future, performed at the request of President Nixon and directed by Dixie Lee Ray, chairperson of the Atomic Energy Commission, advised in the

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[34]Ugo Coty, "Wind Energy Mission Analysis: Executive Summary," Lockheed California Company, Burbank, CA, NTIS SAN/1075-1/3 (October 1976), p. 2.

[35]Daniel F. Ancona, "Overview: U.S. Department of Energy Wind Energy Program" in *Proceedings of the Workshop on Economic and Operational Requirements and Status of Large Scale Wind Systems*, held in Monterey, CA (28-30 March 1979), p. 1; Ben Wolff, *Workshop on Economic and Operational Requirements*, p. 394. For purposes of comparison, in 1979 the United States used 78.7 quads of energy.

[36]Interview with Divone.

fall of 1973 that the Federal government spend $30 million on wind power over the next five years.[37] As data in Table 2 show, wind development received support substantially in excess of that recommendation. Only the election in 1980 of President Ronald Reagan, a fiscal conservative and windmill-skeptic, blanched the burgeoning Federal wind budget.

| **TABLE 2: Annual Federal Wind Budgets FY 1973 to FY 1981** | |
|---|---|
| Fiscal Years 1973-1974 | $1.8 million |
| FY 1975 | $7.9 million |
| FY 1976 | $14.4 million |
| Transitional quarter | $ 4.97 million |
| FY 1977 | $24.6 million |
| FY 1978 | $35.3 million |
| FY 1979 | $59.6 million |
| FY 1980 | $63.4 million |
| FY 1981 original allotment | $87.0 million |

Data from John R. Justus *et al.*, "Fact Book on Non-Conventional Energy Technologies," Congressional Research Service, Report No. 79-47 SPR (12 February 1979), p. 194, and; Fred J. Sissine, Barbara Luxenberg and J. Glen Moore, "Wind Energy," Congressional Research Service, Issue Brief No. IB80091 (original 31 October 1980, update 23 November 1981), p. 2. Figures refer to appropriations, rather than actual expenditures.

Divone started his team with only about five people, including a meteorologist, some engineers and supporting staff. To back them up, he made use of university professors such as Robert Thresher, who had explored wind energy at Oregon State University as a professor of mechanical engineering, and who had done some research for West coast utilities. Thresher remained a part of the Federal wind effort, persevering through the lean years of the 1980s, and today directs the Wind Energy Division of the National Renewable Energy Laboratory (NREL).

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[37]Dixie L. Ray, "The Nation's Energy Future: Review of Federal and Private Energy R&D--Report to the President of the United States," AEC Report WASH-1281 (1973).

Another player who has gone the distance with Federal renewable energy programs is Daniel Ancona, today the Senior Project Manager for the DOE's Division of Wind, Hydro and Ocean Power. Hired by Divone in 1977, he had a background in mechanical engineering and graduate degrees in industrial engineering and operations research. He jokingly speculates that the DOE justified hiring him for the wind project by noting his abilities as a sailor, but believes Divone took him on for his experience in leading new technologies through the development process while with the Army and the automotive industry.

Ancona gained a reputation in some corners of the wind community as an advocate of giant turbines, but he sees his contribution as the introduction of the automotive industry's manufacturing principles. "I knew what volume production was," he says, "and it wasn't going to come from the aerospace industry... I remember looking at the multi-hundred-dollar rivets that they were using on the blades of some of the early machines." To counteract the aerospace influence, Ancona recalls pushing for the involvement of industrial firms with experience in building "big, dumb cheap stuff."[38]

Eventually, the Federal program employed eighteen people, including perhaps five upper-level managers such as Divone and Ancona. Together, they struggled to integrate the high-tech influence of their major contractor, NASA, with the high-volume industrial principles articulated by Ancona, and other perspectives. Conspicuously absent was the small-scale decentralized vision of the counter-culture.

## PART IV: Consolidation of Control

The story of windpower illustrates not only the diversification of Federal energy policy, but its consolidation as well. When President Nixon called in 1971 for R&D on clean energy technologies, he had warned that new programs alone would not resolve America's energy problems. "The Nation has been without an integrated energy policy in

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[38]Telephone interview with Ancona.

the past," the President declared, and he proposed that "all of our important Federal energy resource development programs be consolidated within [a] new Department of Natural Resources." Nixon argued that decentralized planning of government programs in an area responsible for 20% of the country's capital investment had given rise to remarkable inefficiencies, and he noted that energy sources had grown increasingly interchangeable, making necessary complex comparisons of proposed energy policies. Only a new centralized agency, the President suggested, could formulate and execute energy policy in such an environment.[39]

Some members of the Democrat-controlled 93d Congress had long lobbied for the same concept, notably Sen. Henry Jackson (D-WA), chairman of the powerful Senate Committee on Interior and Insular Affairs. In April of 1973, Jackson's committee released a report warning that "whether the subject is oil import policy, energy-resource management, or R&D programs, the lack of adequate authority and proper coordination is all too clear." The report named sixty-four Federal agencies whose actions, directly or indirectly, comprised national energy policy.[40]

Congress never endorsed Nixon's proposed Department of Natural Resources, but momentum grew for a central energy agency. Voters, legislators believed, wanted a strong response to the nation's energy problems. Washington reacted by creating reassuringly-strong new entities able to coordinate broad-ranging policy. In January of 1975, Congress launched the Energy Research and Development Administration,[41] which assimilated the

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[39]Nixon, "Energy Resources, June 4, 1971," p. 713.

[40]Report cited in Gordon D. Friedlander, "Toward a national energy policy," *IEEE Spectrum* 10 (June 1973), pp. 36-38.

[41]The consolidation of energy R&D into Federal hands forms part of a trend toward government management of science and technology noted by historians. For instance, in discussing the creation of NASA after the launch of Sputnik in 1959, one author writes that "in these years the fundamental relationship between the government and new technology changed as never before in history. No longer did state and society react to new tools and methods, adjusting, regulating, or encouraging their development. Rather, states took upon themselves the primary responsibility for generating new technology." Walter A. McDougall, *...the Heavens and the Earth: A Political History of the Space Age* (New York: Basic Books, Inc., 1985), p. 7.

NSF's Wind Energy Conversion Branch into its Division of Solar Energy. In August of 1977, the Carter administration's new Department of Energy absorbed the ERDA and gave windpower its own Federal Wind Energy Program.[42]

## Conclusion: Imbalance of Power

Spurred by the embargo of 1973, control over American energy policy rapidly consolidated, as energy R&D diversified. The DOE, formed in 1977, concentrated decision-making in one central agency, but it also spread crumbs of its R&D funds among many technologies previously shut out from Federal largesse. Windpower benefitted from both trends. The resultant funding fell far short of the level necessary to capture the rewards depicted by Heronemus, nor did the program condone the social goals of alternative energy advocates such as Lovins. Still, it sustained a small, dedicated wind community, which rapidly set out to assess the state of the technology and the potential of the resource, and to set goals for contributing to an anticipated era of energy scarcity.

In hindsight, several aspects of the FWEP's early years bear emphasizing. First, to the community assembled by the Federal government to cooperate in the development of windpower, questions of technology and economics seemed not only more easily answered, but also more interesting. While some people voiced concerns over the formation of a market for wind turbines and wind-generated power, most of those involved appeared to assume that if they could produce cheap, elegant, reliable machines, the market would follow.

Second, because the FWEP arose largely in response to a need perceived by policy-makers, rather than by potential turbine customers, the FWEP maintained a close association with the new Federal energy bureaucracy. For this reason, it benefitted greatly from the expanding budgets and Congressional support of the 1970s. But this association soon proved a burden as the DOE fell into increasing disfavor in the 1980s.

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[42]U.S. Department of Energy, *Wind Energy Systems Program Summary*, NTIS DOE/CS/20097-01 (May 1980).

Finally, an incipient rift had opened between two proto-communities. On one side, some people favored windpower for ideological reasons, for example because of they sympathized with the stances of R. Buckminster Fuller or Amory Lovins. Many of these people considered themselves "counter-culture," and hoped that wide use of windpower would help erode the existing centralized energy system. On the other side, many Federal administrators and NASA engineers expressed satisfaction with the current social structure, and sought only a cheaper, cleaner supply technology. From the beginning, the latter group had the upper hand.

# CHAPTER FOUR
# Directions and Decisions for an Appropriate Big Technology

## Introduction: A Bevy of Studies

In the middle and late 1970s, the FWEP commissioned studies on windpower concerning overall direction, optimal technology, and market formation. The Lockheed California Company, a division of the Lockheed Aircraft Corporation, and General Electric, a diversified firm with historic roots in manufacturing electric end-use and generating equipment, each received $500,000 grants to perform mission analyses.[1] General Electric also won a contract to determine the optimum design and size of wind systems; a second such contract went to Kaman Aerospace, a diversified helicopter company.[2] Other investigations considered the potential of windpower in specific sites,[3] evaluated different economic incentive plans,[4] and attempted to normalize previous studies.[5] Additional contractors included the Honeywell Corporation, the Aerospace Corporation, and several universities.

While these studies contained critical uncertainties and inconsistencies--for example, how to assess the economic value of windpower--they agreed on certain points. First, they

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[1]Lockheed, "Wind Energy Mission Analysis;" "Wind Energy Mission Analysis," GE Space Division, Valley Forge Space Center, NTIS fiche COO/2578-1/1 to 1/3, (February 1977).

[2]"Design Study of Wind Turbines 50 kW to 3000 kW for Electric Utility Applications," Kaman Aerospace Corporation, NASA fiche N78-23559 (July 1977); "Design Study of Wind Turbines 50 kW to 3000 kW for Electric Utility Applications," GE, Valley Forge Space Center, NASA fiche N78-12529 (September 1976).

[3]For example, J. Assmussen, Jr., "Wind System Research Project for the City of Hart, Michigan" in Frank R. Eldridge (ed.), *Proceedings of the Second Workshop on Wind Energy Conversion Systems* held in Washington, DC, NSF-RA-N-75-50 (9-11 June 1975), pp. 112-115.

[4]Michael Lotker, *et al.*, "Economic Incentives to Wind Systems Commercialization: Executive Summary and Final Report," Booz, Allen and Hamilton, Inc., Bethesda, MD, NTIS fiche DOE/ET/4053-78/1 (August 1978).

[5]"Summary of Current Cost Estimates of Large Wind Energy Systems," JBF Scientific Corporation, Washington, DC, NTIS fiche DSE/2521-1 (April 1977).

offered a consensus that windpower could help the nation conserve scarce fossil fuel, and that policy-makers should conceptualize these savings in economic (rather than, say, in social or geopolitical) terms. Second, they identified the technological path with the best economic potential and least developmental risk as the development of large horizontal-axis machines between 2 and 4 MW in capacity. Third, they agreed that in terms of energy production--the only terms that mattered--electric utilities provided the logical market for wind machines.

Largely due to these studies, the FWEP represented a bold centralized effort to devise an "appropriate big technology." The windpower community fought many battles over decimal points and the appropriate use of economic criteria. Often the economic justification for big turbines, giant corporations and centralized power production rested on an ideological underpinning. But these ideas rarely appeared in the open, to the increasing frustration of proponents of small turbines, decentralized power production, and entrepreneurial business.

## PART I: Who Would Use Wind Machines?

The FWEP funded the Lockheed and GE mission analyses to assess the potential impact of windpower on the American "energy economy." As former Lockheed engineer Donald Bain recalls, Lockheed finished its report first, and delivered a draft copy to the ERDA. He believes that the ERDA initially dismissed as an exaggeration Lockheed's affirmation that windpower might potentially supply 18% of the nation's electricity needs, mostly in utility applications, and refused to release the Lockheed report until the GE study surfaced six months later with similar results. Although GE showed a lower potential for wind early on, Bain calculated both studies forward to 2010, and found that they gave "virtually identical conclusions." Bain suspects that the ERDA always maintained some skepticism toward wind, demonstrated by its failure to pursue aggressively some of Lockheed's ideas, such as wind/hydro-storage systems.[6]

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[6]Interview with Donald Bain, Political Analyst for Renewables at the Oregon Department of Energy, in Savannah, GA (3 October 1993).

The two Mission Analyses reached similar conclusions concerning the potential of various applications for wind turbines. The market in industrial applications such as petroleum pipeline pumping or paper-making seemed small and unfeasible at current equipment prices. Farm use had promise for medium-sized machines in applications not requiring energy storage or utility back-up, such as pumping and crop drying. The limited market for windpower in remote communities provided an "excellent application" for windpower in its early stages of development. Residential applications of windpower had substantial potential, but GE pointed out that because homeowners would require utility back-up power, "capital investment by the utilities in power generation equipment may not be diminished by the residential use of WECS. Indeed, the cost of electricity to the homeowner may even increase."[7]

GE and Lockheed analysts agreed that, as GE put it, "the single most important application of WECS which will yield maximum national impact is in electric utilities." For purposes of illustration, Lockheed estimated that if fuel costs rose 10% annually by 1995, windpower could economically supply 18.7% of national demand; if fuel costs rose by just 4% annually, windpower could contribute 11.4%. As the most probable scenario, however, Lockheed expected a modest annual 4% increase in fossil fuel prices until 1995, encouraging rises in electricity demand, and a subsequent 10% annual increase, stifling demand. If that occurred, Lockheed anticipated selling 25,400 4-MW turbines to utilities by 1995, when a total national wind capacity of 100.4 GW would generate 8% of national demand. Lockheed concluded that "it appears that the implementation of WECS is not a question of *if* so much as it is a question of *when*." Without new storage technologies, Lockheed believed, the penetration of windpower into utility grids would depend on the amount of readily available spinning reserve--perhaps 8%. GE agreed, noting that gas turbines with low capital costs could back up wind turbines, but warned that if the electric utility industry had

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[7]Coty, "Mission Analysis: Executive Summary," 7/41, 7/57; GE, "Mission Analysis: Executive Summary," pp. 2-3.

correctly predicted continuation of a trend toward nuclear power plants, which utilized a fuel cheaper than oil or gas, windpower would find it hard to compete.[8]

Nevertheless, the mission analyses remained mute regarding what "commercialization" of an energy technology by the Federal government might entail. Nor did the DOE seem to know. As a DOE official frankly admitted in 1978, the only precedent--a shaky one at best--concerned the subsidization of the light-water reactor by the AEC and the military in the 1960s. In most other cases, the marketplace had provided incentives to industry for researching, developing, and producing new technologies.[9]

Indeed, some diversified corporations did invest their own funds in wind R&D, presumably because they saw wind turbines as a new way to sell their expertise (*e.g.*, helicopter technology). However, the nation's utilities, identified by Lockheed and GE as the primary "market" for wind turbines, demonstrated little enthusiasm for this symbol of an alien ideology. Equally important, the traditional regulatory structure encouraged utilities to produce reliable, cheap power, and it discouraged investment in risky ventures such as large R&D programs. The utilities' wary response suggested to some observers that the Federal government needed to think more carefully than it had about how to make government-sponsored R&D compensate for a lack of market-pull; without such an effort, the wind industry might remain a perennial ward of the state.

## PART II: What Would the Machines Look Like?

In addition to the Mission Analyses, the FWEP commissioned two design studies to define an optimum turbine for utility use. One award went to GE, supported by a propeller company, the Hamilton Standard Division of the United Technologies Corporation.

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[8]Coty, "Mission Analysis: Executive Summary," pp. 7/29-7/39; GE, "Mission Analysis: Executive Summary," p. 1.

[9]Comments of John O'Leary, Deputy Secretary of Energy, in "DOE Role in Support of Small-Scale Appropriately Distributed Technology: Official Transcript of Public Briefing," in Washington, DC, CONF-780132 (April 1978).

(Through the United Technologies Research Center, Hamilton-Standard had access to the rotor data of another company subsidiary, the Sikorsky Aircraft Division, which manufactured helicopters.) GE also hired the Austrian wind pioneer Ulrich Hutter as a consultant. Kaman Aerospace, a diversified helicopter firm, won the other design contract. NASA, responsible for managing these projects, requested each grantee to develop designs for one machine between 50 and 500 kW, and another between 500 and 3000 kW. The contract specified horizontal axes, unattended operation, and the use of off-the-shelf technology where possible. Each design should produce energy at the lowest possible cost over a 30-year life, but costs should be calculated for "production quantities." The designs need not include storage provisions, and they must be compatible with electric utility grids.[10]

Significantly, NASA's instructions specified a lower capacity limit well above the sizes attractive to residential windpower users; the FWEP never commissioned a comparable small-turbine mission analysis or design study. Indeed, neither Kaman nor GE chose to approach the lower boundary of 50 kW. They concurred in finding, as GE's report noted, that "dramatic cost reductions were available by designing systems at power levels at or greater than 500 kW; significant cost reductions continued to accrue up to the 1500-2000 kW range." Each firm opted to consider a 500-kW unit, the biggest "small" machine allowed by the contract, and a larger unit of about 1500 kW. Based on production quantities of 100 units, GE estimated the cost of generating energy with the smaller unit at 4.04 cents/kWh in a site with 12-mph winds, at a capacity cost of $935/kW. GE's larger unit, at an 18-mph site, came in at 1.57 cents/kWh, with a capacity cost of $430/kW. Kaman Aerospace reckoned energy costs at 7.1 and 2.7 cents/kWh, and capacity costs at $900 and $480/kW, respectively. Lockheed's Mission Analysis offered similar conclusions, suggesting that wind energy "can be economically converted to electrical energy" by turbines flying rotors between 300 and 350 feet in diameter, with capacities between 2 and 5

[10]Kaman, "Design Study: Executive Summary," pp. 2-3; GE, "Design Study--Volume I: Summary Report," p. 1/1.

MW, in wind regimes between 12 and 27 mph; given production runs of 10,000 machines, Lockheed calculated the cost of energy (COE) between 1.7 and 2.8 cents/kWh.[11]

The investigations commissioned by the FWEP relied on a number of disparate and in some cases optimistic assumptions. For instance, GE's Design Study placed the total annual costs for running a wind turbine at 16.4% of the capital cost, but neglected to include local taxes or insurance; the GE Design Study also assumed a capacity factor of 51%,[12] which far exceeded the 38% projected in the GE Mission Analysis. The Kaman Design Study, on the other hand, assumed a production run of 1000 units (ten times more than GE), a capacity factor of 43%, and an annual cost of 20%. The JBF Corporation (a small consulting firm in Wilmington, MA), after normalizing production quantity, wind characteristics, learning curve and capacity factor for all the FWEP studies, reported Kaman's true energy cost as 3.38 cents/kWh, GE's as 2.39 cents/kWh, and Lockheed's as 3.29 cents/kWh. While FWEP managers found it reassuring that JBF arrived at a normalized cost of energy between 2.4 and 3.8 cents/kWh for the entire set of reports, it alarmed them that the "experts" had such diverse assumptions concerning windpower and its operating environment.[13]

The design studies left the FWEP with some important guidelines. First, they suggested that a site's median wind speed at hub height constituted the most important parameter affecting energy and capital cost, which emphasized the importance of wind resource mapping. However, for a given turbine, optimized to generate its cheapest electricity at a given wind speed, energy cost and capital cost rose only slightly at wind speeds greater or less than the optimum. Although Kaman considered 2300 kW the optimum rating for sites with 18-mph winds, the report noted that turbines rated a few

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[11]Kaman, "Design Study: Executive Summary," pp. 39, 70; GE, "Design Study--Volume I: Summary Report," p. 1/4; Coty, "Mission Analysis: Executive Summary," p. 1.

[12]An energy system's capacity factor represents its average power output divided by its rated power output. Capacity factors depend largely on time spent off-line due to forced outages and routine maintenance.

[13]JBF, "Summary of Current Cost Estimates," pp. B/7-B/10. All costs in 1975 dollars.

hundred kilowatts in either direction would produce energy at nearly the same cost per kilowatt-hour. Thus, Kaman claimed that its 500- and 1500-kW designs suited "a range of median wind speeds from [9 mph] to [22.4 mph] with less than one-half cent per kWh penalty attributable to their not being optimum at a particular median wind speed... This means that only two standardized WGS are needed." The study also pointed out a point of diminishing return with regard to power versus windspeed. In sum, Kaman stressed the importance of area windspeed, but found it unnecessary to seek out unique, highly windy sites, or to design turbines especially for such locations.[14]

Second, although larger rotors provided greater energy capture, particularly in low-wind regimes, GE calculated that the rotor might compose 40% of the system's total cost. Moreover, current fabrication techniques prohibited very large blades. Both factors, it seemed, limited rotor diameters in the near term. The GE designs sported rotors of 183 and 190 feet, made of filament-wound (fiberglass) composite material on a spar-shell frame. Kaman made similar recommendations. The two studies also agreed that early turbines should fly two blades, rigidly attached to the rotor hubs, mounted downwind of steel truss towers; while teetered blades (*i.e.*, attached to the hub by a hinge, able to swing freely across the plane of rotation) and flexible concrete shell towers might lower costs and loads, available technology pointed toward more conservative designs.

With regard to rotor technology, GE asserted that propeller-type blades posed a lower development risk than heavier, more expensive helicopter-type rotors balanced at the quarter-chord point, and noted that Hutter had demonstrated the propeller concept years earlier. (This conclusion may have disappointed United Technologies, the parent of GE's subcontractor Hamilton Standard, since they had hoped to apply new helicopter-rotor

[14]Kaman, "Design Study: Executive Summary," pp. 22-23.

technology to advanced wind turbines.[15]) Thus, both studies recommended techniques to allow cheaper rotors with larger diameters, for example filament-wound blades.[16]

These caveats notwithstanding, both Kaman and GE agreed that, as GE put it, "while the challenges should not be minimized, only a modest development risk appears to be present due to the well developed supporting technologies involved in the design." The real challenge to developing windpower, they advised, lay in reducing the machines' capital cost, which formed the major component of the cost of energy. GE suggested that one avenue lay in reducing safety tolerances once designers had learned more about turbine dynamics and stresses. Another lay in reducing weight, which GE believed, "will relate directly to cost."[17] The FWEP eventually identified price per pound and even annual energy per pound as important measures of its turbines' cost effectiveness.[18] The FWEP and its contractors believed that they could effect cost reductions in small, steady increments as they came to understand better such riddles as rotor construction, tower vibration, and wind mapping. In effect, the studies affirmed the correctness of NASA's early assessment that, unlike photovoltaic cells which required substantial technological breakthroughs, wind technology could achieve economic viability with only modest refinement.

In the following years, the FWEP largely followed the advice of the Design Studies. In 1978, Divone wrote that "no major feasibility questions are involved" in the development

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[15]Marvin C. Cheney, Jr., United Technologies Research Center, "Composite Bearingless Rotor Control Concepts for Wind Turbines" in Eldridge (ed.), *Second Workshop*, pp. 249-253.

[16]GE, "Design Study: Executive Summary," pp. 1/6, 1/9.

[17]*Ibid.*, pp. 3/11, 3/20.

[18]Divone, "Recent Developments in Wind Energy," presented at the Second International Symposium on Wind Energy Systems in Amsterdam (3-6 October 1978), p. A3/21, figures 11-12.

of large commercial turbines,[19] and he drove the large turbine program to push the size envelope to its limits. As Divone explained in 1977,

> Up to a point, energy costs are decreasing with increasing sized systems due to scale effects. These are estimates, however, and no-one has ever built rotors in the 200 to 400 foot diameter size range. Thus, one of the key needs is in the development of wind power is to confirm both the absolute costs and to locate the point of upturn.[20]

As NASA's large turbine program progressed, the successive generations of turbines grew ever larger.

Building a 400-foot fiberglass rotor constituted a taller order than Kaman and GE intimated. The diameter of the largest composite-material rotor in America belonged to the 49-foot Boeing Vertol UTTAS helicopter. Even the largest helicopter rotor in the world (belonging to the Soviet MIL Mi-10) fell over ten feet short of the rotors of the FWEP's first "experimental" utility-scale turbines. In fact, those turbines' 125-foot rotors approached the wingspan of a Lockheed C-130 transport plane. The FWEP's 200-foot "first-generation" turbine outstretched the wingspan of a Boeing 747. The 300-foot second-generation units fell just short of the largest plane ever built, Howard Hughes' disastrous 320-foot Spruce Goose--an "unfortunate comparison," Divone conceded, but the only one possible. The single member of the third and last generation actually matched the infamous flying boat in size.[21]

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[19]Divone (Task Force Chairman), "Commercialization Strategy Report for Large Wind Systems," NTIS fiche TID-28843 (1980), p. 2. Six years later, however, Divone observed that although many people considered a wind turbine blades as a modified helicopter rotor or airplane wing, "the best analogy I can think of is an old Northrop Flying Wing bomber doing continuous barrel rolls (with an occasional snap roll) fifty meters off the ground in a turbulent boundary layer for thirty years." The difference, in other words, lay not in the blade's shape but in its environment and its performance goals. Divone noted dryly that "it is not a design problem to make one sanguine." Divone, "Wind Energy--A Glimpse at the Future," presented at the Fourth International Conference on Energy Options, sponsored by The Institution of Electrical Engineers, in London (4 April 1984), p. 4.

[20]Divone, "An Overview of Wind Energy Developments," presented at the Annual Meeting of the American Association for the Advancement of Science in Denver, CO (20 December 1976), p. 2.

[21]Divone, "Overview," pp. 2, 5, figure 7.

The large turbines' power ratings followed a similar trend. Early experimental machines matched the output of some European turbines erected early in the century, but the 2000-kW first-generation unit dwarfed even the 1250-kW Smith-Putnam machine. The second generation produced 2500 kW, and the third 3200 kW. Before abandoning its projected third-generation machine in the design stage in 1983, General Electric envisioned a capacity of 7300 kW and a diameter of 400 feet for what was to be the final NASA large turbine.[22]

Perhaps with its corporate tongue in cheek, GE characterized its wind development strategy as "find the windiest site and build the largest WTG possible."[23] Indeed, because the wind blows harder high off the ground, bigger turbines capture more energy (although critics of the FWEP observe caustically in hindsight that smaller, less risky rotors on high towers would have done the trick, too[24]). In addition, the weight and cost of elements such as electronic controls stay constant. While these factors suggested that bigger was better, the engineers also knew that given a constant design, a wind turbine's power output increases according to the square of its rotor diameter, while the mass rises much more quickly, according to the diameter's cube. Since cost follows mass, a huge turbine will cost too much. The FWEP managers concluded that the optimum size lay somewhere in between too small and too big--not a helpful insight.

The DOE's Divone draws the curve of size versus cost of energy as a curved "*W*." A tiny machine represents mostly fixed costs--the shipping case and advertising, for example. Even sending maintenance personnel to repair a very small turbine can cancel out a year's worth of energy. As the machine grows, it produces more energy at a lower cost per kWh--the first downward leg of the *W*. But some simple components used in small

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[22]Darrell H. Baldwin, NASA, and Jerry Kennard, Sverdrup Technology, Inc., "Development of Large, Horizontal-Axis Wind Turbines," NTIS fiche DOE/NASA/20320-62 (March 1985), p. 5, figure 1.

[23]GE, "Mission Analysis: Executive Summary," p. 1/17.

[24]Telephone interview with Robert Lynette, R. Lynette and Associates (29 July 1994).

machines fail at larger sizes, for instance the tail fin used in many small machines for yaw control. One can solve the problem by going to electronic control systems, Divone points out, but because they cost quite a bit, the cost of the turbine starts to climb as size increases--the first upward leg of the *W*. "You build bigger to cover the cost of those widgets, and the cost of energy starts dropping again," he says, describing the second downward leg. "But eventually," he says, completing the *W*, "the square-cube law catches up again." In the mid-1970s, the FWEP managers simply had no idea what numbers to write next to the turning points of their *W*. To fill in the blanks, they opted to build big turbines and see what happened.[25]

Some observers expressed reservations. A 1981 Congressional briefing report noted that "the DOE wind energy program seems to emphasize large wind energy machines," and asked, "Is enough attention being given to the role of small and intermediate machines in meeting U.S. energy needs?"[26] But such voices formed a small minority, and the NASA-managed FWEP effort continued to pursue its twin goals of exploring the upper limits of size and power, and reducing capital costs.

**PART III: How Should One Evaluate Wind Machines?**

The FWEP's goal remained the development of cost-competitive wind machines to reduce America's dependency on expensive imported oil. The FWEP identified the primary market for wind equipment, electric utilities, on the basis of its ability to produce significant amounts of energy; the secondary market, residential users, could produce far less. They also identified an intermediate objective toward satisfying that market: to identify the size and power rating at which wind machines might achieve maximum economies of scale. However, within that general directive, it became necessary to perform fine economic

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[25]Interview with Divone. See also Divone, "Evolution of Modern Wind Turbines" in Spera (ed.), *Wind Turbine Technology*, pp. 108-109. Thanks to Mr. Divone for a snappy seminar on wind turbine design.

[26]Fred J. Sissine, Barbara Luxenberg and J. Glen Moore, "Wind Energy," Congressional Research Service, Issue Brief IB80091 (original 31 October 1980, update 23 November 1981), p. 9.

comparisons. This task, assessment of the economic value of windpower to the potential market, proved complex and difficult.

Assessments of windpower used a variety of scales, including capital cost and cost of energy, two measures common to the utility industry. The capital cost, expressed in dollars per kilowatt of installed capacity ($/kW), denoted the amount of money a user would have to pay to have the potential to generate a certain amount of power. Thus, for example, in 1945, the Central Vermont Public Service Corporation ended its association with the Smith-Putnam project based on a valuation of windpower capacity at $190/kW, some $65/kW above the capability of the S. Morgan Smith Company to produce the machines.

Thirty years later, the Lockheed and GE Mission Analyses discussed in detail the breakeven capacity cost, the price at which utilities would presumably consider buying wind turbines. These discussions revolved around the concept of incremental revenue, the sum of the differences between production cost and true value to the utility for each turbine the manufacturer would have to fabricate before reaching the breakeven point. Someone--the manufacturer, the purchaser of the turbine, the ultimate consumer of the electricity, or the government--would have to supply this incremental revenue, the difference between price and value.

According to Lockheed's Mission Analysis, manufacturers could facilitate early sales by pricing early units at the projected average unit price of the entire production run:

> The actual cost of manufacturing the first units is much higher than the selling price; the last unit, much less. If the total planned number of units are sold, the manufacturer has recovered his investment and has achieved his profit goals. The investment decision by the manufacturer, then, depends on his confidence in his ability to: (1) Sell a given number of units as a pre-determined price; (2) Manufacture the units for the estimated cost, and; (3) Meet the performance, maintenance, and other guarantees.[27]

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[27]Lockheed, "Mission Analysis: Final Report," p. 7/13.

By taking unexceptional business risks, such as the common "loss leader" strategy of selling the first few production units below their actual cost in order to establish a market, Lockheed believed that manufacturers could ameliorate this serious obstacle.

However, discussions of windpower's capacity value failed to capture what many utility executives considered the technology's major drawbacks. First, utilities could not dispatch windpower to meet daily and seasonal demand peaks. They classified windpower as "non-firm;" while a given turbine might have the physical capability to generate 1500 kilowatts of power, the power actually generated would depend on the strength of the wind and the mechanical reliability of the machine, among other factors. Second, minute-to-minute variations in the wind might send undesirable current fluctuations into the utility grid if the turbine failed to maintain a constant rotation. For such reasons, the wind industry used a second measure of the value of windpower, the COE, expressed in dollars per kilowatt-hour ($/kWh).

Cost of energy I: wind machines

Comparisons between windpower and other varieties of generating capacity based on COE contained not one, but two controversial calculations. First, disagreement existed over the true cost of wind-generated electricity. Second, it proved difficult to calculate a utility COE for purposes of comparison.[28]

Although the "fuel" for a wind turbine costs nothing, the machine itself costs a good deal. Maintenance costs as well. The owner also pays interest on capital borrowed to make the purchase, as well as depreciation, insurance, and property, income and other taxes; these combined expenses spread over the machine's lifetime constitute an "annualized fixed charge rate." In 1979, NASA defined the COE for wind turbines operating on electric utility grids as:

[28]For a detailed account of how utilities calculate COE, see Carl J. Weinberg and Daniel F. Ancona, "A Utility Perspective on Wind Energy" in Spera (ed.), *Wind Turbine Technology*, pp. 591-593.

$$\frac{0.18 \times (\text{Capital Cost})}{\text{kilowatt hours per year}} + \frac{(\text{Annual O\&M costs})(\text{Levelizing factor})}{\text{kilowatts hours per year}}$$ [29]

where 0.18 represented the annualized fixed charge rate. This relationship captured an important truth. As a representative of Hamilton Standard, then trying to develop a 3-MW machine without DOE assistance, vehemently explained at a DOE conference:

> We at Hamilton Standard feel that this equation should be stenciled on the forehead of each of our designers, displayed prominently on office walls and, in fact, have the same emphasis as the *THINK* program at IBM.[30]

The speaker noted that if cheaper hardware reduced energy capture or increased operations and maintenance costs, nothing had been gained.

Clearly, prototype turbines posted a far higher capital cost (and hence cost of energy) than later versions of the same design, due to spreading out of fixed costs such as tooling a production facility, and to progress along the learning curve.[31] Yet the original FWEP studies had diverged widely on presumed learning curve and production quantity. Lockheed's Mission Analysis assumed a whopping 10,000 units produced by four separate facilities; because of "relatively simple structural concept and the number of off-the-shelf components," the cost of unit 2500 (*i.e.*, the last at each facility) would be 89% of the first unit's cost.[32] GE's Mission Analysis, on the other hand, assumed learning curves between 80 and 90%, but supposed production runs of 100 units.[33] Because of these disparities, and

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[29] J.R. Ramler and R.M. Donovan, "Wind Turbines for Electric Utilities: Development Status and Economics," NASA TM-79170 (1979). A levelizing factor adjusts the price for inflation.

[30] Thad M. Hasbrouck, Hamilton Standard, "Cost of Energy Evaluation" in "Large Wind Turbine Design Characteristics and R&D Requirements," NASA fiches N80-16453 thru N80-16482, papers from a workshop at Lewis Research Center in Cleveland, OH (24-26 April 1979), p. 397.

[31] The "learning curve" describes reduction in costs inherent in producing a given design. A 90% (or 0.9) curve assumes that after each doubling of production quantity, costs drop by 10%.

[32] Coty, "Mission Analysis: Executive Summary," p. 4/73.

[33] GE, "Mission Analysis: Executive Summary," p. 25; JBF, "Summary of Current Cost Estimates," p. B/9.

others concerning capacity factors (which ranged between 26% and 59%), fixed costs, turbine size and other elements, the JBF attempt to normalize the different studies resulted in widely divergent energy costs.

Amid such confusion, observers and participants in the wind community found it difficult to assess windpower's potential. Yet, even if agreement had existed on the appropriate variables to plug into the equations for calculating the cost of wind-generated electricity, windpower advocates and skeptics argued even more implacably over the value to which they should compare that figure. That is, because of the peculiarities of windpower, it was difficult to define the appropriate utility COE that wind turbines had to beat.

Cost of energy II: utilities

By 1980, NASA identified the advantage of windpower almost solely as the conservation of scarce fossil fuels:

> In most applications for the near future wind turbines will be used as fuel savers. The electric energy produced by a wind turbine in a utility system will enable the utility to reduce or shut down the generation from conventional, fuel-burning powerplants that would otherwise be required. The fuel thus saved can be credited to the wind turbine. In this mode, wind turbine power would be used whenever it is generated.[34]

Yet, utilities could not base decisions to buy windpower on simple comparisons of wind to their average cost of generating energy from other sources. Rather, they had to compare the cost of wind energy to the fuel actually displaced, which required a complex stochastic calculation.

Most utilities rely on a mix of different generating technologies, each with distinct characteristics. "Baseload" capacity consists of coal, nuclear or pumped water storage; such plants cost a lot to build, but have low fuel costs. Because they run more efficiently without

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[34]W.H. Robbins, Ronald L. Thomas and D.H. Baldwin, "Large Wind Turbines--A Utility Option for the Generation of Electricity," Lewis Research Center, NASA fiche N80-32858, presented at the American Power Conference in Chicago (21-23 April 1980) and the Annual Solar Energy Program Review in Rockport, ME (26-28 April 1980), p. 7.

interruptions, utilities tend to use them to meet the portion of demand which remains constant throughout the day and year. As demand waxes in each cycle, utilities bring on line their intermediate units. As demand peaks, say on summer afternoons in California or winter evenings in Minnesota, the utility fires up plants burning oil or natural gas; these smaller and comparatively cheap plants reach operating temperature more efficiently and quickly than a baseload plant, but they consume costly fuel.

Because of differences in fuel availability and in transportation and labor costs, the price of electricity varies widely with region. In 1979, it cost New England utilities 2.910 cents/kWh to generate electricity from fossil fuels (*i.e.*, coal, oil and natural gas), and utilities West of the Rockies a touch more, but those in the Northern Plains paid only 1.856 cents/kWh. In general, nuclear and natural gas showed the widest disparity, but each fuel also varied with region. Nuclear power cost .962 cents/kWh in the Northern Plains and 1.993 cents/kWh in Illinois and Michigan; electricity from natural gas ranged from 3.453/kWh in the Central Plains to 4.894 cents/kWh in the West.[35] These variations in generation costs produced similar differences in retail prices, but national residential prices averaged about four cents/kWh. Commercial service generally cost a penny more.[36]

Naturally, proponents of windpower preferred to match their machines against the costliest sources of energy in the costliest areas of the country, particularly during the early days of development. Thus, the FWEP placed early turbines in Oahu, HI, dependent on imported oil for 90% of its electricity needs, and in isolated Clayton, NM, unconnected to utilities from which to buy power and dependent on expensive natural gas and diesel fuel.

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[35]Coty, "Mission Analysis: Executive Summary," figure 2.1-2 and tables 2.3-1, 2.3-3 and 2.3-4. In almost all cases, Hawaii and Alaska demonstrated higher costs. The prices noted refer to generation costs. Retail prices also include transmission and distribution costs, and, among other components, the utility's allowed profit.

[36]John R. Justus, *et al.*, "Fact Book on Non-Conventional Energy Technologies," Congressional Research Service, Report 79-47 SPR (12 February 1979), p. 188.

Unfortunately for windpower, most utilities relied on a more diverse mix of generating resources. Moreover, because the wind ceases with little notice, the relevant COE that windpower had to meet consisted of a statistical average of all the various technologies in use by the utility. For example, if the wind blew reliably on August afternoons in California, windpower might provide an attractive alternative to the oil-fired plants brought on line to cope with the increased air-conditioning load. If, on the other hand, the wind blew at 3:00 a.m., wind turbines would have to generate electricity more cheaply than nuclear plants to have any value to utilities. The very difficulty of performing such a complex COE calculation formed a substantial barrier to windpower adoption; it also required access to the utilities' operating data.

In sum, the FWEP had decided by 1980 that windpower's chief value lay in allowing utilities to conserve scarce fuel. However, actual comparisons proved quite difficult. The capital costs and taxes applicable to wind equipment needed clarification. More importantly, because of the wind's variability, no-one could predict whether windpower would displace expensive oil or cheap nuclear fuel at any given moment. Although engineers had high hopes for "mature" versions of the prototypes then scheduled for design, wind development clearly had a long way to go before wind-generated electricity could compete as a utility generating resource. Small turbines in particular appeared substantially farther from viability than large machines. Thus, advocates of windpower searched for ways to increase its economic value to utilities.

<u>Capacity credits</u>

In 1978, a government task force on the commercialization of large wind turbines reported that

> A fraction of the wind system's rating is realized as added capacity, however, due to variations in the wind resource this changes the overall economic target by only a modest amount. Thus, the primary economic value of wind turbines is found in fuel savings--fuel savings which are determined by the joint occurrence of load variations and wind variations.[37]

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[37]Divone, "Commercialization Strategy for Large Wind," p. 8.

Yet, some advocates of windpower rejected the FWEP's assertion that windpower acted solely as a fuel saver; they claimed that windpower also partially relieved utilities of the obligation to build conventional powerplants.

While such advocates agreed that a utility making use of windpower had to maintain a reserve of dispatchable capacity for operation during calm periods, they asserted that windpower ought to receive a fractional "capacity credit." That is, they argued that some percentage of a wind generator's rated capacity counted as "firm." If, for instance, a utility placed ten 2-MW wind generators at dispersed locations on its grid, the nature of the local wind regime might permit the assumption that at least three or four would generate power at full capacity at any given moment. In that case, the utility would not only save a certain amount of fuel; windpower would also relieve the utility of the need to construct between 3 and 4 MW of new capacity---not much, but nonetheless a real savings that utility planners ought to include in their calculations.[38]

Traditionally, utilities calculated the capacity credit for conventional generating technologies on a plant-by-plant basis. Any power plant spends time off-line due to forced outages and routine maintenance, but in judging whether to allow a utility to include a conventional generating facility in its rate base (*i.e.*, whether it could pass on to its customers the cost of constructing the plant,) state regulators generally required a capacity factor of 70 or 80%. Some utility executives held that individual wind turbines should meet the same criteria. Windpower advocates objected that baseload plants rarely achieved such high capacity factors. In fact, baseload plants posted capacity factors between only 63 and

[38]See, for example, "Large Wind Energy Focus Group Results," prepared for the DOE by Market Facts, Washington, DC, NTIS fiche DOE/TIC-10038 (August 1978), pp. 17-18.

67% during the 1970s.[39] Nevertheless, even that level remained rather out of the reach of wind turbines, typically supposed to have capacity factors around 45%.[40]

Moreover, wind industry insiders argued that to take full advantage of windpower, one would not add a single isolated unit, as did the experimental phases of the FWEP, but rather a widely-spaced array of units, a substantial number of which would generate power at any given moment.[41] Divone himself proclaimed that "a wind system cannot be considered as an individual entity."[42]

Supporters also noted that the fuel adjustment clauses used by regulators to determine electricity rates allowed utilities to pass the "energy cost" of generating electricity directly to their customers.[43] As wind analyst Michael Lotker put it, "fuel expense is not a risk to the utility, it is an expense to the consumer." By contrast, installing a wind unit and petitioning for a rate increase to recover the turbine's cost constituted a risk to the utility.

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[39]U.S. General Accounting Office, "Status of Various Electric Energy Conservation Programs, Activities and Powerplant Capacities in the United States," GAO/RCED-83-193 (19 September 1983), p. 48.

[40]GE's "Mission Analysis: Executive Summary" estimates capacity factors of 45% for a 1500-kW turbine in a 15-mph wind regime (p. 4). The Kaman Design Study, however, estimated that under certain conditions the capacity factor of a large number of wind turbines might fall as low as 10% (p. 39). In fact, the first and only large turbine produced in the FWEP expressly for commercial sale achieved annual capacity factors under 17% in a wind regime which would have allowed between 34 and 38% had the machine attained 100% availability. Don R. Smith and Mary Ilyin, "Solano MOD-2 Wind Turbine Operating Experience Through 1988," prepared by Pacific Gas & Electric Co. for the Electric Power Research Institute, EPRI GS-6567 (November 1989), p. 4/1. A recent Federal report lists *average* capacity factors for all wind machines before 1975 as 10%, current average capacity factor as 20-25%, and the goal for 2000 as 30%. The same report notes availabilities of 60-70% before 1975, 95% currently, and hopes to exceed that level by 2000. U.S. DOE, *Wind Energy Program Overview, Fiscal Year 1993*, DOE/CH10093-279 (May 1994), p. 3. For purposes of comparison, a modern wind project anticipates capacity factors of 40% and availability of 95%. David Bright and Stephen Salaff, "Start on Biggest Windfarm in Canada," *Wind Power Monthly* 9 (September 1993), p. 16.

[41]The capacity value of windpower depends also on the match between wind peaks and demand peaks. But even where the wind habitually blows exactly when the local utility requires peaking capacity, the value of windpower to the utility falls as planners add more turbines to the system. Because of the variable nature of the wind, increasing penetration of windpower into the system increases the chance that they will generate power when only baseload units with low fuel costs are on line.

[42]Divone, "An Overview," p. 6.

[43]"Large Wind Focus Group," pp. 25-26.

"That," Lotker pointed out, "is a disincentive."[44] As long as utilities perceived no incentive to pursue cheaper fuels, supporters felt, they would follow their native conservatism in ignoring windpower, whose fuel cost nothing at all.

Furthermore, traditional concepts of fuel and capacity credits seemed to break down in assessing windpower. Certainly, investment in wind turbines requires more "rated" capacity to equal a given shortfall than a purchase of conventional "firm" capacity such as coal- or oil-burning plants. But, the crucial point lay in the type of capacity backing up the turbines. A utility could maintain the same amount (in MW) of rated generating capacity, but, by adding wind turbines and changing the composition of its generating mix, save a substantial amount of money. That is, the utility could purchase cheap natural gas generators (which burn an expensive fuel) instead of expensive baseload plants (which use much cheaper fuel) and only operate them during windless periods. As a 1977 report from the Brookhaven National Laboratory argued,

> ...there is no direct relationship between "capacity credit" and utility economics, and it is utility economics which are ultimately of interest.[45]

For reasons such as this, windpower supporters tried to show that traditional utility concepts inherently discriminated against their technology.[46]

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[44]Michael Lotker, Booz, Allen and Hamilton, "Economic Challenges of WECS" in Theodore R. Kornreich (ed.), *Proceedings of the Third Biennial Conference and Workshop on Wind Energy Conversion Systems*, held in Washington, DC, CONF-770921/1-2 (19-21 September 1977), p. 883.

[45]Harry Davitian, "The Role of Wind Power in Electric Utilities," Brookhaven National Laboratories, Technology Assessment Group, National Center for Analysis of Energy Systems, Upton, NY, NTIS fiche BNL-50736 (September 1977), pp. 10-11.

[46]The capacity credit question remains unresolved. A recent request for energy project proposals by Wyoming's Division of Economic and Community Development notes that "...due to the variable nature of the wind, utilities and state utility commissions have had concerns about how to value wind generation as a possible baseload capacity resource versus an energy resource... If this reliability issue could be dealt with, the development of wind generation would be greatly accelerated... This project should be a demonstration of any technology or methodology which would make wind generation more attractive to utilities and PUCs as a dispatchable resource. Possibilities of power storage to alleviate peaking problems at any Wyoming municipality would be considered." "Wyoming Releases Formal RFP for Renewable Demonstrations," *Wind Energy Weekly* (electronic version) 13 (19 March 1994).

Storage

A final complicated issue concerned the relevance of storage to windpower economics, proclaimed a critical issue by Palmer Putnam in 1945. But by 1979, neither cheap chemical batteries, flywheels, superconducting magnets, or systems for storing and delivering heat, compressed air or hydrogen had appeared on the market. Rather, pumped water provided the best storage option for windpower, as it had in Putnam's day, notwithstanding energy efficiencies of only 66%. While dedicated hydro storage (*i.e.*, reservoirs constructed specifically to "firm up" wind capacity) remained too expensive to contemplate, windpower fit in well as an addition to existing hydro systems. Encouraged by the FWEP, the agency in charge of Federal hydroelectric installations, the Bureau of Reclamation (BuRec), later purchased a FWEP-funded Boeing design and a privately-designed Hamilton Standard unit, for a demonstration of hydro-wind systems at Medicine Bow, WY.[47]

In most cases, however, windpower used the existing utility grid as storage. Since utilities generally maintained 8% or so of their capacity as spinning reserve, ready to meet momentary surges in demand, windpower analysts asserted that penetration by windpower of 10 to 15% of total system capacity required no special provision for additional storage.. More important, they pointed out that if seasonal and daily wind peaks matched demand peaks, storage became irrelevant--the wind turbines contributed energy to the grid exactly when needed. The slow, and in some cases grudging, realization by utilities that they could in this way integrate windpower into their systems removed a major stumbling point to the adoption of large wind turbines.

Unfortunately, the decreasing importance of storage to the utility-oriented large turbine initiative opened yet another division between small and large machines. Homeowners with small plots often lacked a site where the wind consistently blew when the

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[47]Testimony of R. Keith Higginson, Commissioner of the Bureau of Reclamation, in U.S. Congress, House of Representatives, Committee on Science and Technology, Subcommittee on Energy Development and Applications, *Wind Energy Systems Act of 1980*, 96th Congress, 1st Session (17 October 1979), Serial No. 96-137, pp. 208-209.

home needed power; a cheap storage system would have greatly assisted these consumers in incorporating wind systems. It would also have aided those who wished to rely on windpower and leave the grid altogether. Thus, although cheap storage would have improved the economics of all varieties of windpower, it ceased to figure critically in the FWEP's development plans for large turbines, and champions of small wind found themselves left behind.[48]

## Conclusion: The Relevance of Economics

The FWEP struggled to articulate a way to measure windpower's value and to define the roles of small and large turbines. Such issues had roots in the "energy crisis" of 1973. In the eyes of its DOE overseers, the program's goal remained the reduction of national dependence on foreign oil. While some advocates of windpower praised windpower's social value, the FWEP assessed it in purely economic terms, for example capital cost per kilowatt of capacity, or cost per kilowatt-hour of energy.

Given the goal of producing significant amounts of energy, the FWEP quickly identified electric utilities as the most promising market for wind turbines. After identifying cost of energy as the major criterion for assessing windpower, the FWEP chose to develop megawatt-scale horizontal-axis machines, which they believed showed great potential and modest development risk as low-cost energy generators. Finally, the FWEP identified two ways to lower energy cost. As successive designs sought to lower capital cost, for example by reducing weight, engineers pursued maximum economies of scale by constructing progressively larger and more powerful turbines.

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[48]See the testimonies of James A. Lerner, Senior Technical Advisor for the California Energy Commission, and Eric Leber, Director of Energy Research for the American Public Power Association, in U.S. Congress, *Wind Energy Systems Act*, pp. 67-68, 102-103; and Worth Bateman, Deputy Under Secretary of Energy at the DOE, in U.S. Congress, House of Representatives, Committee on Science and Technology, Subcommittee on Energy Development and Applications, *Oversight: Wind Energy Program*, 96th Congress, 1st Session (30 July 1979), Serial No. 96-35, p. 57.

Ironically, both advocates and skeptics of windpower resisted assessment of the new technology on purely economic grounds. As one alternative energy proponent wrote:

> ...the true environmental-societal costs of conventional power are not recorded in the ledger books. Wind power offers society no "Faustian bargain," as does nuclear power; nor does it pollute the air to cause death and disease, as does the combustion of coal and oil.[49]

For their part, utility managers hesitated to belittle windpower publicly. Many phrased their resistance in terms of the disturbances that an untried technology might introduce to their already stressed system, or by objecting to government encroachment into the energy business. As an industry representative told Congress:

> We recognize the need for the development of... new sources and we will support and cooperate with those programs... [O]ur concern is not over what fuels or what forces or engineering systems are used in the production of electricity. Rather, our concern is over the nature of the organizations that will build the systems... If you believe in the basic free enterprise system under which our country has developed, you share our conviction that it is in the interest of everyone in the country that our system of investor-owned utilities be preserved.[50]

However, both advocates and skeptics realized that, down the road, they would fight the battle over adopting windpower on economic grounds. For this reason, they grappled to establish definitions and assessment methodologies favorable to their point of view. Before joining that battle however, the manufacturers had to lower the price and improve appreciably the reliability of their machines.

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[49]Clark, *Energy for Survival*, p. 562.

[50]Testimony of Malcom Y. Marshall, Edison Electric Institute, in U.S. Congress, Senate, Committee on Energy and Natural Resources, Subcommittee on Energy Conservation and Supply, *Energy Supply Act (Title X)*, 96th Congress, 1st Session (10 July 1979), pp. 20-21.

# CHAPTER FIVE
# The Federal Wind Energy Program in the 1970s

## Introduction: A Preferred Technological Path

The Federal Wind Energy Program harbored a number of divisions. Separate program elements explored small, vertical-axis and innovative turbines. But this chapter demonstrates that these avenues of research, and the small-turbine program in particular, lacked the cohesion of the large-turbine effort. Federal policy-makers devoted substantial funding to small turbines, but they issued no manifestos calling for individuals or communities to install wind machines on every roof and leave the utility grid. The FWEP managers lacked consensus on the potential of smaller turbines and "radical" configurations, and it often seemed unclear why the program pursued such technologies at all.

In contrast, champions of the FWEP's large-turbine element displayed a cohesive vision of thousands of multi-megawatt horizontal-axis turbines, grouped into utility-owned "farms"[1] and linked to the nation's electric grid like any conventional powerplant. Three factors account for the FWEP's decision to concentrate on this type of turbine and operating scenario. First, although American wind development virtually ceased after World War II, post-war European engineers chose turbines with propeller-type rotors on horizontal axes as the best suited to generating large amounts of electricity. The American Smith-Putnam project used the same configuration. Thus, FWEP managers selected large horizontal-axis machines on the basis of available operating data and lower perceived developmental risk, rather than demonstrated economic or technical superiority.

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[1]The origin the term "windfarms" remains obscure. Although today it connotes agglomerations of medium-scale, privately-owned machines, the DOE referred in 1981 to a cluster of three 2.5-MW MOD-2s owned by the Bonneville Power Administration (BPA) as the first windfarm. See U.S. DOE, BPA, "Building the World's First Wind Farm," DOE/BP-55 (May 1981). See also Thomas A. Starrs, "Legislative Incentives and Energy Technologies: Government's Role in the Development of the California Wind Energy Industry," *Ecology Law Quarterly* (1988), p. 107.

Second, unlike Amory Lovins and other energy analysts endorsed by the counter-culture, the Federal effort never condoned social goals such as unplugging from the utility grid. From its beginning as a RANN program, the FWEP aimed "to develop the technology for practical cost-competitive wind conversion generator systems that can be used for supplying significant amounts of energy to help meet the nation's energy needs."[2] One industry executive estimated the combined market for residential and agricultural windpower at 2.5 quads, at a cost of $95 billion/quad for residential and $62 billion/quad for agricultural; he compared this to 10.7 quads in the utility sector at a cost of $28 billion/quad.[3] Given that goal and such cost estimates, the FWEP's technological path made sense.

Some members of the windpower community objected to the FWEP's exclusion from its assessment criteria of the social benefits inherent in a switch to windpower. Testifying before Congress in 1979, Ben Wolff of the American Wind Energy Association responded to a query concerning the potential of small turbines:

> Well, it depends on what you mean by contribution. Government is involved in energy development for a number of reasons--the economics to stop the balance of payments, as national security and defense... it is easy to see how large machines will make a substantial quad impact. If you consider maximizing social choices, or keeping your options, where we want to go as a society, small machines tend to do more in that direction... very small machines [in] single-family residences have an impact in the fact that they are up there and people can see where their energy is coming from and how it is being used. If it is a large machine tied to the utility line... it does not make that difference.[4]

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[2]Ronald L. Thomas, R. Puthoff, Joseph M. Savino and W. Johnson, "Plans and Status of the NASA-Lewis Research Center Wind Energy Project," Lewis Research Center, NASA fiche N75-21795, presented at IEEE/ASME Joint Power Conference in Portland, OR (28 September 1975), p. 1.

[3]Testimony of John Barchet, Manager of Wind Energy Systems for General Electric, in U.S. Congress, *Wind Energy Systems Act*, p. 152.

[4]Testimony of Ben Wolff, Executive Director of the AWEA, in U.S. Congress, House of Representatives, Subcommittee on Energy Development and Applications, *1980 Department of Energy Authorization*, No. 16, Vol. V, 96th Congress, 1st Session (28 February 1979), pp. 392. Wolff estimated that 85% of windpower's ultimate potential might come from centralized applications, but stressed that centralized wind installations might use multiple intermediate-sized machines, rather than a few megawatt-sized units.

But Federal spokespeople rarely voiced such sentiments. Rather, as Wolff implied, they stressed the potential of horizontal-axis turbines between 2 and 4 MW to fulfill the program's goals of producing *large* amounts of *cheap* energy, rather than any social effects of choosing a certain technological path.

Third, the FWEP and its contractors chose to follow the path of high technology pioneered by Palmer Putnam and the Austrian engineer Ulrich Hutter. To increase lower the cost of energy, Hutter relied on low weight and aerodynamic efficiency, rather than the sturdy reliability exemplified by Johannes Juul's Gedser machine (on which later Danish experimenters successfully built). Indeed, the early FWEP turbines followed Hutter's design and espoused his high-technology principles quite faithfully.

Its image as a radical alternative to the conventional energy system notwithstanding, the FWEP operated as a branch of the Department of Energy and shared that agency's links to the established utility industry. Significantly, the DOE traced its genealogy back (through the ERDA) to the Atomic Energy Commission, an agency implausibly intended both to monitor and promote nuclear energy, and criticized for an inability to distance itself from the institutions it was meant to regulate.[5] The DOE, like its institutional ancestor, shared the management culture of utility engineers, who had been enthralled by big, powerful, masculine generating technology for almost a century.

In the words of Carl Weinberg, a retired utility executive, most utility managers of the day believed that "big is beautiful." They ridiculed advocates of alternative energy such as Amory Lovins and California's Governor Jerry Brown, scoffing that "real men don't do

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[5]Daniel Ford, *The Cult of the Atom: The Secret Papers of the Atomic Energy Commission* (New York: Simon and Schuster, 1982), p. 26.

soft energy; real men build big nukes and big dams." In that macho culture, Weinberg speculates, "a 3-MW turbine was as small as [the FWEP] dared to go."[6]

Not surprisingly, given its close ties to the energy industry, its infatuation with size and its preference for technological sophistication, the FWEP sought a centralized, large-scale cooperative effort between Federal agencies and giant corporations to design the largest high-tech wind machines possible. It eschewed the possibility of a decentralized, competitive, entrepreneurial program based on smaller, simpler units. Indeed, large, sophisticated horizontal-axis turbines promised greater near-term economic benefits than any other configuration, but the nation's energy managers, both private and public, also found that path challenging and charismatic for its own sake.

## PART I: Small Wind

The FWEP defined its goal as developing "the technology for practical cost-competitive wind-generator conversion systems that can be used for supplying significant amounts of energy to help meet the nation's energy needs."[7] To many Federal managers, this goal precluded a major role for small wind turbines, which seemed incapable of producing energy cheap enough to compete with utility power. It appeared equally farfetched for household-scale turbines to contribute substantially to meeting America's energy demand. Beyond that, however, the combination of backgrounds in aerospace engineering and the ambitious visions of wind advocates such as William Heronemus may have attracted many NASA and FWEP policy-makers to large turbines, which could ease energy and environmental dilemmas while providing a captivating technological challenge.

In response to a question concerning the use of small turbines for home heating raised at the first wind workshop in 1973, Ronald Thomas explained that NASA's wind

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[6]Interview with Carl Weinberg, President-elect of the AWEA and former director of PG&E's Division of Research, Development and Demonstration, in Savannah, GA (3 October 1993).

[7]Thomas, *et al.*, "Plans and Status," p. 1.

pundits had so far concentrated on "a way to make a major impact using wind supplied energy in a major way." Small turbines might indeed contribute to that mission, he ruminated. NASA would reconsider the role of small turbines, Thomas promised, but he admitted frankly that "you're right, it was not a major part of our thinking."[8]

In subsequent years, the FWEP tried to repair this oversight. Still, many advocates of decentralized power criticized the FWEP's small-turbine program as a poorly-conceived, poorly-funded sop. Often, they took exception to the government's refusal to consider the social benefits that might accrue from a switch to wind. Hans Meyer, formerly an acolyte of R. Buckminster Fuller and later the head of a small-turbine firm, chastised conferees at the FWEP's second windpower workshop in 1975:

> There are many serious questions about the whole philosophy of centralization of our energy system. Because we have been moving in that direction for 75 years does not necessarily imply that we should continue... If there is an energy crisis, it is one of consumption, not of production. We need to learn better how to live on our spaceship Earth...[9]

Divone responded to such affirmations by pushing for a balanced program which included various configurations and scales. In the end, however, the FWEP defined Meyer's musings as irrelevant, by identifying quantity and cost of energy as the primary criterion of assessment.[10]

Fans of small windpower at the margin of the Federal program even questioned the FWEP's administrative and conceptual distinction between small and large turbines. A more meaningful boundary, some members suggested, lay between managed wind systems, which demanded skilled operators, and unmanaged systems appropriate for homeowners and organizations unfamiliar with electricity generation. In addition, some criticized the FWEP's

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[8]Thomas in Savino (ed.), *Wind Energy Conversion Systems*, p. 250.

[9]Meyer in Eldridge (ed.), *Second Workshop on Wind Energy*, p. 515.

[10]Interview with Ancona in Washington, DC (5 July 1994). Still, Ancona maintains that "one of the reasons the wind program was successful, and resulted in a lot of commercial products, was that we balanced those interests. It wasn't just blindly marching down the road on the quad issue."

position that only multi-megawatt machines made sense in a utility environment. They opined that pools of small turbines might better satisfy utility needs by offering reliability and redundancy superior to that of large machines. Windfarm demonstrations, they suggested, could validate the theoretical superiority of many small machines over one large one.[11] The FWEP managers remained unconvinced.

<u>Rocky Flats: "A hell of a rough ride"</u>

In 1977, the ERDA set up a test center for small turbines on a 440-acre site at Rocky Flats, CO, near the town of Golden. Managed for the ERDA and the DOE by the Energy Systems Group of Rockwell International (a major defense contractor), the Rocky Flats Wind Systems Program assembled data on technical topics such as tower vibration and turbine noise, and on institutional issues affecting small turbines. Workers at Rocky Flats built no machines. Rather, they disbursed Federal money to firms working on units between 1 and 40 kilowatts in size. As one researcher explained in 1975, "wind power is still a field where people can innovate things in a garage workshop,"[12] and Rocky Flats' requests for proposals often contained "small business set-asides" won by shoestring enterprises such as Meyer's company, Windworks. While these set-asides forced inclusion of some smaller, entrepreneurial firms, substantial research money for exploration of small windpower went to giants including the Aluminum Company of America (ALCOA), the Grumman Corporation, the United Technologies Research Center, the McDonnell-Douglas Aircraft Corporation, and the Kaman Aerospace Corporation.[13]

Unlike the government of Denmark, whose firms later dominated the wind turbine manufacturing industry, the FWEP never instituted safety or performance standards for wind

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[11]"Small Wind Energy Focus Group Results," prepared for the DOE by Market Facts, Washington, DC, NTIS fiche DOE/TIC-10018 (August 1978), pp. 23-24.

[12]William L. Hughes of Oklahoma State University, quoted in Roger Hamilton, "Can We Harness the Wind?" *National Geographic* 108 (December 1975), p. 824.

[13]U.S. DOE, *Wind Energy Systems Program Summary* (May 1980), pp. 127-142; Terrence J. Healy, Program Manager for Wind Energy at Rocky Flats, and Lou Seaverson, "Rocky Flats: Testing Small-scale Wind Systems," remarks at AWEA conference, reprinted in *Wind Energy Digest* (December 1976), pp. 39-41.

equipment. Rather, Rocky Flats tested turbines at the request of manufacturers, even those machines produced without Federal support; between 1976 and 1982, fifty-four different units braved the wild gusts blowing off the Rocky Mountains. Manufacturers groused that the site's low mean wind speed (under 14 mph) kept annual energy generation figures too low to impress buyers, but, in Divone's phrase, the periodic storms "gave the turbines a hell of a rough ride," and quickly identified flimsy machines.[14]

In fact, many turbines tested at Rocky Flats performed poorly, including each of the first thirteen installed. Failures ranged from cracked tail vanes to thrown blades.[15] Those turbines that survived the storms gained a valuable reputation for reliability. Jay Carter, Jr., for example, recalls that Carter Wind Machines' frail-looking 25-kW unit, which featured flexible blades and a flexible tower, sailed through the Rocky Flats center with honors. "Lots of bets went around that the first good little windstorm that came along, this thing is going to be spread out for fifteen miles," Carter chuckles, but it outlasted all the others. "They must have sold two or three hundred machines for us, because people would call Rocky Flats, and they'd say, 'Well, Carter's is the one.' Everybody wanted one..."[16] While Rocky Flats did not charge for performing such tests, they insisted on publicizing the results. Budget cuts in the early 1980s ended plans to do proprietary tests for manufacturers willing to pay for the service.[17]

Some of the designs developed with Rocky Flats' funding eventually succeeded commercially, such as the 2-kW North Wind HR-2. Other manufacturers drew on experience gained during their contract work to design new machines. And five Rocky Flats employees jumped ship in 1980 to form their own firm, Energy Sciences, Inc., which

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[14]Interview with Divone.

[15]Roger L. Moment, Rockwell International, "Systems Development and Test Center Activities in the Wind Systems Program at Rocky Flats" in Kornreich (ed.), *Third Biennial Conference*, pp. 131-132.

[16]Interview of Jay Carter, Jr., by Robert D. Kahn (June 1993). Provided courtesy of Mr. Kahn with the permission of Mr. Carter.

[17]Interview with Divone.

manufactured a successful 50-kW machine for the emerging "windfarm" market.[18] FWEP manager Ancona estimates that two-thirds of the small-turbine contracts resulted in commercial products.[19]

Institutional barriers and market formation

Most members of the small-wind community identified problems of reliability and safety as the greatest barrier to commercialization. As one member put it, "we need a Model T," a unit perceived by the public as a risk-free purchase. A lack of income and investment compounded the problem, and several manufacturers struggled to stay afloat financially, even as their R&D efforts progressed.[20]

Equally important, several institutional barriers to the emergence of a market waited ominously in the wings. A critical uncertainty concerned the price utilities would charge users of small turbines for back-up service. Members of the industry expected that a few turbine users would strive for self-sufficiency by "unplugging" from the grid. However, due to the high cost of energy storage systems and to the perception that complete reliance on windpower required unpalatable lifestyle changes, they anticipated that most would purchase back-up service from local utilities during calm periods. The threat of added "demand charges" for back-up power constituted a powerful disincentive to prospective consumers. By 1978, five utilities had received permission from their state regulators to institute such charges.[21]

From the utilities' perspective, demand charges seemed just. Regulators insist that utilities maintain enough capacity to cover maximum possible loads, which requires capital

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[18]Naar, *The New Wind Power*, pp. 91, 146-150.

[19]Interview with Ancona.

[20]"Small Wind Focus Group," p. 18.

[21]Kornreich and Daryl L. Tompkins, "An Analysis of the Economics of Small Wind Energy Systems" in Kornreich (ed.), *Third Biennial Conference*, p. 164.

investment in facilities large enough to meet any eventuality. Of course, utilities only earn back the cost of these facilities during periods of use. Unfortunately, from the utilities' point of view, customers owning wind turbines draw on utility electricity only a small fraction of the time. To utility executives of the late 1970s, forced by law to buy equipment to serve wind turbine-owners, it seemed fair to charge enough to recompense their investors for the time the equipment stood idle. Windpower advocates rejoined that such reasoning allowed utilities to penalize those who tried to relieve the energy crisis. Just or not, demand charges threatened to raise substantially the average cost of energy for a home with a wind system. Manufacturers believed that few Americans would invest in a wind turbine--or a wind turbine company--while the issue remained unresolved.[22]

Throughout discussions of these issues, the small-wind industry blamed the FWEP for failing to marshall its wares out of the laboratory and into the marketplace. Without a clear exhibition of windpower's effectiveness, manufacturers claimed, a wary or uninterested public would refuse to buy even good machines. To support the struggling industry, they asked the Federal government to establish a managed demonstration of wind technology, presumably by subsidizing the purchase of small turbines. William Drake of Enertech Corp. suggested "putting a limited number of reliable, off-the-shelf wind machines in highly visible locations, where large numbers of people will be exposed," perhaps along the Federal lands of the interstate highway system. Not only would such exhibitions raise public awareness; they would steer revenue to the cash-starved manufacturers, accumulate performance data, and enlarge the pool of individuals with technical experience operating small turbines.[23]

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[22]Divone (Task Force Chairman), "Commercialization Strategy Report for Small Wind Turbines," NTIS fiche TID-28844 (1978), pp. 14-15. This fear derived in part from a 1977 decision by the Colorado Public Utility Commission to assess demand charges on solar water heaters. Until overturned in the face of DOE intervention and public outcry, this policy threatened to squelch the state's solar industry. In some cases, the demand charges discussed for windpower, if averaged over total energy production, would have added six cents/kWh to the cost of energy. Testimony of Bennet Miller, DOE, Director of Solar, Geothermal and Electric Energy Systems, in U.S. Congress, *Oversight*, pp. 66-68.

[23]"Small Wind Focus Group," pp. 16, 25; William Drake, President of Enertech Corp., "A National Wind Demonstration Program," *Wind Energy Digest* (Spring 1978), pp. 13-14.

Divone agreed that the small turbine industry required safer, more reliable products. Federal development funds seemed the best way to meet that need. As a long term market lever, a 1978 DOE task force on small-turbine commercialization recommended incentives such as tax credits and long-term, low-interest loans for purchasers. In the short term, however, the task force cautiously endorsed the concept of a demonstration project of perhaps 500 units.[24]

In 1980, on the basis of such recommendations, Rocky Flats initiated the Field Evaluation Program, which authorized Federal purchases of 100 small turbines from a variety of manufacturers for connection to local utility grids in each American state and territory. FWEP officials hoped to collect data on institutional barriers such as zoning regulations, building safety codes, state requirements for environmental impact statements, and utility rate structures including possible demand charges. Equally important, the project would expose the public to windpower, and infuse the small-turbine industry with some welcome cash to tide it over until a market coalesced.[25]

Not all small-turbine manufacturers approved of the structure of the Field Evaluation Program. A Grumman executive voiced a common concern in predicting sourly that the turbines would perform poorly in a number of states. He complained that "it doesn't make sense to test wind systems in areas where there is no wind, and it doesn't make sense to test systems in states with unusually low energy costs."[26] Rather, manufacturers wanted to situate the machines in areas where high winds and costly utility prices allowed windpower its best possible showing. The DOE, however, opted to spread the machines thinly, which they believed would maximize information on institutional barriers to windpower. The

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[24]Divone (Chairman), "Commercialization Strategy for Small Turbines," pp. 19-20.

[25]Divone, "The Current Perspective on Wind Power Based on Recent U.S. Results [first version]," presented at the Third International Symposium on Wind Energy Systems in Lyngby, Denmark (26-29 April 1980), p. 2.

[26]Testimony of Ronald B. Peterson, Chairman of Grumman Energy Systems, Inc., in U.S. Congress, *Oversight*, pp. 155.

disagreement suggests, perhaps, that the manufacturers wanted advertising and revenue, while the government wanted research.

<u>The American Wind Energy Association</u>

Parallel to but apart from the Federal wind community, a non-governmental community developed in the mid-1970s,[27] interested primarily in small machines and centered loosely on the American Wind Energy Association. Founded in 1974, the AWEA functioned as a trade association, and it provided an important voice for the small-turbine industry, particularly the smaller manufacturers. As one FWEP administrator ironically recalls, "Back then, a lot of AWEA wore bib overalls, and carried babies on their hips... Now they're in pinstripe suits."[28] Former Executive Director of the AWEA Thomas Gray agrees, casting the association's original constituents as members of the "counter-culture" movement, with the corporations "grafted on later."[29]

By 1979, the AWEA represented some 1200 members, half of whom had an economic interest in windpower. Other members included enthusiastic individuals, consumers, equipment distributors, legislators and environmentalists. The organization held its own conferences and exhibitions distinct from those run by the FWEP, but it also won a number of Federal contracts to research the windpower market and industry. AWEA publications included the *AWEA Newsletter* on industry events, the *Wind Power Digest* for general readership, and *The Wind Technology Journal.* Most important, it became an effective advocate for the industry before Congress.[30]

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[27]See, for example, Paul Gipe, "Wind Activists in the Commonwealth," *Wind Energy Digest* (Summer 1977), pp. 28-31.

[28]Interview with Ancona.

[29]Interview with Thomas Gray, Northeast Representative for the AWEA, in Savannah, GA (3 October 1993).

[30]Herman M. Drees, Pinson Energy Corporation, "The American Wind Energy Association and the Wind Energy Industry" in Kornreich (ed.), *Third Biennial Conference*, pp. 183-184.

The AWEA struggled uneasily to increase attention on small wind systems and smaller manufacturers, while trying not to defame its corporate members. AWEA President Richard Katzenberg, for example, earnestly explained in 1977 that although the association had pressed Washington policy-makers to step up efforts to develop small machines, "we are not in any way against the large scale machine program," and he declared that "we did not feel that it was in the country's best interests to have a large machine perspective to the total exclusion of the potential of dispersed systems..."[31] Divone admits to occasional irritation with the AWEA, telling them "you've got to stop bad-mouthing Hamilton-Standard and GE, because they're up on [Capitol] Hill lobbying for wind power." Divone wonders if he might have done more to convince the wind industry to speak with one voice, but the AWEA's internal conflicts imply that the problem lay in the bifurcated industry itself.[32]

## **PART II: The Eggbeater and Other Oddities**

Whereas the saga of small windpower demonstrates the FWEP's commitment to generating large amounts of cheap power, the story of vertical-axis turbines shows the program's goal of rapid development. Throughout the 1970s and early 1980s, FWEP researchers investigated a wind machine resembling an eggbeater on end. The machine's vertical shaft, around which two or three flexible blades whirled, rested on a gearbox and alternator; cables fixed to the apex of the shaft guyed the structure to the ground. Partisans of the intriguing machine continue to assert its superiority today.

Patented in 1931 by George Darrieus of France, Canadian researchers unwittingly re-formulated the eggbeater concept in the early 1970s.[33] Engineers at NASA's Langley Research Center in Virginia played with the concept[34] until the newly-formed FWEP

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[31]Richard Katzenberg, AWEA, "Introductory Remarks" in Kornreich (ed.), *Third Biennial Conference*, pp. 8-10.

[32]Interview with Divone.

[33]Bennie F. Blackwell and George E. Reis, "Blade Shape for a Troposkein Type of Vertical-Axis Wind Turbine," Sandia, NTIS fiche SLA-74-0154 (April 1974), p. 1.

[34]"Windmill Eyed for Lighting," *The Washington Post* (13 February 1974), p. A7.

moved vertical-axis research to at Sandia National Laboratories in Albuquerque, NM. ALCOA eventually won FWEP grants to develop a three-bladed, 11-kW Darrieus turbine with a diameter of 34 feet for residential use, but it abandoned the contract, stating that the unit showed little potential for cost effectiveness. The firm continued work on 100-kW and 500-kW models.[35] By 1979 ALCOA had received about $600,000 from the FWEP, to which it added over $1 million of its own funds. However, the FWEP declined to fund a 1-MW Darrieus project proposed by ALCOA and a consortium of electric utilities.[36]

The Darrieus posed several advantages over horizontal-axis turbines. Its ground-level works allowed safe and convenient maintenance. Vertically symmetric, the Darrieus required no complicated yaw machinery to orient it into prevailing winds. It experienced steadier dynamic loads, and the central tube threw less of a shadow on the rotor than the truss towers of conventional turbines. Darrieus units exhibited greater aerodynamical simplicity as well; ALCOA engineers fabricated inexpensive aluminum blades by extrusion (*i.e.*, forcing semi-solid aluminum through a die in the shape of a blade cross-section), a technique impractical in the case of the twisted, tapered airfoils of horizontal machines.[37]

Unfortunately, engineers failed to adapt the Darrieus to tower operation, limiting the concept to less energetic winds. Wind shear also stumped Darrieus designers, who found no analog for the techniques of tilting the axes of horizontal machines up into the wind, or teetering the blades to conform to instantaneous differences in wind angle at the top and bottom of the arc. Engineers also believed that Darrieus turbines required an external boost

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[35]P.C. Klimas, "Darrieus Wind Turbine Program at Sandia National Laboratory" in Irwin E. Vas (ed.), *Wind Energy Innovative Systems Conference Proceedings*, sponsored by the DOE in Colorado Springs, CO, NTIS SERI/TP-245-184 (23-25 March 1979), pp. 57-69. ALCOA contract summaries in: U.S. Department of Energy, *Federal Wind Energy Program--Program Summary*, NTIS DOE/ET-0023/1 (January 1978), p. 53; DOE, *Wind Energy Systems Program Summary* (1980), pp. 185, 189.

[36]Testimony of Thomas W. Callahan, Associate Director of ALCOA Laboratories, in U.S. Congress, *Oversight*, p. 171.

[37]*Ibid.*, pp. 168-169.

to start rotation,[38] unlike horizontal-axis machines that started up when the wind reached their cut-in speed.[39] Finally, Darrieus machines used more material per unit of power than the horizontal-axis competition.

Ultimately, however, the FWEP selected the horizontal-axis turbine as the program's workhorse because the availability of technical data from earlier innovators lowered development risk and time. The FWEP specified that the Mission Analyses consider only horizontal-axis machines; as Lockheed explained,

> lack of experimental data regarding design and design-cost optimization on [the Darrieus] has precluded their use in this study although further work may prove them cost effective for certain applications.[40]

In fact, Lockheed included an appendix co-authored by Oregon State University's Robert Thresher which concluded that

> ...the Darrieus rotor has performance which appears to be nearly equal to that of a propeller type machine. Its simple design seems to make it a promising candidate for economical power production.[41]

Thus, rather than indicating a higher potential, the decision to devote FWEP resources to horizontal-axis machines reflects the perceived need to develop a reasonably promising renewable energy option quickly.

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[38]For example, see Eldridge, "Wind Machines," p. 23.

[39]Unhappily, a spectacular failure proved this assumption false. In July of 1978, Canadian workmen, believing spontaneous start-up impossible, left a 250-kW experimental Darrieus unattended overnight with the brake disconnected. As engineers calculated after events had mooted the question, Darrieus turbines indeed start themselves under certain wind conditions. After rotation began, blade flaps responsible for preventing rotor overspeed failed, and the turbine raced unimpeded from its normal 30 rpm. With the brake disconnected, observers could not stop the whirling runaway. At 74 rpm, the location of a mechanical resonance, the blades struck the machine's guy wires, and the unit collapsed. R.J. Templin and R.D. McDonnell, "Summary Report on the Collapse of the Magdelen Islands Wind Turbine" in *Workshop on Economic and Operational Requirements*, pp. 353-365.

[40]Coty, "Mission Analysis: Executive Summary," p. 12.

[41]Robert W. Thresher and Robert E. Wilson, "Characteristics of the Vertical Axis Wind Machine" in Lockheed California Company, "Wind Energy Mission Analysis: Appendix," Burbank, CA, NTIS SAN/1075-1/2 (October 1976), p. 4/5.

Still, vertical-axis systems maintained adherents, and the FWEP hedged its bets by cautiously funding Darrieus development. In 1984 Divone considered the best design for large machines a "toss-up" between the two, even though no American firm had built a Darrieus over 500 kW. With respect to intermediate-sized machines, he predicted that the COE from simpler, easy-to-maintain Darrieus units would temporarily dip below that of the horizontal machines. In flat open terrain, he speculated, the intermediate-sized Darrieus might retain the advantage, but dependence on guy wires for stability made them impractical for use on rough ground. Horizontal machines, Divone thought, would dominate the small sizes.[42] Demonstrating the possibility alternative paths, however, the Canadian government developed Darrieus machines almost exclusively until canceling its alternative energy program in 1985.[43]

Atlases, windpumps and the search for "jet engines"

The FWEP assigned the task of assessing wind resources and developing siting techniques to Pacific Northwest Laboratories (PNL), operated by the Battelle Memorial Institute in Richland, WA, and funded by the DOE. While the former focus led to publication of wind atlases covering large regions of the nation, the latter resulted in handbooks on how best to situate small and large turbines on a given site.[44]

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[42]Divone, "Glimpse at the Future," p. 4.

[43]In 1988, a private consulting firm bought the last large Canadian Darrieus, a 3.6-MW unit located on the Gaspe peninsula, from Canada's state utility, Hydro Quebec. Shawna Vogel, "Wind Power," *Discover* 10 (May 1989), pp. 46-49; "Hawaii's wind turbine delivers smooth power," *New Scientist* 117 (11 February 1988), p. 36. The troubled $37 million turbine has since been down-rated to 2.5 MW. "Vertical Axis Still Attracting Interest," *Windpower Monthly* (July 1993), p. 30. Development of Darrieus turbines continues. FloWind Corp., the world's most successful vertical-axis firm, recently introduced a 300-kW model with an elliptical profile; in addition to the advantages described above, FloWind claims that vertical-axis machines kill fewer birds. "FloWind Installs New Vertical Axis Turbine," *Wind Energy Weekly* (electronic version) 13 (4 April 1994).

[44]Larry L. Wendell, "Wind Resource Assessment Status" in *Workshop on Economic and Operational Requirements*, pp. 83-94; H.L. Wegley, M.M. Orgill and R.L. Drake, *A Siting Handbook for Small Wind Energy Conversion Systems*, PNL, Washington, PNL 2521, UC-60 (May 1978); D.L. Elliot, *et al.*, PNL, *Wind Resource Atlas of the United States* (Golden, CO: Solar Technical Information Program, 1986).

Other FWEP work occurred under the auspices of the U.S. Department of Agriculture (USDA), which tested windpumps and battery-chargers at Bushland Research Station in Texas. Various subcontractors also won awards through Bushland and Rocky Flats to test rural applications of small wind turbines. For instance, a professor at Virginia Polytechnic Institute and State University received $242,000 to explore the use of a 6-kW unit for cooling stored apples.[45]

A final element of the FWEP, overseen by the Solar Energy Research Institute (SERI) in Golden, CO, investigated breakthrough concepts. As the FWEP's Ancona put it in 1979, "we don't want to overlook something like the jet engine."[46] Many of the innovative projects investigated augmented turbines, in which funnels directed wind onto the rotor, or dynamic tip inducers, which consisted of a "slice" of funnel fixed to the tip of each rotor blade. Such features increased power, but raised the weight--and hence the cost of energy--unacceptably.[47]

The FWEP employed relatively few DOE personnel. By 1978, programs and budgets had outstripped DOE hiring activity, and Branch Manager Louis Divone and Program Manager Daniel Ancona managed a budget of $35 million with no help. After Divone's promotion in the early 1980s to oversee all solar electric technologies, Ancona headed the Wind Division as it grew to eighteen people including support staff. Not all of these managers worked out of the DOE's Washington headquarters. In July 1979, as part of an effort to dilute the influence of Washington on the organization, program manager

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[45]Joe Carter, "USDA's wind testing program," *Wind Power Digest* (Spring 1977), pp. 38-40; *Wind Energy Systems Program Summary* (1980), p. 140.

[46]Ancona, "Overview" in "Large Turbine Design," p. 5. The DOE later elevated SERI to national laboratory status, renaming it the National Renewable Energy Laboratory.

[47]Vas (ed.), *Innovative Systems Conference*, *passim*.

George Tennyson opened a DOE Field Office in Albuquerque, NM, to administer activities at Rocky Flats, Sandia and PNL.[48]

A large number of government employees at other agencies devoted some or all of their time to FWEP activities. In the program's heyday in 1979, these included about thirty full-time NASA employees, and fifty others from Lewis Research Center associated in some way with the FWEP. At Rocky Flats, sixty-eight Rockwell International people worked full time on the small-turbine program; these included about twenty-five on testing activities, fifteen with the Field Evaluation Program, and a technical staff. In addition, Sandia's Darrieus research, the USDA's rural systems, SERI's institutional research and innovative systems programs, and PNL's wind resource program occupied varying numbers of government employees.[49]

## PART III: Large turbines

Such activities notwithstanding, many observers cast NASA's large-turbine program as the FWEP's focus. A typical account affirmed in 1982 that Lewis Research Center received over half the FWEP budget "as a consequence of the DOE's emphasis on large-scale wind-generation of electricity."[50] In response to such comments, Divone notes that most data show arbitrary budget structures which changed from year to year, making it inconvenient to pin down the sums going to different size machines. (For examples, see Tables 3 and 4, below.) He also notes that in the early years, the 100-kW MOD-0 test bed received the lion's share of the funding. But Divone estimates that by the late 1970s generic research and small, medium and large machines each received about 25% of the budget.[51]

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[48]George P. Tennyson, "The Federal Wind Energy Program: An Overview" in Vas (ed.), *Innovative Systems Conference*, p. 9, and; Daniel Ancona, FWEP, "Overview" in "Large Turbine Design," p. 8.

[49]U.S. Congress, *Oversight*, pp. 61-62, 102, 106.

[50]Naar, *The New Wind Power*, p. 116.

[51]Divone adds that after the Reagan election, "all bets were off since anything other than research was strictly political and not program directed." Personal correspondence from Divone to Adam Serchuk (19 October 1993).

| TABLE 3: FWEP's FY 1979 authorized expenditures--method I | |
|---|---|
| Development and Technology Improvement | $10.1 million |
| Farm and Rural Systems | $14.8 million |
| Small (kW) Wind Systems | $10.9 million |
| Large (MW) Wind Systems | $19.1 million |
| Large-Scale, Multi-unit Systems | $4.4 million |
| TOTAL operating expenses | $59.3 million |
| Capital equipment | $1.4 million |
| **TOTAL APPROPRIATIONS** | **$60.7 million** |

Data from John R. Justus, *et al.*, "Fact Book on Non-Conventional Energy Technologies," Congressional Research Service, Report No. 79-47 SPR (12 February 1979), p. 195.

| TABLE 4: FWEP's FY 1979 actual expenditures--method II | |
|---|---|
| **1.0 Planning, Management and Analysis** | **$5.0 million** |
| 1.1 Economic Analyses | (non-differentiated) |
| 1.2 Operations and Applications Requirements | |
| 1.3 Institutional and Environmental Analyses | |
| 1.4 Program Development and Planning | |

| | |
|---|---|
| **2.0 Wind Characteristics** | **$4.4 million** |
| 2.1 Wind Energy Prospecting | $1.5 million |
| 2.2 Support for Design and Operations | $0.9 million |
| 2.3 Site Evaluation | $2.0 million |
| **3.0 Technology Development** | **$9.8 million** |
| 3.1 Small Systems Technology | $3.7 million |
| 3.2 Intermediate and Large Systems Technology | $4.5 million |
| 3.3 Evolving Technologies | $0.6 million |
| 3.4 Innovative Concepts | $1.0 million |
| **4.0 Engineering Development** | **$34.0 million** |
| 4.1 Small Systems Development | $8.1 million |
| 4.2 Intermediate Systems Development | $6.0 million |
| 4.3 Large Systems Development | $20.0 million |
| **5.0 Implementation and Market Development** | **$5.0 million** |
| 5.1 Small Systems | $4.7 million |
| 5.2 Intermediate Systems | $0 |
| 5.3 Large Systems | $0 |
| 5.4 User Outreach Program | $0.3 million |
| **All Operating Expenses** | **$58.2 million** |
| Capital Equipment and Construction | $1.4 million |
| **TOTAL EXPENDITURES** | **$60.0 million** |

Data from U.S. Department of Energy, *Wind Energy Systems Program Summary*, NTIS DOE/CS/20097-01 (May 1980), p. 15. Sector Three consists of conceptual design, turbine component design, development of analytic tools and evaluation of innovative concepts. Sector Four consists of designing, fabricating, installing and operating turbines on utility grids, and improving those systems through the use of technological advances. Sector Five includes purchases of turbines for the Field Evaluation Program.

Demonstrating the dicey nature of untangling funding according to size, Program Manager Ancona, in an unofficial calculation, puts the funds allocated for wind technology from FY 1973 to FY 1985 at $391.2 million. He divides this into $202.1 million (52%) for large and intermediate machines, $60.0 million (15%) for small machines, $22.3 million (6%) for Darrieus development, and $106.8 (27%) million for generic R&D.[52] (Note, however, that intermediate machines never constituted an end in themselves, but served as practice for designing larger turbines.) However, while the FWEP may indeed have spent more on large machines, the question of the program's focus implicates not only budgets. The large-turbine element simply manifested greater coherence and vision.

Generational development

Divone's team planned a program of generational development to produce large commercial wind machines. "The first ones probably wouldn't work," he recalls today. "A second generation based on lessons learned might or might not be good enough for niche use, might be reliable, might be cost-effective. It would take a third generation."[53] At that point, the Federal government would back out, leaving industry to make further advances. As the years passed, the FWEP chalked up numerous technical successes, but had less luck meeting economic goals.

In general, Divone limited his team of project managers to decisions concerning broad programmatic strategy, while leaving to Red Robbins and the other NASA engineers the technical decisions concerning, for example, strength of materials or operating parameters. However, as FWEP project manager Dan Ancona recalls, he and his colleagues

[52]Ancona, "Wind Energy Budget: Approx. Technology Allocation," personal document. Note that Ancona's figures do not include funds devoted to non-technological research.

[53]Interview with Divone. See Divone (Chairman), "Commercialization for Large Wind," pp. 5, 23, for an early statement of the generational scenario.

rode herd closely on NASA, chivying them to keep on schedule and on budget. NASA's habit of "low-balling" their first cost estimates and subsequently asking for more money constituted an especially pesky problem. In one episode, the FWEP managers judged during a review of the MOD-2 project that the turbine's weight and projected COE had risen unacceptably. They forced NASA to return to the concept planning stage and appraise new technologies. It delayed them in the early stages, Ancona recalls, but the machine came in on time and at cost.[54]

Actually, the FWEP designed and built two large turbine models even before the "three generations" described by Divone. In 1973, NASA decided to begin its large-turbine program by constructing a 100-kW machine as soon as possible. They chose this "intermediate" size, according to Divone, because "it was as big as we could afford, big enough to get at issues we needed, but not so big that you couldn't scale it down, too."[55] In designing the $850,000 MOD-0 (the hipness of the name is misleading; MOD referred to "model"), NASA closely followed the design principles of its advisor, Ulrich Hutter--specifically, high rotor velocity, low weight, and an aerodynamically-efficient two-bladed rotor featuring pitch control.[56] They installed the machine at Plum Brook Station. The area's low windspeeds--about 10 mph--prevented a convincing demonstration of windpower's economic potential, but, at this stage, NASA considered irrelevant both the cost and quantity of energy generated by the MOD-0. Rather, they built the unit to provide engineering data for future turbines, and to serve as a "test bed" for new components and subsystems.[57]

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[54]Telephone interview with Ancona (28 June 1994).

[55]Interview with Divone. In fact, no-one seems to have scaled down the MOD-0.

[56]Heymann, "Why were the Danes the best?" p. 7. See also Eldridge (ed.), *Second Workshop*, p. 27.

[57]Ronald L. Thomas, "Large Experimental Wind Turbines--Where We Are Now," Lewis Research Center, NASA fiche N76-21683, presented at Third Energy Technology Conference/Exposition at Washington, DC (March 29-31, 1976), p. 2.

In September of 1976, after eighteen months of design and fabrication, a crane lifted the MOD-0 nacelle/rotor assembly to the top of a 100-foot steel-truss tower. The 125-foot rotor sat downwind of the tower, preventing the blades from striking the tower, but also making the rotor pass through the tower's "wind shadow." Considered too heavy for free-yaw operation ("weathercocking"), the 35,000-lb. nacelle and rotor assembly included a yaw motor, which tracked the slow passage of weather fronts, although not rapid shifts in wind direction. From the rotor, a low-speed shaft transferred the low-rpm, high-torque force to a three-stage gearbox, which stepped it up at a ratio of 45:1. A high-speed shaft carried the resulting low-torque, 1800-rpm force to a synchronous alternator by means of a belt system. During initial operation, NASA personnel dumped the generated electricity; subsequently, they ran the turbine in parallel with a small diesel turbine, and finally as an element of the Ohio Edison Company grid.[58]

Unlike Hutter's early 100-kW machine and the Smith-Putnam turbine, the MOD-0's blades did not teeter with changes in wind shear, but were fixed solidly to the hub. This arrangement proved cheaper, although it increased the strain on the blade roots. To regulate rotation at 40 rpm, a hydraulic system in the rotor hub similar to that used in early aircraft adjusted the pitch of the blades according to changes in wind speed. The MOD-0 cut in at winds of 8 mph. Between 8 and 18 mph, it generated power according to wind speed, up to a maximum of 100 kW at 18 mph. Between 18 and 60 mph, the power stayed constant at 100 kW, with the canted blades spilling the excess wind energy. In winds over 60 mph, the computerized control system fully feathered the blades parallel to the wind, and applied the brake.[59]

Where possible, the MOD-0 design incorporated existing technology and off-the-shelf components, such as the steel truss tower, in common use by electric utilities for transmission lines, and the gearbox. The rotor proved the primary exception; with custom

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[58]Thomas, *et al.*, "Plans and Status," pp. 3-4.

[59]*Ibid.*

blades by Lockheed, the rotor comprised half of the MOD-0's total cost. (Another quarter came from the tower and foundation.) NASA engineers attributed the exorbitant $5000/kW capacity cost to necessary over-design and safety margins. They could shave these tolerances in hypothetical later editions of the design and lower costs to perhaps $1000/kW, they surmised, making the MOD-0 roughly competitive with diesel generators in areas with high fuel costs.[60]

The MOD-0 experienced only a few serious problems. Most disturbing, the blade roots suffered much larger bending moments (*i.e.*, a tendency to rotate around the point of stress, in this case the joint between the blade and the hub) than expected. To calculate the loads on the blades, NASA had arranged for the adaptation of a computer program called the Modular Stability Derivative Program (MOSTAB), originally developed in 1970 for the U.S. Army's use in analyzing helicopter rotors. The MOSTAB-WT model predicted cyclic bending moments on the blades of -60,000 to +4000 foot-pounds, under the assumption that the tower retarded the wind by 24%. To NASA's surprise, loads during initial operation measured between -120,000 and +7000 foot-pounds, a range predicted by MOSTAB only if one assumed that the tower retarded the wind by 93%. The engineers modified the computer models, but they also streamlined the tower and replaced the non-aerodynamic staircase with an elevator.[61]

The NASA team immediately planned tests on tower turbulence. NASA also used the MOD-0 to investigate turbine-generated television interference and rotor noise, and the effect of upstream obstacles on the rotor in order to determine future turbine spacing requirements. Use of the MOD-0 as a test bed included experiments with a one-bladed rotor, a rotor with blades constructed of cloth-covered wood ribs, free-yaw operation (*i.e.*, operation without a yaw motor, during which the nacelle swings freely with the wind), and

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[60]*Ibid.*, pp. 4-5.

[61]Thomas, "Where We Are Now," p. 3; Thomas, *et al.*, "Plans and Status," p. 7; Robert E. Donham, Lockheed California Company, "100-kW Hingeless Metal Wind Turbine Blade Design, Analysis, and Fabrication Considerations" in Eldridge (ed.), *Second Workshop*, pp. 210-211.

comparisons of upwind and downwind configurations. NASA even set the entire structure on leaf springs to simulate "soft" tower designs, in which a flexible tower vibrates at lower frequencies than the speed of the rotor.[62]

Interconnection with electric utilities

In 1974, as the MOD-0 project gathered steam, the NSF began soliciting utility participation in its wind program through direct contacts and advertisements in various industry publications. This second phase of the large turbine effort aimed at obtaining "early wind turbine operation and performance data while gaining initial experience in the operation of large, horizontal axis wind turbines in typical utility environments."[63] FWEP managers hoped to demonstrate to utilities that wind turbines would not introduce frequency fluctuations into their grids, and that wind turbines could safely operate unattended. They would serve to gauge public acceptance as well. Rather than designing a new machine, NASA accelerated the program by upgrading the 100-kW MOD-0 design to 200 kW; they called the "new" units the MOD-0A, perhaps to stress that the MOD-0As did not count as a "real" generation.[64]

Thirty utilities asked to host a wind turbine in response to the solicitation. (After some utilities complained that they had not received requests to participate, the FWEP enlarged the pool of candidate sites to nearly seventy.) The NSF and NASA provided the turbine itself, as well as project support, guidance and data processing. Candidates supplied a year of meteorological data taken with NASA instruments, and, if selected to host a turbine, prepared the site and provided personnel to run the turbine during a two-year

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[62]Divone, "Overview," p. 4.

[63]Thomas, "Where We are Now," p. 3.

[64]*Ibid.*, pp. 3-4.

operational phase.[65] The FWEP chose sites at Clayton, NM, on Block Island, RI, on Culebra Island in Puerto Rico and on Oahu, HI.

The FWEP chose the Clayton site primarily because of its high fuel costs and limited supply options. The Town of Clayton Light and Water Plant served 3000 customers by burning natural gas and diesel fuel; purchasing additional power would have required construction of sixty miles of transmission line. Windpower constituted an option equally needed by the island sites, which depended on expensive imported oil. Puerto Rico had requested NASA's help in assessing its wind resources even before the embargo, and in 1974 the City of Honolulu had become the first local government in the country to fund its own study of alternative energy.[66]

NASA engineers fabricated the first MOD-0A at the Lewis Research Center, but awarded a contract for construction and installation of the remainder to the Westinghouse Electric Corporation, a diversified firm with experience manufacturing electric generating equipment. After installation in November of 1977 and preliminary testing, Federal engineers turned the first unit over to the Clayton utility in March of the following year. The Clayton MOD-0A experienced minor bugs. For example, NASA had feared that icy blades would impede performance; they found that while centrifugal force and blade flexing prevented icing, the chunks flung off the whirling blades (whose tips reached speeds of 260 feet per second) posed a public hazard. They outfitted the blades with an aircraft-type sensor to warn of ice build-up, and opted not to operate the turbine during icy weather. The desert summer posed problems, too, but the addition of a fan to the computerized control

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[65]Thomas, *et al.*, "Plans and Status," pp. 6-7; Thomas, "Where We Are Now," pp. 8-9; Interview with Grant Ayers, Jr., Vice President for Operations and Engineering, Blue Ridge Electric Membership Corporation, in Boone, NC (11 April 1994).

[66]"Hawaii Eyes Windmills as Source of Energy," *The Washington Post* (26 November 1974), p. A6.

system dissipated the heat which had triggered false shut-downs, and air filters removed the grit that permeated the control building.[67]

Unfortunately, like its predecessor in Sandusky, the Clayton MOD-0A suffered an alarming build-up of stress in its Lockheed-built blades. In March, Clayton personnel noted a missing fastener near a blade root, and a May inspection revealed more loose fasteners. After receiving reports of "loud creaking noises" from Clayton, and finding minute cracks in the blades' aluminum skins, NASA program managers shipped the blades back to Lewis for repair. There, engineers attributed the stress to the pitch-control system which, they believed, rotated the blades into full-feather position too quickly when it became necessary to halt the rotor in high winds. They reduced the feather rate, redesigned the blade root, added a sensor or two, and by September of 1978 they had returned the MOD-0A to action.[68] Eventually, in a search for a cheaper but equally lightweight alternative to Lockheed's aluminum blades, NASA fitted the MOD-0As with experimental fiberglass and laminated wood-epoxy blades.

Discounting shutdowns caused by the problems described above, on average the Clayton machine produced 91.8 kW. The utility appeared to keep higher than usual spinning reserves to allow for the wind's variability, but momentary oscillations proved too fast to trip the controls of the diesel generators, allowing maintenance of synchronism. The other three MOD-0As posted equally satisfactory records, and in July of 1978 NASA declared the project a success and ended it. The Oahu machine achieved a capacity factor of 48% in its final months of operation, prompting the Hawaiian Electric Company to pursue windpower seriously. According to Divone, "the most important contribution of the four MOD-0As was that they produced the first visible evidence that wind turbines, while not yet

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[67]J.C. Glasgow and W.H. Robbins, "Utility Operational Experience on the NASA/DOE MOD-0A 200-kW Wind Turbine," presented at the Sixth Energy Technology Conference in Washington, DC, NASA fiche N79-20494 (26-28 February 1979), pp. 6-8.

[68]Glasgow and Robbins, "Experience on the MOD-0A," pp. 6-7. According to Robbins, Lockheed had over-machined the blades during fabrication. "NASA Discovers Cracks in Clayton Mill: Plum Brook Blades Sent as Replacement," *Solar Energy Intelligence Report* 4 (3 July 1978), p. 198.

cost effective, could be successfully integrated into a utility's normal operation and could produce high-quality AC power of value to that utility."[69]

Cost of energy

By the late 1970s, wind machines' COE approached competitiveness in sites with high fuel costs and limited energy supply options. The MOD-0As' lifetime COE lay around 21 cents/kWh, compared to between 9 and 21 cents/kWh for remote diesel generators, even though NASA had intended the MOD-0As to explore utility interconnection issues, rather than to produce competitively-priced energy. FWEP planners hoped that the cost of energy of the next generation of turbines, the MOD-1 (described in detail in Chapter Six), would approach the cost to utilities of generating power, which in 1977 lay between 0.7 and 3.2 cents/kWh. In 1976, NASA reported that early design studies for the MOD-1 indicated a COE of 1.7 to 2.0 cents/kWh for mature (*i.e.*, produced at a rate of 100 per year) versions. These forecasts proved rather optimistic.[70]

In 1978, Divone affirmed that "because of the mix of conventional power plant types in the typical utility, and applying constant loss-of-load and reserve requirements, a cost goal of 1-2 cents/kWh must be reached to obtain [a] widespread market."[71] In 1980, however, Robbins and his NASA team reported unhappily that, at about 10 cents/kWh, the prototype MOD-1 was "not competitive."[72] Mature versions of the MOD-1, this report speculated, would probably demonstrate COE a little above 5 cents/kWh. At this price, the NASA engineers surmised, some utilities would still show interest in windpower, but the FWEP had already turned hopefully toward the second-generation MOD-2 (described in Chapter Seven). NASA expected initial versions of the MOD-2 to generate electricity at 5-8 cents/kWh, but

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[69]Divone, "Evolution," in Spera (ed.), *Wind Turbine Technology*, p. 117.

[70]Thomas, "Where We Are Now," p. 9.

[71]Divone (Chairman), "Commercialization Strategy for Large Wind," p. 8.

[72]Robbins, Thomas and Baldwin, "Large Wind Turbines," p. 8.

at 2 cents/kWh, the most optimistic COE projected for mature versions of the MOD-2, NASA expected nearly all utilities to evince interest.[73]

Shortly thereafter, the FWEP requested proposals for the manufacture of third-generation, advanced turbines, specifically a large MOD-3 and an intermediate MOD-4. The request stipulated a COE of 1-2 cents/kWh. To the program managers' dismay, while they received some responses, few manufacturers accepted the challenge of meeting the target COE. Westinghouse, the only firm with experience in intermediate-sized turbines, declined to submit a proposal at all, protesting that the cost goals had "no chance of being achieved."[74] The FWEP canceled the MOD-3 and MOD-4, and in 1979 the DOE's request to Congress for the following year's budget authorization elevated the cost target for future machines to "3 cents/kW or less for quantity production."[75] In 1980 Divone and the NASA engineers began reporting it as 2-4 cents/kWh.[76] In 1994, turbine manufacturers see 5 cents/kWh as their target; even given inflation, this figure remains well above early FWEP goals.

Small turbines seemed even farther from viable economic performance. In 1978, Divone reported that the median COE for a turbine between 1 and 15 kW at a 12-mph site fell around 16 cents/kWh.[77] Other estimates placed it between 11 and 26 cents/kWh, almost competitive with remote diesel power in locations such as Alaska, but far from

[73]Divone (Chairman), "Commercialization Strategy for Large Wind," pp. 5, 8.

[74]Testimony of D.K. Ward, General Manager of Westinghouse Special Services Division, in U.S. Congress, *Oversight*, p. 144.

[75]U.S. Congress, House of Representatives, Committee on Science and Technology, *1980 Department of Energy Authorization*, No. 1, Vol. I, 96th Congress, 1st Session (8 February 1979), p. 283.

[76]1980 prices given in terms of 1977 dollars. For change in cost goals, see, for instance: Robbins, *et al.*, "A Utility Option," pp. 7-9, and; Tennyson, "An Overview" in Vas (ed.), *Innovative Systems Conference*, p. 3.

[77]Divone, "Recent Developments," p. A3/21; Divone (Chairman), "Commercialization Strategy for Small Turbines," p. 11.

normal residential and commercial rates.[78] Demand charges threatened in some cases to double the effective COE from residential wind turbines using utility back-up power.

Environmental Issues

While the MOD-0As achieved reasonable technical success, they provoked concerns over potential environmental problems. Windmills had little apparent impact on the plants, animals and microclimate that many people considered "the environment," but the danger posed by swiftly-turning blades for night-flying or soaring birds provided an important exception. At least one environmental group reportedly had concerns in this area, but Divone assured his audiences that the possibility of bird strikes "appeared minimum." Advocates of windpower pointed out that turbines posed a far lower threat to the environment than alternative sources of energy such as nuclear power plants.[79]

Nevertheless, by 1980 reasons existed to doubt Stewart Udall's 1971 claim that windmills had "zero environmental impact."[80] Since then, activists had stretched the definition of "the environment" to include "worldly" concerns that affected everyday human comfort, and the interaction between human beings and wind machines gave rise to prickly issues. Noise provided one example. Industry insiders considered the level of noise produced by wind machines acceptable, although occasionally labeling this or that model "a real screamer." As to the possibility of public annoyance due to generation of very low frequency sounds, one insider joshed that "it bothers the earthworms."[81] Still, NASA worried. Another issue concerned visual impact. While NASA reported that the community of Clayton had expressed satisfaction with its conspicuous neighbor, manufacturers fretted

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[78]Justus *et al.*, "Fact Book," p. 189.

[79]The environmental group is referred to, but not named, in "Large Wind Energy Focus Group Results," prepared for the Department of Energy by Market Facts, Washington, DC, NTIS fiche DOE/TIC-10038 (August 1978), p. 23. See also Glasgow and Robbins, "Utility Experience on the MOD-0A," p. 8, and; Divone, "Overview," p. 7.

[80]Udall, "Turned On by Windmills," p. 27.

[81]"Large Wind Focus Group," pp. 22-23.

that the public might react adversely to the erection in scenic locales of great numbers of wind turbines the size of 35-story buildings.[82] Land-use conflicts also threatened to hamper windpower development.

One problem constituted an immediate source of concern. The spinning metal blades of the big turbines interfered with television reception--a shortcoming guaranteed to enrage even those Americans normally unlikely to ally themselves with environmentalists. Depending on a variety of factors, televisions up to two miles from the turbine suffered what NASA called "the jitters," rhythmic flashes in time with the turbines' rotating blades. On Block Island, the DOE finally installed a cable television system to soothe the community, but that solution proved rather costly. Fiberglass blades reduced the interference, but did not eliminate it.[83]

Murky local and state laws constituted another barrier to windpower development. Ironically, in addition to the suitability of wind turbines to building codes and zoning regulations, windpower proponents confronted the very laws passed partly in response to the "conventional" power industry. A study performed by the JBF Corporation, a consulting firm, noted that erection of wind equipment would trigger many states' requirements for environmental impact statements, mandated by the National Environmental Policy Act of 1970.[84]

The FWEP took seriously these troubling characteristics of windpower. In 1976, the University of Michigan received funds that ultimately totalled $316,000 to explore broadcast

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[82]See the testimony of J. Robert Maxwell, Director of Solar Programs in Westinghouse's Advanced Energy Systems Division, in U.S. Congress, *Oversight*, p. 176.

[83]"Wind Power for Block Island," video produced for the DOE and SERI by the University of Michigan Media Resources Center (no date).

[84]Kornreich and Richard J. Kottler, Jr., "Environmental Issues Assessment" in *Economic and Operational Requirements*, pp. 105-109.

interference by wind machines.[85] SERI received a similar amount to examine turbines' noise characteristics and to study the environmental impacts of small units, including air and water emissions from equipment fabrication, noise and television interference, and the relationship between turbine design and visual impact.[86]

Policy-makers had begun to tread carefully. An environmental movement able to halt the construction of powerplants and hydroelectric dams warranted wary respect. One consultant, referring to a group that had succeeded in blocking the Seabrook nuclear plant in Massachusetts, cautioned that "we may find instead of a Clam Shell Alliance we have a Pine Cone Alliance that doesn't want large wind turbines in remote areas on mountains tops and it just happens that is where the good sites are."[87] And, as a 1977 report cynically warned, "human nature being what it is, people will want the benefits of cheaper, more plentiful power as long as the wind generator is in the other fellow's backyard."[88] Equally important, while some electric utilities perceived alternative energy as a way to burnish their public image, they shied from having to file yet another EIS, or to defend a decision that deprived local homes of the prime-time sitcoms.

## Conclusion: The View in Hindsight

Hindsight often distinguishes only the most dramatic features of a landscape. Viewing the Federal Wind Energy Program as it finishes its second decade, one tends to focus on the spectacular and often troubled large turbines. Contrary to accounts which depict the FWEP as a large-turbine effort, the program investigated small, innovative and vertical-axis turbines, as well as windpumps. It explored institutional issues involved in windpower commercialization, and it performed other activities such as wind resource

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[85]DOE, *Wind Energy Program Summary* (1978), p. 23.

[86]DOE, *Wind Energy Program Summary* (1980), pp. 61-64.

[87]Testimony of Edward E. Johanson, Vice President for Research and Engineering, JBF Scientific Corp., in U.S. Congress, *Wind Energy Systems Act*, p. 60.

[88]Kaman, "Design Study," p. 35.

mapping. Tables 3 and 4 demonstrate that these program areas received substantial funding, and they met varying success throughout the 1970s.

Nevertheless, the large-turbine program, managed by NASA's Lewis Research Center, received somewhat more generous funding and the bulk of media and public attention. These machines produced by giant aerospace corporations flew rotors up to 320 feet in diameter, and exceeded by many hundreds of times the capacity of the old aerogenerators of the 1920s. The heart and soul of the FWEP consisted of a vision of thousands of turbines 2 to 4 MW in capacity. Purchased by utilities, grouped into large "farms," and connected to the existing grid, the Federal government hoped that these machines would support conventional generating facilities. Even at the time, the Federal giants captured the imagination of the public, the media, and perhaps even FWEP administrators as other aspects of the program did not.

Ultimately, the FWEP strived to produce a technology capable of significantly reducing fossil fuel imports as soon as possible; FWEP managers believed massive quantities of large utility-owned turbines would be capable of doing so most effectively. Other aspects of wind research seemed tacked on to the program as an afterthought to placate those people who believed that technological decisions should shape American society. The FWEP represented an uneasy amalgam, but no doubt existed that its managers prized the large machines as the thoroughbreds of the FWEP stable. As the 1970s drew to a close, the program seemed poised to use these engineering marvels in the pursuit of its goals.

# CHAPTER SIX
# The High-water Mark

## Introduction: A Positive Outlook for Windpower

In May of 1979, the FWEP's George Tennyson outlined for a wind conference what he called the "energy quadrangle." Four forces shaped the outlook for alternative energy, Tennyson expounded. Affecting prospects negatively, many voters seemed disgusted with high taxes and government spending. Tennyson noted that Californians had recently approved a referendum slashing real estate taxes, which funded programs including the state's ambitious windpower research. The success of California's "Proposition Thirteen" kindled a national "tax revolt," and by late 1979 thirty-seven states had ordered cuts totalling many billions of dollars.[1] The empowerment of fiscal conservatives, Tennyson conceded, made legislators chary of spending money on such "frivolities" as windpower. But on a more positive note, the oil supply problem, President Carter's determination to allow domestic oil prices to ascend to the world market level, and the 1979 accident at the Three-Mile Island nuclear reactor all made alternative energy research seem like a sound investment. While cautioning against viewing the Federal government as an easy touch, Tennyson insisted that conditions, for the moment, favored wind.[2]

All told, Divone and his crew at the FWEP had reasons for optimism. The Federal program represented a diverse, robust technical program incorporating small innovators as well as large diversified corporations. The small-turbine program harbored nagging problems, but numerous studies showed that windpower's real economic potential lay in large turbines generating power for utilities. Although the large turbines' cost of energy

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[1]Deborah Rankin, "The Effects of Proposition 13," *The New York Times* (23 October 1979), p. D2; John Herbers, "Nationwide Revolt on Taxes Showing No Sign of Abating," *The New York Times* (5 August 1979), pp. 1, 38.

[2]Tennyson, "Overview" in Vas (ed.), *Innovative Systems Conference*, pp. 1-2.

hovered above the FWEP's targets, improving technology inspired hope that three generations of development would bring economic viability.

Both the executive and legislative branches of the Federal government endorsed windpower. President Carter had requested $87 million for windpower in FY 1981, and Congress, continuing a seven-year trend of rising wind budgets, showed every sign of approving the figure. Legislation favored windpower. Most important, the Wind Energy Systems Act of 1980 authorized massive subsidies for purchases of wind equipment, thus responding to the riddle posed by Savino seven years earlier at the first wind workshop: how to match technology push with market pull? And while the environmental movement in some ways threatened an energy option it had previously championed, it still represented a source of popular support. In any case, the FWEP seemed able to handle possible environmental conflicts.

In explaining his optimism to an international symposium (actually, a descendent of Savino's first windpower workshop in 1973), Divone broadcast his confidence that windpower could supply 800 MW to the national energy economy by 1988:

> If the machines can, in fact, be developed and debugged so that they're reliable (and there's no reason why they can't be), then I think we're going to see wind grow... I think that the next two years are going to be very difficult and also very exciting years.[3]

Unfortunately, the difficulty of the coming years exceeded anything Divone anticipated.

Between 1979 and 1981, the Federal windpower initiative reached its high-water mark, crested, and began to ebb. Although many supporters attributed the demise of Federal windpower in the 1980s to falling oil prices and Republican antipathy to renewable energy, this chapter shows that the FWEP stumbled even during the final year of Jimmy Carter's administration. Problems in the field forced re-evaluation of the FWEP's quickstep pace of technology development. Meanwhile, Congress, prodded by calls for decisive energy action,

[3]Divone, "Current Perspective," p. 7.

seized the initiative for long-range windpower planning by passing the ambitious Wind Energy Systems Act--a victory for windpower, but a clear expression of disapproval for DOE management. These problems set the stage for the troubles of the new decade.

## PART I: Technical difficulties--The Field Evaluation Program

In June of 1980, Divone addressed a meeting of the American Wind Energy Association. His audience included small-turbine manufacturers using Federal funds to develop their own machines, as well as representatives of larger firms working under direct FWEP supervision. Divone's remarks, especially those concerning the Field Evaluation Program's purchases of small turbines, contrasted sharply with his usual earnest and upbeat speeches, and they merit extensive reproduction. Their bitter counterpoint to his accustomed style illuminates the evaporation of political support in the coming Reagan years, which one might otherwise attribute solely to ideological opposition or partisan politics.[4]

To predict windpower's future, Divone mused, perhaps one should start with the recent past and extrapolate. For years, he reminded the conferees, the wind industry had lobbied for Federal help in establishing a market. They had declared themselves ready to go commercial, frustrated by a lack of public awareness and unfair institutional barriers. The government had come through, Divone pointed out. President Carter's proposed budget for FY 1981 included $87.0 million for wind, 30% over the previous year's allotment. Over the years, industry had received substantial contracts for research and development. To encourage investment in wind equipment, Congress had created and subsequently raised the wind investment tax credit. To provide an initial market for small turbines, as well as to collect data and showcase the industry's wares, the Field Evaluation Program had begun to make purchases, about ten per manufacturer.

And with what result, Divone asked? Manufacturers of machines purchased for the Field Evaluation Program had racked up abysmal delivery records, often running six months

[4]The following passages are drawn from Divone, "Perspectives on the Future of Wind Energy," presented at the AWEA Conference in Pittsburgh, PA (11 June 1980).

or more behind schedule. Operation records were even worse. To make his point, Divone gave examples:

> I'll just randomly run down a few. Tail failure leading to blade failure--complete replacement required. Hub loosened up, blades cracked--major gearbox damage. Rotor failure--major gearbox damage--major rework, then gearbox failed again. Electrical damage due to unlabeled switch and unclear manufacturer's directions... Pitch control failed--still putting out only 10-20% of predicted power. Control system failed twice--machine doesn't run in right direction. Blade failure--destroyed itself in 40-mph wind...

"These," he asked rhetorically, "are supposed to be commercial products?"

Divone emphasized that these mishaps had not involved prototypes installed in Rocky Flats' harsh conditions, but highly visible field evaluations of machines proclaimed "commercially available" by their manufacturers. Rather than simply too flimsy for the operating environment--although many did lack the necessary robustness--the turbines often arrived mis-wired, incorrectly adjusted, with instructions either missing or unintelligible. Operators had found spare parts and maintenance scarce or nonexistent. Divone bluntly told his audience that "wind technology is in a transition stage--not really commercial yet."

Divone lambasted the industry's representatives for jeopardizing their hard-won political capital by such a poor public showing:

> If credibility is lost, and an image of poor reliability is established, it will take 10 years to recover in the market place... Political support can be very transient... I prefer not to sit in front of some Congressional committee next year and try to explain what we are doing to protect the consumer from being hurt financially and physically.

Divone also made it clear that he spoke not only of small manufacturers producing small machines:

> We've had a lot of complaints sometimes about the "aerospace" influence, but I haven't always seen aerospace quality. There are equivalent horror stories about intermediate and large machines and cold solder joints, repetitive failure of hydraulic systems and bearings and controls and on and on. I'm not sure yet how we're going to handle this problem or what's going to be done... I'm getting just a little bit tired and a bit angry, but I really feel that wind energy as a whole has come too far to take the risk of failure now.

Divone announced that the FWEP would suspend the disastrous Field Evaluation program[5] and back off from advanced system development or commercialization. In FY 1981 they would fund work to increase reliability. Divone concluded his address by emphasizing the legislative support for windpower recently shown by Federal and state government. Windpower, he insisted, stood on the verge of political success.

## PART II: Technical Difficulties--The MOD-1

While the small-turbine industry tried to put on a respectable showing in the Field Evaluation Program, NASA's large-turbine effort had problems with the heralded first-generation MOD-1, as well. Like the Field Evaluation Program, the MOD-1 demonstrated that planners had underestimated the difficulty of turbine design and the complexity of the wind environment. It also raised serious questions about the management and operation of the FWEP.

By early 1976, well before the rotor of the experimental MOD-0 first turned, NASA initiated plans for a 1500-kW turbine with a rotor diameter of 200 feet. NASA planned to install one MOD-1 by December 1977 and, if funding permitted, another by June 1978. The project aimed to "involve industry and users in the design and implementation of optimized wind turbines that are capable of supplying electrical power at costs competitive with conventional power sources."[6] Project objectives included provision of performance data for a megawatt-scale turbine, demonstration of safe unattended operation, involvement of a utility as a user and operator, involvement of industry in design, fabrication and installation, and assessment of public reaction.[7] In July of 1976, the DOE approved the MOD-1, and the FWEP awarded a contract to General Electric.

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[5]In the end, the Field Evaluation Program installed only about 40 of the planned 106 turbines before official discontinuation in 1983, and many of those failed to perform acceptably. Divone, "Evolution" in Spera (ed.), *Wind Turbine Technology*, p. 92.

[6]Thomas, "Where We Are Now," pp. 2, 4.

[7]John L. Collins and Richard K. Shaltens, NASA, and Richard H. Poor and Robert S. Barton, GE, "Experience and Assessment of the DOE-NASA MOD-1 2000-kilowatt Wind Turbine at Boone, North Carolina," NTIS DOE-NASA-20366-2 (April 1982), p. 25.

Although NASA often presented the MOD-1 design as the result of the Kaman and GE Design Studies,[8] the actual contract specifications called for a 15:1 scale-up of the MOD-0A experimental turbine, which the FWEP had designed long before Kaman and GE described the optimum size and configuration of a wind machine.[9] Originally intended to generate 1500 kW in 25.5-mph winds, the 655,000-lb. MOD-1 flew a 200-foot rotor downwind of a steel truss tower. The rigid rotor (*i.e.*, no teeter) stood 140 feet off the ground, and used pitch-control to maintain constant rotation at about 35 rpm. A GE synchronous generator turning at 1800 rpm provided power for a utility intertie.[10]

The only major innovation planned for the MOD-1 concerned the rotor. Hamilton Standard, subcontracted by GE, had proposed filament-wound, glass-fiber reinforced plastic blades, whose fabrication they in turn subcontracted to the Allegheny Ballistics Laboratory. After a somewhat mysterious failure during static testing of this innovative component, which would have been the longest fiberglass structure ever wound, GE terminated its contract with Hamilton Standard in the summer of 1977 and ordered a back-up design for a metal blade from Lockheed. One member of Lockheed's wind R&D group suggested that NASA and GE had realized that huge fiberglass blades represented "a big step in the state of the art and that it wasn't right around the corner."[11] GE eventually commissioned Boeing to construct two blades composed of a welded-steel leading edge and a polyurethane trailing edge, covered with steel skins.

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[8]For example, in Thomas, "Where We Are Now," pp. 4-6.

[9]Testimony of Reinhold J. Barchet, Manager of Wind Energy Programs for GE, in U.S. Congress, *Oversight*, p. 118.

[10]Poor, "MOD-1 Wind Turbine Generator Program Status Report," in *Economic and Operational Requirements*, pp. 248-282.

[11]Michael Dubey, Lockheed California Company, quoted in "Perspectives," *Wind Energy Digest* (Summer 1977), p. 40. However, few official accounts refer to the failure. For example, a 1979 DOE conference featured a paper on large turbines by NASA's David Spera. Spera appears on the conference schedule, and fielded questions from the floor, including one concerning "damage to the structure of the fiberglass blade." However, the published conference proceedings replaced his paper with one by Robbins and Thomas, which made no mention of the fiberglass blade. See Vas (ed.), *Innovative Systems Conference*, p. 229. For a rare but sketchy account, see "Executive Summary: MOD-1 Wind Turbine Generator Analysis and Design Report," General Electric Company: Space Division, NASA fiche N80-11558 (March 1979), p. 1/2.

Equally troubling, the cost of the MOD-1 project soared during fabrication. Although NASA's Thomas had hoped in 1976 for cost-competitive energy from the machine,[12] by mid-1979 GE projected a COE of 18 cents/kWh, far higher than competing energy sources. The firm estimated capital costs (for a second unit) at $2900/kW. The MOD-1 itself finally cost $6 million, and the whole project cost about $30 million, almost double earlier forecasts.[13]

As fabrication continued, GE struggled to hold the line by instituting design changes. To cover the new Boeing blades, they requested heavy but cheap stainless steel, rather than expensive lightweight aluminum, which Lockheed had used in the MOD-0As. In addition, GE lowered blade-tip clearance from 50 to 35 feet to reduce the tower height, reduced cut-out speed from 50 to 35 mph to lower drive-train tolerances, and increased rated generator power from 1500 to 2000 kW (although the blades limited the turbine to 1818 kW).[14] In September 1978, the MOD-1, minus the delayed blades, began its journey to Boone, NC, where it would contribute power to the Blue Ridge Electrical Membership Corporation's (BREMCo) distribution grid. By then, NASA had given up hope that GE's design could generate electricity at an acceptable cost. In 1980, Red Robbins, chief of the wind energy office at the Lewis Research Center, frankly classed the MOD-1 as "not competitive."[15]

Howard's Knob

BREMCo served some 36,000 customers in seven counties of western North Carolina. Primarily a distribution cooperative, the utility maintained a tiny hydroelectric plant but purchased most of its electricity from the Duke Power Company. Prior to the oil embargo of 1973, BREMCo's demand for power had grown at a steady annual rate of 8 to

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[12]Thomas, "Where We Are Now," p. 4.

[13]Poor, "The General Electric MOD-1 Wind Turbine Generator Program" in "Large Wind Turbine Design Characteristics and R&D Requirements," NASA fiches N80-16453 thru N80-16482, papers from a workshop at Lewis Research Center in Cleveland, OH (24-26 April 1979)," p. 42.

[14]Poor, "The MOD-1 Program" in "Large Turbine Design Characteristics," p. 41.

[15]Robbins, Thomas and Baldwin, "Large Wind Turbines," p. 8.

10%, but since then it had fallen to 3%; by the late 1970s, BREMCo satisfied a modest peak demand of 136 MW. General Manager Cecil Vivarette proudly noted that due to members' conservation efforts, the cooperative had avoided construction of a new transmission line, and he encouraged construction of independent power projects. The company prided itself on its innovative spirit, and it sought opportunities to diversify its supply--and also to reduce dependence on Duke Power.[16]

To house the machine during its two-year operational test, BREMCo chose a site on nearby Howard's Knob, a 4420-foot promontory overlooking the college town of Boone. Throughout early 1979, local interest grew as the tower on the knob, clearly visible from downtown, rose higher. Students at Appalachian State University and Boone's sizable hippie population particularly approved of the project, but "townies" joined the fun as well. Children sported "Windpower" buttons, which BREMCo handed out by the thousands, and Joe Miller, the local druggist, sold--or, at least, offered for sale--cans of air "sliced by the world's largest windmill." In April of 1979, an over-sized flatbed truck finally reached Boone with the blades, each one prominently stencilled "Department of Energy--NASA Wind Turbine Generator Blade, designed and built by *The Boeing Co.,* Seattle, Washington, for installation by *The General Electric Co.*, in Boone, North Carolina." Much of the community turned out to see them climb tortuous Cherry Lane up to Howard's Knob.[17]

The community turned out again on July 11, 1979, for a street party celebrating the MOD-1's dedication. Cloggers demonstrated traditional mountain dances, a barbershop quartet performed, and druggist Joe Miller hawked wooden MOD-1 model kits. Journalists, including those from television's "Today Show," wandered the crowd, pouncing on "human interest" angles. A journalism class from the university, producing its own video account,

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[16]Interview with Ayers; remarks of Cecil Vivarette, General Manager, BREMCo, in "Windmill Dedication," video produced by AV Services, Appalachian State University (11 July 1979).

[17]Interview with Robert Bumgarner, BREMCo's Watauga District Manager, in Boone, NC (11 April 1994); some observations from Bumgarner's personal slide collection. See news footage from UNC-TV, available on video through Appalachian State's University Archive.

spoofed the professionals by donning plaid jackets and serious demeanors. A group chanted "No nukes," and displayed for the cameras a banner which advised the President: "Jimmy C., use your cranium; make power from wind, not uranium." John F. McCarthy, Director of NASA's Lewis Research Center, described the MOD-1 as "sophisticated aerospace technology... being applied to real problems with real results" to a crowd well aware of the passage overhead of another NASA project, Skylab, spiraling that day toward its unfortunate end. A representative of Governor John B. Hunt praised the cooperation between industry and government, and, after the obligatory reference to Don Quixote, he characterized the MOD-1 as "tilting its lance at the OPEC cartel, [which] cannot be allowed to influence and dominate the way we live." In short, everybody had a lovely time, partying and pursuing their various agendas. In the following months, Boonites waited eagerly for the turbine to begin full-time operation.[18]

Both NASA and the news media assiduously tracked public reaction to the project. One particular episode demonstrates their solicitude. After NASA and GE engineers began testing the turbine, a student named John Fairweather shot a gag film about a cult called the "Whooshies," who supposedly belonged to the Pan Galactic Unified Church and Restaurant, and prayed to the mighty machine. "He thought it would be funny," recalls Professor Joseph Murphy. The local *Mountain Times* heard of the Whooshies and ran a story, subsequently picked up by the *Winston-Salem Journal.* Later, the Associated Press got hold of it, and distributed it to journals and newspapers around the world. Unfortunately, somewhere along the line, the details blurred, and the story reached General Electric as an account of an organized protest against the MOD-1. Immediately, GE contacted the Chancellor of Appalachian State to protest the protest; the chancellor called Murphy, who called BREMCo's Watauga District Manager, Robert Bumgarner, who assured GE that the Whooshies did not really exist.[19]

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[18]Joseph Murphy, *et al.*, "Windpower," video (1979); "Windmill Dedication," video, and; Lloyd Karnes, "The mill: It's still being tested, officials say," *Johnson City Press Chronicle* (8 October 1979), p. 1.

[19]Interview with Professor Joseph Murphy, Department of Curriculum and Instruction, Appalachian State University, Boone, NC (11 April 1994).

GE never relinquished control of the turbine to BREMCo's engineers. Bumgarner believes today that NASA intended the MOD-1 to produce data, not energy. BREMCo Vice President Grant Ayers, who shared responsibility with Bumgarner for BREMCo's end of the project, reminisced that GE's handlers never left the MOD-1

> to run alone, although it was designed to do so. They had a special van that sat there, special charts of the stresses... Looking back at it, I began to appreciate that this was totally a research machine. It was not a machine that they were intending to be a production machine...[20]

Bumgarner and Ayers doubt that BREMCo correctly understood the research nature of the project until later.[21]

The public certainly looked forward to using clean, cheap energy from the MOD-1. According to Ayers,

> ...there was a lot of expectation built up in people's minds that this was really going to be a generation machine. Most every time you talked about it, people wanted to know "how much power? How many homes is it going to generate power for?" It was hard to get away from that question.[22]

NASA's publicity reinforced the common belief that the MOD-1 would serve the community as a powerplant. The agency continually described the machine as large enough "to meet the needs of about 500 homes in and around Boone,"[23] and the figure cropped up in articles and interviews. Most participants in the Dedication Day bash seem to have interpreted GE's translation of the turbine's capacity into "human" terms as an indication that it would actually serve that many households.[24] In NASA's defense, a spokesperson at

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[20]Interview with Ayers.

[21]Interview with Bumgarner. In support of his hypothesis, Bumgarner recalls that GE never trained BREMCo personnel to operate the MOD-1, although they may have intended to do so later on. However, the University's student newspaper reported that BREMCo technicians did receive training during the MOD-1's nightly shutdowns. John Kirk, "Noisy Windmill to be Hushed," *The Appalachian* (30 September 1980), p. 1.

[22]Interview with Ayers.

[23]NASA Release 78-105 and DOE Release R-78-270, referred to in *Astronautics and Aeronautics, 1978* (Washington, DC: NASA, 1986), p. 171.

[24]Murphy, *et al.*, "Windpower" video.

the dedication characterized the MOD-1 as "experimental," and predicted that the MOD-2, then under construction, would achieve the performance and cost goals necessary to justify mass production. Still, he depicted the MOD-1 as a working unit that would power "500 homes," not simply as an exercise to test the possibility of constructing such a machine.[25]

Even if NASA intended to pack the charts and engineers into the special van and leave the MOD-1 in BREMCo's hands, the events of the winter of 1979-1980 changed their plans. Even before the turbine's first full-power test in February, residents living in its shadow complained of odd noises, distinct from the anticipated low-level whooshing. Accounts of the sounds resemble records of visit from a poltergeist:

> Most affected residents describe the annoyance as consisting of periodic "thumping sounds and vibrations" similar to having someone walk heavily across a wooden porch or hearing a heavy truck passing with a flat tire. Some have reported the rattle of loose picture frames or small objects and most agree the noise level is greater inside their homes than out. Most complaints have indicated the periodicity of the sounds is the most annoying aspect with the level becoming louder and more consistent during the evening.[26]

Mystified, Divone admitted that the noise problem...

> ...caught us by surprise; I have to be frank about that. There is no reason why the MOD-1 should cause a noise problem. There is some strange flow phenomenon going on behind the tower.[27]

Sound levels averaged 70 decibels (dB), but some sort of atmospheric focussing occasionally produced sound at distant locations louder than the sounds at the tower base.

To make matters worse, families in the area griped to BREMCo of ghostly images that flickered across their television screens when they tried to tune in certain channels during tests of the big turbine on the mountain above. Sometimes, the picture disintegrated completely. The phenomenon depended on the channel, the weather, the receiver and the

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[25]"Windmill Dedication" video.

[26]N.D. Kelly, "Noise Generation by Large Wind Turbines" in *Proceedings of the Wind Energy Technology Conference*, held in Kansas City, MO (16-17 March 1981).

[27]Divone, "Current Perspective," p. 4.

antenna, among other factors, but Boeing's steel blades clearly interfered with the transmission of the video portion of television signals. Like the noises, the interference occurred in seemingly random locations, up to a mile-and-a-half from Howard's Knob.[28]

Out of a community of 35,000, BREMCo received formal noise complaints from only ten households, and complaints of television interference from thirty-five. NASA took those few rather seriously. They halted operation of the MOD-1 during "prime time" in the early evening, unfortunately the windiest time of day on Howard's Knob, and eliminated night tests altogether. In addition, they reduced the rotation of the turbine from 35 to 23 rpm, and replaced the 1800-rpm generator with a 1200-rpm model.[29] While this cut the noise by 8-10 dB, engineers discovered that operation of the MOD-1 at low speed occasioned a resonance in the drive train. However, the generated current remained within BREMCo's limits, so testing at reduced speed continued.[30]

Then, on January 22 of 1981, twenty-two studs on the low-speed shaft sheared off, severing the link between the rotor and the drive-train. Later analyses blamed the disaster on improperly installed studs, failure of a slip clutch intended to release the drive train in the event of too great a torque, and occasional cyclic and peak torque overloads throughout the MOD-1's operational lifetime.[31]

In the months following the catastrophe, the MOD-1's future hung in question. Repairs would cost $500,000, but the new Reagan DOE seemed poised to cut the FWEP's

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[28]Collins, *et al.*, "Experience and Assessment of the MOD-1," pp. 12-15. Ayers vaguely recalls discussion of possible noise problems before installing the MOD-1, but says "no-one expected it." He guesses that "some people" might have anticipated the television problem, but NASA's extreme reaction indicates that the severity of the problem surprised them, too. Interview with Ayers.

[29]Kirk, "Noisy windmill," p. 1.

[30]Collins, *et al.*, "Experience and Assessment of the MOD-1," pp. 16, 18.

[31]*Ibid.*, pp. 19-20. Neither this report nor any other relates the shaft failure to the resonance problems or to the reduced-speed operation.

budget, perhaps for several years to come. In August of 1981, NASA decided to mothball the machine for the winter, and await new developments. NASA's Thomas reported that "since the MOD-1 has met most of its project goals and wind program funding has been reduced, it has not been decided to immediately repair the machine. The future of the MOD-1 is presently under evaluation..."[32] But an unnamed NASA spokesperson opined that "the decision will soon be reached for termination of the project."[33]

BREMCo explored the possibility of buying the machine, but the co-op's members shied from GE's asking price of about $2 million, especially given yearly operating expenses between $35,000 and $40,000, most of which consisted of a salary for a computer technician to monitor the control system. BREMCo also professed uneasiness at having to perform an environmental impact assessment.[34] The Hawaiian Electric Company (HECo) exhibited some interest in purchasing the machine, but backed off after evaluating the transportation costs.[35] (HECo later purchased Boeing's MOD-5B turbine.) Finally, in November of 1982, NASA and GE notified BREMCo that they had canceled the project. McBess Industries, a nearby yarn company, bought the MOD-1 at an auction for $51,600 after promising to cart off the giant turbine within forty-five days; McBess planned to donate the tower to Georgia Tech and install the generator in a refurbished hydroelectric plant on the South Fork River.[36]

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[32]Ronald L. Thomas and D.H. Baldwin, "The NASA Lewis Large Wind Turbine Program," prepared for Fifth Biennial Wind Energy Conference and Workshop in Washington, DC, NTIS DOE/NASA/20305-7 (5-7 October 1981), p. 3.

[33]"Windmill's Shutdown a Signal of Doom?" *The Charlotte Observer* (12 August 1981), p. 2B; "Boone Windmill's Future Seen as Uncertain," *The Journal-Patriot* (August 13, 1981), p. D5.

[34]"Boone Windmill Saga Ends," BREMCo news release (4 November 1982).

[35]Forrest B. Greene and J. Linn Mackey (eds.), "A Study of the MOD-1 Wind Turbine in Boone, N.C. and its Future Options: A Project Report by the College of Business Productions and Operations Class, and The Watauga College Earth Studies Preparations Class," (Boone, NC: Appalachian State University, 1982).

[36]Bruce Henderson, "Yarn Factory Wins Contract to Cart Away Fated Windmill," *Charlotte Observer* (1 July 1983).

Assessing the MOD-1

NASA claimed success in achieving its goals for the MOD-1 project, reporting that the machine had "operated successfully in all modes of operation," maintaining synchronism with the utility grid and furnishing power to residential users. Data from the MOD-1 "verified the performance, loads and structural dynamics codes" used in its design. In sum, NASA claimed, the project "demonstrated the compatibility of a megawatt wind turbine operating in a utility grid in a stable and well controlled manner."[37]

While these claims captured part of the truth, another side of the story clearly existed. NASA had proclaimed the MOD-0A project a success partially because the four machines had accumulated some 38,000 hours of operating time by the project's end in June of 1982.[38] The MOD-1, by contrast, ran for 130 hours (never more than eight hours at a time) before failing. It never even generated its rated 2000 kW.

Bumgarner, who now believes that the project aimed at research rather than power generation all along, accepts NASA's contention that it accomplished many of its goals. He points out that "we know that it did work. It was successfully done." However, he also notes that to the public, who expected BREMCo to operate the machine as a powerplant, "it became a joke."[39] In this sense, one must evaluate skeptically NASA's claims to have documented public acceptance of the big turbine. Certainly, most Boone residents liked the MOD-1, and wished BREMCo could have kept it running; in short, they approved of windpower as a concept. However, the project gained the reputation of a $30-million boondoggle. As one Boonite grumped, "I've never seen that rig workin'... It's just a lot of

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[37]Ronald L. Thomas, "DOE/NASA Lewis Large Wind Turbine Program," prepared for National Rural Electric Cooperative Association and DOE Rural Electric Wind Energy Workshop in Boulder, CO, NTIS DOE/NASA/20320-42 (1-3 June 1982), pp. 2-3.

[38]Divone, "Evolution" in Spera (ed.), *Wind Turbine Technology*, p. 117.

[39]Interview with Bumgarner

money where it wasn't no use."[40] The MOD-1 suffered the ignominy of being carted off for scrap to the jeers of the community that had jubilantly welcomed it shortly before.

Even had the MOD-1 operated without problems, its immense cost provides another reason to question its success. Although GE's last-minute design changes--made feasible by delays due to the failure of the fiberglass blades--lowered capital costs, GE complained that NASA's rigid technical specifications for the MOD-1 prevented them from incorporating advanced concepts. Phrasing the criticism as politely as possible, GE's project manager Reinhold Barchet told a Congressional subcommittee that the MOD-1 experience had taught GE that "the stiff-tower, rigid-rotor concepts, used on the 200 kW MOD-0A and specified by the Government for MOD-1, cannot result in light-weight, commercially attractive, megawatt-class wind turbines."[41]

GE gamely continued work on its MOD-1 contract, but the firm also began a NASA-directed "strawman" design study for a hypothetical turbine. Unconstrained by the top-down specifications that had cramped the MOD-1, this effort aimed to design a machine with the same operational characteristics, while reducing COE from 18 to 5 cents/kWh, capital cost (for the second unit produced) from $2900 to 1000/kW, and weight from 650,000 to 400,000 lbs. The resulting "MOD-1A" design replaced the rigid steel tower used on the MOD-1 with a "soft" conical shell tower, intended to vibrate at frequencies lower than the rotor frequency. Other features included a built-in gearbox and a teetered hub on an inclined axis. To control rotation speed, the downwind rotor used partial-span pitch control (*i.e.*, only the outer 15% of the blade swiveled). If built, GE predicted that the second MOD-1A would generate electricity for 6 cents/kWh and cost $985,000, or $1050/kW. GE never made a MOD-1A, but many of the concepts appeared in Boeing's MOD-2s and GE's MOD-5A design.[42]

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[40]Quoted in Greene and Mackey (eds.), "Study of the MOD-1," p. 83.

[41]Testimony of Barchet in U.S. Congress, *Oversight*, p. 118.

[42]Poor, "The MOD-1 Program" in "Large Turbine Design Characteristics," p. 42. All costs in 1978 dollars.

Although Barchet blamed rigid contracting procedures for the economic fiasco of the MOD-1, Divone pointed to the ambitious schedule that the FWEP had set itself. Before a Congressional oversight committee, he recalled that test data from the MOD-0 arrived after the MOD-1 design effort had reached full steam. "To our surprise," he confessed, "when one plotted initially the test data and the theoretical calculations, those early figures looked like a shotgun blast." He explained that the FWEP at first lacked the analytic tools to predict correctly the stresses and vibration frequencies on a large wind machine. "What happened was the weight of the machine went up very rapidly to take those added loads that we had not known about." Divone also self-consciously suggested that the DOE and its contractors misjudged the program's need for senior managers in addition to competent engineers. As it turned out, he concluded, "we found ourselves in rather sophisticated development work very early in the program."[43]

Divone's analysis rings true in some ways. NASA's difficulties in adapting the MOSTAB helicopter rotor models to wind turbine design, the blade problems experienced by the Clayton MOD-0A, and the television interference produced by the Block Island MOD-0A all sounded warnings that engineers lacked complete understanding of the interaction between wind turbines and their operating environment. Yet the program clipped along, designing first- and second-generation machines before assimilating the data from the experimental units built only a year or two before. Even as BREMCo awaited word on the fate of the MOD-1 languishing on Howard's Knob, the FWEP focussed its attention on the second generation of megawatt turbines, three 2.5-MW MOD-2s undergoing installation in Washington. Yet, as GE's Barchet argued, Federal inflexibility compounded the problem. While NASA optimistically pointed out that the MOD-1 had taught the FWEP valuable lessons in what *not* to do, GE's MOD-1A study suggested that NASA might have learned some of the material without such egregious mistakes.

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[43]Testimony of Divone in U.S. Congress, *Oversight*, pp. 74-75.

Historian Richard Hirsh describes a similar condition afflicting the fossil-fuel generating sets used by the utility industry. Manufacturers had long assimilated their customers' operating experience in designing new, ever-larger machines. As the pace of development accelerated after World War II, equipment firms moved to a "design-by-extrapolation" approach, assuming that each new generation would behave as had its predecessors. But with increasing size, temperature and pressure, the new generating sets failed to perform as expected. By the mid-1960s, extrapolative design had produced a generation of complex, cranky machines whose poor performance belied their tremendous expense.[44]

Hirsh's discussion demonstrates that to account for "technological" failures of hardware, one must frequently look to the "social" aspects of management culture and design style, an insight important in understanding the windpower story. Although the electric equipment industry and the FWEP's large-turbine program adopted incautious design techniques for different reasons, the effects proved equally unfortunate. In particular, the FWEP's managers may have moved so fast in order to maintain momentum in their funding efforts, in obedience to the maxim of 'use it or lose it' regarding Federal budgets. While that strategy for planning an R&D effort makes unfortunate sense given government fiscal procedures, it condemns each unit--especially large units with long lead times--to a measure of failure, by causing planners to solidify their design plans before accruing data from previous models.

## PART III: The Wind Energy Systems Act

Problems for the FWEP brewed in Washington as well as out in the field. While Divone and Tennyson correctly assured their audiences that Congress supported windpower, legislators had already expressed dissatisfaction with management of renewable energy programs by the young Department of Energy. Support and passage of the Federal

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[44]Hirsh, *Technology and Transformation*, pp. 103-109. See also Hirsh, "Bigger is No Longer Better: Technological Stasis, Regulatory Change, and Innovation in the American Electric Utility Industry," paper presented at the Third Conference on Large Scale Technological Systems, Sydney, Australia (1-5 July 1991).

Photovoltaic Utilization Act, the Solar Photovoltaics RD&D Act, the Energy Security Act (which established the Solar Energy & Energy Conservation Bank), and the Ocean Thermal Energy Conversion Act[45] demonstrated legislators' concern for popular renewable energy programs. Leaders of the renewable coalition included Sens. Gary Hart (D-CO), Paul Tsongas (D-MA), Charles Percy (R-IL) and Spark Matsunaga (D-HI), as well as Reps. Norman Mineta (D-CA), Thomas Blanchard (D-MI), James Jeffords (D-VT) and Richard Ottinger (D-NY). When this group turned to windpower, they demanded that the DOE explain how it intended to get its experimental wind turbines out of the laboratory and into the marketplace.[46]

In 1979, partly in response to legislators' grumbling, President Carter ordered a Domestic Policy Review (DPR) of Solar Energy. The DPR reported to the President that windpower came closer to economic viability than other solar technologies, and recommended a goal of 1.7 quads annually from windpower by 2000. To achieve this goal, the DPR suggested that the President ask Congress for $100 million for windpower in FY 1980. To the disgust of the wind energy community, however, the President's Office of Management and Budget asked Congress to authorize $67 million, only $7 million over the previous year.[47] To make the slight to windpower worse, the OMB heeded the DPR's counsel in the cases of all other solar energy programs.

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[45]Respectively: P.L. 95-619, Title V, part 4; P.L. 95-590; P.L. 96-294, and; P.L. 96-310.

[46]Scott Sklar, "The Role of the Federal Government in the Commercialization of Renewable Energy Technologies," *Annual Review of Energy* 15 (1990), pp. 121-132. See also U.S. Congress, House of Representatives, Committee on Interstate and Foreign Commerce, Subcommittee on Energy and Power, *The 95th Congress and Energy Policy*, study prepared by the Congressional Research Service for the 96th Congress, 1st Session (January 1979), Committee Print 96-IFC 1.

[47]U.S. Congress, House of Representatives, Committee on Science and Technology, "Committee Report on Establishment of Wind Energy System Research, Development and Demonstration Program," 96th Congress, 1st Session (29 November 1979), Report No. 96-662. For more on the contentious DPR, see, for example: "White House Rejects DPR Status Report; Potential Anywhere From 7.3 to 31.6 Quads," *Solar Energy Intelligence Report* 4 (7 August 1978), p. 236. The figures in this title refer to all solar technologies. At this stage in carrying out the DPR, estimates of windpower's yearly potential ranged between 0.3 and 5.0 quads annually by 2000. Such differences reportedly had DOE solar officials complaining of exclusion from the DPR's inner circles, storming out of offices, and threatening to quit.

Supporters of windpower in Congress interpreted the OMB's decision as further evidence of the pro-nuclear President's shilly-shallying on renewable energy. In February of 1979, the FWEP announced to Congress its intention to cancel the "second-generation" intermediate-sized MOD-3 and large MOD-4. According to one DOE emissary's July testimony, the agency had perceived that "some of the goals we had set for program were not going to be realized... We really felt we had to slow down to take advantage of what we were learning in the MOD-0 and MOD-1 program."[48] But Congress, unconvinced, took the cancellation as final evidence of the DOE's inability, or perverse reluctance, to bring windpower to market.

In April of 1979, Representatives Mineta, Blanchard and Jeffords introduced H.R. 3558, the Wind Energy Systems Research, Development and Demonstration Act of 1979. The bill proposed a seven-year program to install 500 MW of windpower by 1986, of which at least 5 MW would come from small systems. The key provisions authorized Federal aid to purchasers of wind systems, limiting such grants to the difference between the costs of wind systems and conventional energy systems (a trickier calculation than the legislators realized), and phasing out the subsidies by 1986. The bill enjoyed wide support, collecting 118 co-sponsors before subcommittee mark-up.[49]

In July of 1979, as the wind bill wound through the legislative labyrinth, the House held its first oversight hearing on the FWEP. Rep. Ottinger, Chairman of the Subcommittee on Energy Development and Applications, mercilessly grilled representatives of the FWEP and their DOE superiors. Again and again, he inquired whether the program had bogged down in endless R&D, and he tried to goad witnesses into criticizing the OMB's decision to

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[48]Testimony of Bennet Miller, Director of Solar, Geothermal and Electric Energy Systems, in U.S. Congress, *Oversight*, p. 69. The FY 1980 budget request submitted by the DOE to Congress explained that "the overlap in schedules and rapid timing did not allow for the incorporation or development of sufficient technological advances. Additional studies and the examination of proposals led to the conclusion that the costs would be higher than originally estimated." U.S. Congress, *1980 DOE Authorization*, pp. 287, 288.

[49]U.S. Congress, "Brief Summary of H.R. 3558," *Congressional Record* 125, 96th Congress, 1st Session (13 June 1979), p. 14,734.

ignore the DPR's recommendation. "Are there possibilities for substantial acceleration of the program if more funds were devoted to it?" he asked Worth Bateman, Deputy Under Secretary of Energy. "Do you think you would profit by having more money?" Bateman stoutly responded that "the pace of the program can be accelerated. Whether it can be done in such a way that takes full advantage of what we are learning from previous efforts I think is questionable." Bateman pointed out that although OMB's request of $67 million for FY 1980 fell short of the DPR's figure, it nearly doubled the FY 1978 budget.[50] In a bizarre series of similar exchanges, Ottinger seemed to dangle before each witness a wealth of funding that they could have merely by going on record as asking for it.

During the hearing, many witness from outside the government situated the problem not only in funding levels, but in the DOE's inability to enact commercialization programs. Part of the difficulty lay in the yearly budget procedure itself. Large corporations happily competed for short-term research grants, knowing that each might be the last. By contrast, they shied from investing in large-scale fabrication facilities without firmer assurances that the government would maintain its commitment.

For example, Ronald Peterson, in charge of Grumman's wind program, characterized the DOE's direction and planning as sporadic and unpredictable. "It is now time," he warned, "for the DOE to announce its commercialization plans so that the rest of the industry can respond."[51] Ben Wolff of the AWEA concurred. After praising the FWEP

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[50]Testimony of Worth Bateman, Deputy Under Secretary of Energy, in U.S. Congress, *Oversight*, p. 61. Adding to the unpleasantness of the experience for the DOE team, their Department had originally requested that the OMB ask Congress for $95 million in FY 1980, before the OMB produced the administration's official figure of $67 million. But the complexities of Federal budget-making require the Departments (part of the Executive branch) to defend the recommendation of the OMB (also under the President) in authorization hearings before the legislative branch. Thus, the DOE officials had to defend a budget request substantially less than their own initial recommendation, before a Congress suspicious of their progress. (Perhaps more to the point, the managers directly responsible for wind programming such as Divone had to support the position taken by their superiors in the DOE.) Yet, it would obviously court disaster to justify slowing down by telling Congress that the machines produced so far had "failed."

[51]Testimony of Ronald Peterson, Chairman of Grumman Energy Systems, Inc., in U.S. Congress, *Oversight*, pp. 154-155

management itself as "excellent... comprehensive, innovative and flexible," he complained of the DOE's "apparent inability to switch from research to application."[52] Ottinger commiserated with the industry representatives, and derided the DOE efforts to commercialize energy technology. "Everything seems to stay in research forever," he complained. How, he asked them, could Congress help push windpower to market?

The witnesses' responses focussed on two areas. First, they suggested that Federal agencies purchase large numbers of wind turbines. The Bureau of Reclamation, responsible for Federal hydroelectric facilities, and large Federal power marketing agencies such as the Bonneville Power Administration received frequent mention. Second, the government should offer incentives to private users. These might take the form of subsidies or tax incentives for purchasers of wind equipment. Wolff, for example, suggested that Congress offer tax credits for investment in wind power, and recalled that Hollywood and the railroads had benefitted from their status as tax shelters for citizens with no interest or experience in movies or boxcars.[53]

Later, in July of 1979, the Senate held hearings on its own proposed renewable energy legislation, presided over by Sen. John Durkin (D-NH), Chairman of the Subcommittee on Energy Conservation and Supply. The brusk New Englander had cast the only Democratic vote against the establishment of a Department of Energy, but he professed

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[52]Testimony of Wolff in U.S. Congress, *Oversight*, pp. 171, 173. Elsewhere, Wolff used blunter language, telling Ottinger and Rep. Albert Gore, Jr. (D-TN) that "the Department of Energy is a constipated organization that can't get its programs moving." Testimony of Wolff in U.S. Congress, *1980 DOE Authorization*, pp. 388-389. Even that seemed mild compared to the invective of some members of the alternative energy community, who (in their own fora) mocked Federal caution. One solar activist wrote: "'You can't throw money at us!' That's the constant, pathetic cry in the halls at DOE-Solar. 'We don't have the staff to monitor all the money Congress shovels at us,' they say, as if they couldn't staff up if they really wanted to... This slowpoke, one-step-at-a-time, linear thinking seems dangerously out of place... Certainly, the nuclear fission and fusion areas have had billions thrown at them for the last 30 years, without such a lack of enthusiasm, lack of staff, or tendency to return the money... Divone [is a] conservative MIT scientist who can think only of going from A to B, and B to C, slowly and without innovation." Lee Johnson, "DOE: Department of Solar Evasion," *RAIN: The Journal of Appropriate Technology*, reprinted in *Wind Power Digest* (Spring 1978), p. 15. In fairness to Divone, most members of the wind community praised him highly.

[53]Testimony of Wolff in U.S. Congress, *Oversight*, p. 184.

equal distrust of big business, declaring suspiciously declared that "the oil company is the invisible government in this country."[54] Durkin adamantly favored extraction of promising new energy technologies from the DOE's clutches as soon as possible.

Concerning the DOE's purported "top-down" management style, Durkin's subcommittee heard that Massachusetts-based U.S. Windpower Associates had developed an intermediate-sized turbine without any government assistance, and had already signed promising contracts to provide wind-generated electricity to various utilities. The firm's representative charged that the DOE "could never understand that the best way to bring new technology into the market might be to try alternate design philosophies and let these alternatives compete in the marketplace,"[55] and noted that his firm found mid-range turbines simpler and less prone to disaster than megawatt-scale machines.

With regard to incentives to purchasers, Grumman's Peterson explained that the current tax code allowed businesses to deduct monthly utility bills from their income tax as an operating expense, but prohibited them from deducting the capital cost of a wind system. However, he warned Congress to institute tax incentives retroactively, asserting that an eighteen-month gap between announcing and implementing solar credits had nearly killed that industry, as consumers waited for the tax credit before making their purchases.[56] Virtually all witnesses found the goal of 5 MW for small systems laughably conservative. Autumn hearings in the House on the Mineta-Blanchard-Jeffords bill only reinforced these messages.

Taken as a group, the hearings reinforced Congress's suspicion that the Carter DOE had proven incapable of crafting a long-term commercialization initiative. Both houses of Congress agreed to take long-term windpower planning out of the DOE's hands by passing

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[54]U.S. Congress, *Energy Supply Act*, pp. 10, 13.

[55]Testimony of Alvin Duskin, Executive Vice President of USW, in U.S. Congress, *Energy Supply Act*, p. 43.

[56]Testimony of Peterson in U.S. Congress, *Energy Supply Act*, pp. 37-40.

substantially modified versions of the original H.R. 3558. The resulting law, dubbed the Wind Energy Systems Act of 1980,[57] authorized spending almost a billion dollars over eight years, beginning with $100 million in FY 1981--the very figure rejected by the OMB. The Wind Act adopted the DPR's estimate of windpower's potential at 1.7 quads per year by 2000, and set a national goal of installing at least 800 MW of windpower by 1988, including 100 MW from small systems. Lawmakers heeded testimony warning them away from the morass of calculating comparative costs of energy. Instead of subsidizing the difference between wind and conventional energy systems, as originally intended, the Wind Act simply promised to reimburse purchasers (presumably utilities in most cases) for half the cost of large wind systems during the first six years of the program's duration, and one quarter in the last two years. Other program components included low-interest loans for equipment purchases, authorization of Federal procurement of wind systems, and allotment of $10 million for wind resource assessment studies. President Carter signed the Wind Act into law on September 8 of 1980, politely praising the original three sponsors, but perhaps also a bit nettled at the slap Congress had delivered to his Department of Energy.[58]

## Conclusion: The Tide Turns

The Wind Energy Systems Act of 1980 marks the high-water point of the FWEP. As Divone implied, it demonstrated Congressional support for windpower by authorizing aggressive goals for the 1980s. But the tide's momentum had already failed, and the Wind Act represented serious troubles for the FWEP. In passing a long-term commercialization plan, Congress ratified the charges made by small and large companies alike that the DOE, out of bureaucratic lethargy or antipathy to alternative energy, had failed to move windpower into the market. By allowing the subsidization of any technology a consumer cared to select, Congress endorsed criticisms that the DOE had too rigidly specified technological paths of development.

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[57]P.L. 99-386, 42 USCA 9201.

[58]Jimmy Carter, "Wind Energy Systems Act of 1980," *Weekly Compilation of Presidential Documents* 16 (8 September 1980), pp. 1668-1669.

Most ominously, wind equipment manufacturers had proclaimed their wares technologically ready for the marketplace. To convince Congress to take over long-term management of windpower, they argued that only "institutional" barriers such as unfair tax structures and the innate conservatism of electric utilities obstructed the formation of a market. Yet, the performance of small and large machines in the field belied their affirmations. By accepting and acting on such claims, Congress made windpower vulnerable to the charges of a subsequent administration that, since wind turbine technology stood on the threshold of economic viability, the marketplace could assume responsibility for final refinements.

# CHAPTER SEVEN
# Ronald Reagan, the Oil Glut, and Hard Times for Federal Windpower

## Introduction: Declining Support for Windpower

In the 1980s, the Federal Wind Energy Program shrunk from a robust research, development and commercialization program with substantial executive and legislative support to a harried, modestly-funded effort limited to long-term, high-risk research. On Ronald Reagan's election in 1980, the new administration immediately demonstrated its ideological conviction that the free market, not the government, should manage any technology worth its salt. It also demonstrated a specific antipathy to renewable energy.

Combined with the decade's rapidly dropping oil prices, the Reagan team's decision not to request appropriations for windpower dissuaded most manufacturers pondering large-turbine ventures. The FWEP sponsored only five second-generation turbines and one third-generation unit. While the program still exists in 1994, it functions largely as a facilitator of private technology development. 1980 marked the beginning of the end for the FWEP as a centralized program developing its own wind technology.

## PART I: A New Broom

The administrations of Presidents Nixon, Ford and Carter steadily (albeit in some cases reluctantly) inflated the role of the Federal government in energy policy. By the presidential election of 1980, the three-year-old Department of Energy sheltered 19,500 employees and dispensed nearly $10 billion per year for research in a manner characterized as distressingly slipshod by Senate auditors.[1] On the campaign trail, Governor Ronald Reagan of California pooh-poohed the very justification for the agency's existence, the "energy crisis," even in the face of exorbitant oil prices. "For three years and eight months," Reagan asserted, "Mr. Carter has led us to believe that there is an acute shortage of energy

[1] "Why Energy Agency Gets a Low Grade," *U.S. News and World Report* 91 (6 July 1981), p. 48.

in this country."[2] In fact, the candidate claimed, America enjoyed abundant energy resources, whose exploitation the Carter administration had stymied. The bloated and byzantine DOE, despite its multi-billion-dollar budget, had not "produced a quart of oil or a lump of coal."[3] Rather than streamline the DOE, Reagan proposed to scrap it altogether, to slash environmental regulation, and to return energy policy to the hands of businesses and consumers.[4]

The Reagan administration harbored a special animus against alternative energy. Observers traced the new government's antipathy to a melange of reasons. Planned reductions in funding for renewables indicated in part Reagan's public promise to cut Federal spending. Indeed, in 1981 the President warned that America would no longer seek to reduce oil imports "at any cost," because even at its current high price, imported oil in some cases cost more than "available alternatives."[5] However, a Congressional report hypothesized that the cuts also reflected "a broader philosophical commitment to reinvigorate the private sector and diminish governmental function."[6] The very concept of government participation in commercialization discomfited Reagan's hands-off philosophy of government.

But beyond viewing renewable energy technology as economically marginal hardware, the Reagan team also perceived it as symbolic of an alien ideology, the "anti-

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[2]Quoted in Lou Cannon, "Reagan: Carter Discourages U.S. Energy Production," *The Washington Post* (11 September 1980), p. A4.

[3]Quoted in Juan Cameron, "Huffing and Puffing at the Energy Department," *Fortune* 103 (26 January 1981), p. 39.

[4]Kenneth R. Sheets, "Energy Department Twisting in the Wind," *U.S. News and World Report* 91 (6 July 1981), pp. 47-48. For Reagan and energy policy, see: Franklin Tugwell, *The Energy Crisis and the American Political Economy: Politics and Markets in the Management of Natural Resources* (Stanford: Stanford University Press, 1988), pp. 126-136, and; Lawrence G. Brewster, *The Public Agenda: Issues in American Politics* (New York: St. Martin's Press, 1984), pp. 60-66.

[5]"Reagan unveils new energy policy plan," *Science News* 120 (1 August 1981), p. 68.

[6]Larry B. Parker, Robert L. Bamberger and Susan R. Abbasi, "The President's Energy Program: Changing the Federal Role in Energy Policy," Congressional Research Service (16 April 1981), p. 1.

growth" environmental movement. In accepting the Republican nomination, Reagan had declared that the nation's productive capacity "must not be thwarted by a tiny minority opposed to economic growth," and he had affirmed that "the economic prosperity of our people is a fundamental part of our environment."[7] The Republicans' palpable contempt showed itself early in Reagan's presidency, with the removal of solar panels installed by the Carter administration on the White House roof.[8]

Although Reagan's first Secretary of Energy announced his desire to "go to Washington and close the Energy Department down and work myself out of a job,"[9] the DOE enjoyed appreciable support in the Democratic Congress. The Reagan administration discovered early on that even counting the influx of conservative legislators sent to Washington during the tax revolt of the late 1970s and early 1980s, the Democrats retained enough strength to repel many of the Administration's legislative proposals. To bypass intractable Congressional opposition, Reagan increasingly shifted his policy-making (which often consisted of cutting programs, rather than establishing new ones) to the Office of Management and Budget, directed by fiscal conservative David Stockman.[10]

Rather than introduce legislation to eliminate programs perceived as wasteful or wrong-headed but prized by members of Congress, Stockman's OMB simply declined to request funding for them. In the case of renewable energy, the OMB immediately asked Congress to rescind most of the $559 million requested by the outgoing Carter

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[7]Speech at the 1980 Republican National Convention reprinted as "Text of Reagan's Acceptance Speech," *The Washington Post* (18 July 1980), p. A10.

[8]Sklar, "Role of the Federal Government," p. 122.

[9]DOE Secretary James B. Edwards, quoted in Cameron, "Huffing and Puffing," p. 39.

[10]Some observers distinguished between fiscal "conservatives" such as Stockman, who advocated competition between all energy technologies in a level marketplace, and fiscal "corporatists," such as Secretary of Energy James B. Edwards, who saw no inconsistency in cutting solar budgets but heavily subsidizing the nuclear industry. Like the President, Edwards defended this stance by claiming that environmental regulation prejudicial to nuclear power made Federal support necessary and just. See John Abbots, "An industry in search of a subsidy," *The Bulletin of the Atomic Scientists* 38 (August-September 1982), pp. 47-51.

administration for FY 1981. Congress added $105 million to the OMB's request and appropriated $275 million. As Table 5 (on the following page) shows, this pattern continued for the rest of the 1980s; the OMB asked for less money each year and Congress consistently appropriated more money than the OMB had requested.[11]

Often, the government's tactic of cutting programs by not requesting funding for them led it into murky legal waters. A notorious episode concerned the Solar Energy and Energy Conservation Bank, designed in 1979 to assist low- and middle-income Americans in purchasing conservation and renewable energy equipment. In response to a request from the OMB, Congress rescinded almost all of the Bank's $121 million budget in FY 1981, on the condition that the Bank receive the full sum the following year. The Administration subsequently impounded the entire $22-million budget passed for FY 1982, provoking a lawsuit by a coterie of public interest and environmental groups, including five members of Congress led by Representative Ottinger. In June 1982, prodded by a court order, the Bank opened, but with a severely limited provenance.[12]

The Reagan administration argued that its convincing electoral victory constituted approval for its redefinition of environmental and energy policy. Environmentalism had indeed lost momentum in the preceding years, which some pollsters explained as Americans' willingness to let government "take care" of the problem. But, the pundits claimed, as the Reagan government rolled back the "progress" made by earlier administrations, environmentalism regained its former salience. One poll found that the percentage of Americans believing that the Federal government spent too little on environmental protection rose from 48% in 1980 to 71% a decade later. A survey asking respondents to choose

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[11]Regina S. Axelrod, "Energy Policy: Changing the Rules of the Game" in Norman J. Vig and Michael E. Kraft (eds.), *Environmental Policy in the 1980s: Reagan's New Agenda* (Washington, DC: CQ Press, 1984), pp. 213, 220-222.

[12]"Solar Bank supporters sue Reagan," *Science News* 121 (24 April 1982), p. 283; "At long last, the Solar Bank may open," *Science News* 122 (10 July 1982), p. 27; Axelrod, "Energy Policy," p. 212.

| Table 5: DOE funding of wind and total renewable energy programs<br>actual expenditures<br>FY 1975 to FY 1991 in millions of nominal dollars | | |
|---|---|---|
| **YEAR** | **Wind funding** | **Total renewable funding** |
| **FY 1975** | 5.7 | 80.8 |
| **FY 1976** | 14.4 | 146.2 |
| **transitional quarter** | 4.5 | 45.6 |
| **FY 1977** | 22.4 | 338.4 |
| **FY 1978** | 36.7 | 533.7 |
| **FY 1979** | 59.5 | 700.6 |
| **FY 1980** | 60.5 | 844.9 |
| **FY 1981** | 54.2 | 724.2 |
| **FY 1982** | 34.4 | 407.6 |
| **FY 1983** | 31.4 | 304.4 |
| **FY 1984** | 26.4 | 258.3 |
| **FY 1985** | 28.4 | 238.0 |
| **FY 1986** | 27.4 | 215.9 |
| **FY 1987** | 16.5 | 183.9 |
| **FY 1988** | 9.3 | 154.4 |
| **FY 1989** | 8.8 | 154.9 |
| **FY 1990 appropriation** | 9.1 | 137.6 |
| **FY 1991 appropriation** | 11.2 | 201.0 |
| **TOTAL** | **460.9** | **5670.1** |

Data from "Renewable Energy Budget History (ERDA and DOE)," internal DOE document (28 November 1990). Figures refer to funds actually spent, and may not tally with tables of appropriations. Note that in FY 1980 Congress approved $87.0 million for windpower, which the Reagan Administration rescinded to the figure of $60.5 million listed here.

between increased environmental protection and energy supply reported a 10% increase in support for the environment between 1980 and 1982, along with a corresponding decrease in support for energy supply. Such figures imply less enthusiasm for the President's environmental outlook than his staff claimed. Still, the Administration adamantly pursued its fiscal and philosophical goals.[13]

Reaganism and the FWEP: "You say you believe in it..."

During the 1980s, the Federal Wind Energy Program suffered along with other renewable energy efforts. As part of its blitz on renewable-energy funding, the OMB asked Congress to lower the FWEP's budget for FY 1981 from $85.8 million to $26.1 million; Congress appropriated $35.4 million.[14] Wind energy funding later bottomed out in FY 1990 at $8.9 million.[15]

Authorization hearings for FY 1982's budget, held in the Spring of 1981 before the House Subcommittee on Energy Development and Applications, gave the wind community a bitter taste of what to expect in the 1980s. The hearings showed that the tried-and-true strategy of presenting windpower as a technology at the threshold of economic viability sent precisely the wrong message to the inspired government-shrinkers of the "Reagan Revolution." While the new administration believed in kicking new technologies from the nest at the earliest possible date, (as Rep. Ottinger had advocated in 1979,) the idea of doing so through subsidization of private purchases, as the Wind Energy Systems Act of 1980 proposed, struck the newly empowered conservatives as ludicrous.

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[13]Riley E. Dunlap, "Public Opinion and Environmental Policy" in James P. Lester (ed.), *Environmental Politics and Policy: Theories and Evidence* (Durham and London: Duke University Press, 1989), pp. 87-134, esp. 114-117; Christopher J. Bosso, "After the Movement: Environmental Activism in the 1990s" in Vig and Kraft (eds.), *Environmental Policy in the 1990s* 2d ed., (Washington, DC: CQ Press, 1994), pp. 32-33.

[14]U.S. Congress, House of Representatives, Committee on Science and Technology, *Fiscal Year 1982 Department of Energy Authorization*, No. 2, Vol. I, 97th Congress, 1st Session (24 February 1981), p. 109; Axelrod, "Energy Policy," p. 213.

[15]Sklar, "Role of the Federal Government," p. 125.

The witnesses representing the wind industry before Congress in 1981 began with frank pleas for Congress to carry out the programs outlined in the Wind Act. They soon found themselves on the defensive, however, under a withering salvo of questions from junior Republican representatives elected in 1978 and 1980. After hearing upbeat predictions that the Boeing and General Electric MOD-5s would greatly improve on the MOD-2 by incorporating super-advanced technology, Rep. Jim Dunn (R-MI) asked why, if the witnesses so believed in the viability of windpower, they declined to take the investment risk of the advanced MOD-5 on themselves. Boeing's John Lowe objected,

> We're talking about $21 million. In order to pay out $21 million, we have to have sales of 20 times that for the profits we have, to make that investment into a risky area. At the moment we're not going to do that.

Dunn drily observed, "Well, you say you believe in it," and noted that the contractors had neither obligation nor intention of paying back government funds if the project succeeded. Rep. Claudine Schneider (R-RI) followed Dunn, graciously inquiring whether GE and Boeing might accept a cost-sharing arrangement, whereby the manufacturing firms risked their own funds to match Federal support. Lowe and GE's Dan DiGiovacchino hedged uncomfortably.[16]

The situation for wind energy promoters deteriorated further when Rep. Robert S. Walker (R-PA) took the floor. Walker summarized the testimony up to that point:

> You are saying that... we have brought a wind system to the point of commercial feasibility... In some areas of the country the wind systems you have developed could be put on the line commercially at the present time.

Had he correctly interpreted the testimony, Walker asked? Lowe allowed that he had. Walker went on to argue that, given what the committee had heard, Congress had met its goals for windpower:

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[16]Testimony of John Lowe, Director of Wind Energy Programs for the Boeing Construction and Engineering Co., and Dan DiGiovacchino, Manager of the Wind Turbine Program at GE's Advanced Energy Program Department, in U.S. Congress, House of Representatives, Committee on Science on Technology, *Fiscal Year 1982 Department of Energy Authorization--Fossil, Solar and Geothermal Energy and Basic Resources*, No. 6, Vol. II, 97th Congress, 1st Session (3 March 1981), pp. 498, 499.

> ...if I understand correctly, the problem with taking the next step is not with the technology, which this committee is concerned about, but it is with the investment capital within the industry.

Walker ended by arguing that the FWEP had achieved its goal of demonstrating commercial feasibility. Responsibility for reducing costs now fell to the market, where rational businesses would gladly invest in truly promising technologies. The government, meanwhile, ought to apply its scarce resources to other high-potential, long-term development projects.[17]

Perhaps the most damning exchange occurred between Rep. Judd Gregg (R-NH) and William Drake of Enertech, Inc., a firm holding two DOE small-turbine development contracts. Gregg asked Drake if he knew of a wind project run by a Massachusetts company called U.S. Windpower Associates. Gregg termed the private facility, which sold electricity to a New Hampshire utility, as "the first commercial wind farm," and he pointedly told his captive audience that U.S. Windpower had accomplished the feat with no Federal support at all.

> I'm just wondering why you feel there is any need for further Federal support when you have commercially viable projects already not only on the drawing board but functioning as wind farms in states like New Hampshire.

Drake objected that the U.S. Windpower project did not represent a triumph of completely free market policies; only the availability of Federal tax and other incentives allowed such projects to attract private capital. Gregg switched tacks, asking why, if small machines had somehow cracked the market, the government should support big machines? Boeing's Lowe hurriedly interjected that all data showed that "the most viable form, the most economical form, is large turbines." Well, Gregg rejoined, why not leave it to the marketplace to determine which size is better? To this, Lowe sputtered that one 25-unit farm did not really constitute evidence that private capital could develop wind with no assistance.[18]

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[17]U.S. Congress, *1982 DOE Authorization--Fossil, Solar*, pp. 503, 504.

[18]Testimony of William Drake, President of Enertech Corp., in U.S. Congress, *1982 DOE Authorization--Fossil, Solar*, pp. 496, 497.

Using such arguments, Republican administrators and legislators of the 1980s cropped the FWEP. After Divone's promotion to direct all solar electric technologies (including wind), Ancona briefly took over the FWEP's helm and its enlarged eighteen-billet roster. But soon, under pressure from the new Administration, he laid off, fired or demoted people until they left. "We were down to five," he says mournfully. Because of his long service, Ancona remained unaffected--"except emotionally," as he puts it.[19] The FWEP dwindled to a small agency funding theoretical, long-term, high-risk research. It retained that form until 1991, when the administration of President George Bush cautiously began to increase renewable-energy funding, perhaps because of surging popular support for environmentalism, or because the American turbine industry had lost ground in the burgeoning domestic and world windpower markets to aggressive, government-aided European and Japanese firms.

## PART II: The Last Giants

As funding ebbed, the FWEP soldiered on as well as it could with its MOD-2 program. The Bonneville Power Authority, a Federal agency marketing power in the Pacific Northwest, installed a cluster of three MOD-2s in the Goodnoe Hills near Goldendale, WA. The Department of the Interior's Bureau of Reclamation also bought a MOD-2, which it operated near Medicine Bow, WY, in conjunction with a 4-MW unit called the WTS-4, made by Hamilton Standard without FWEP support. BuRec used its turbines as "system verification units" to test the concept of integrated wind and hydro-storage facilities. Finally, Boeing sold a single MOD-2 to the Pacific Gas & Electric Company, the only product of the FWEP-NASA large-turbine program fabricated specifically for sale to a private electric utility.[20]

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[19]Telephone interview with Ancona.

[20]Darrell H. Baldwin and Bradford S. Linscott, "The Federal Wind Program at NASA Lewis Research Center," prepared for Power Engineering Society Conference Sixth Biennial Wind Energy Conference and Workshop in Minneapolis, MN, NTIS DOE/NASA/20320-52 (1-3 June 1983), pp. 3-5.

Hamilton-Standard built the WTS-4 in cooperation with a Swedish firm, Karlskronavarvet, after the pair constructed a 3-MW unit on the same design for the government of Sweden. The WTS-4 and the Canadian vertical-axis Eole are the most powerful wind turbines ever built. After experiencing substantial operating

(continued...)

The MOD-2 incorporated features of GE's MOD-1A study, performed during fabrication of the unfortunate MOD-1. The MOD-2 flew a 300-foot rotor; the outer forty-five feet of each hollow steel blade swiveled to maintain constant rotation speed and power frequency. A yaw motor kept the nacelle upwind of the slender (only 10 feet in diameter) tubular steel tower, eliminating tower-shadow effects on the teetered rotor. An innovative epicyclic gearbox proved smaller, lighter and cheaper than earlier models. In 1981, Boeing estimated the turn-key cost of the 2.5-MW machines at $2.1 million, and projected the COE for the 100th unit at under five cents/kWh in 1980 dollars.[21]

Once installed, the BPA's three MOD-2s at Goodnoe Hills experienced a variety of operational problems. Most serious, Unit #1's low-speed shaft cracked in late 1982; engineers attributed the failure to inadequate design of the shaft and poorly placed holes drilled in it for hydraulic tubing and electrical conduits.[22] A review by NASA and DOE personnel later catalogued twenty-nine areas of concern in the MOD-2, characterizing seven as potentially serious, including the innovative teeter mechanism. In their report, the inspectors questioned some of Boeing's design practices, such as the use of friction joints and plastic shim material, but also criticized quality control during installation, and incomplete and vague installation instructions.[23] These problems required a number of shutdowns and retrofits.

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[20](...continued)
difficulties with the WTS-4, Hamilton Standard in 1982 left the wind business. Entrepreneur Bill Young purchased the WTS-4 as government surplus. His firm, Medicine Bow Energy, sold the WTS-4's electricity to the Western Area Power Authority until the machine perished in January of 1994. "Medicine Bow seeks funding for new Vestas turbine," *Wind Energy Weekly* (electronic version) 13 (18 April 1994).

[21]Bradford S. Linscott (NASA), Joanne T. Dennett (Rdd Consultants) and Larry H. Gordon (NASA), "The MOD-2 Wind Turbine Development Project," NTIS fiche DOE/NASA/20305-5 (July 1981).

[22]Larry H. Gordon, NASA-Lewis Research Center, "MOD-2 Wind Turbine Field Operations Experience," NTIS DOE/NASA/20320-69 (December 1985), pp. 2-3.

[23]William R. Johnson, *et al.*, "Government Review of the MOD-2 Wind Turbine (As-Built)," NTIS DOE/NASA/20320-63 (June 1985).

Complicating the story, different parties disagreed as to whether the MOD-2 represented a research effort or a commercial product. In an article mentioning the MOD-2's operational problems, a utility trade journal reported that "never intended as mature commercial wind turbines, the MOD-2s were viewed within the federal R&D program as the steppingstone to a more advanced turbine that could generate energy at an even lower cost."[24] NASA, by contrast, speculated that "although further wind turbine development is planned, MOD-2 machines carried into the production stage may form the backbone of the nation's first wind clusters."[25] This claim seems odd, given that elsewhere NASA identified the purpose of the third-generation MOD-5 as "to develop technology for multi-megawatt wind turbines that would be more cost competitive than the MOD-2."[26] Even as Boeing competed for contracts to sell the MOD-2, John Lowe predicted to Rep. Tom Harkin (D-IA) in the FY 1982 authorization hearings that the COE of Boeing's MOD-5 should fall 20-30% below the MOD-2, making the MOD-2 obsolete.[27]

"The nail in the coffin?"

Meanwhile, the electric utility industry, ostensibly the largest potential market for wind equipment, watched developments in the FWEP warily. For the most part, they looked to the Electric Power Research Institute for answers. Founded in 1972 to serve as the industry's research arm, EPRI drew membership dues from about 500 utilities. Since 1975, EPRI's Solar Energy Program had investigated the environmental impact of windpower, the lifetime and behavior of turbine materials and components, and the role of windpower in utility operations.

Edgar DeMeo, Manager of EPRI's solar branch, calls early utility interest in renewable technologies "defensive," as utilities looked for information to justify their

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[24]Taylor Moore, "Wind Power: A Question of Scale," *EPRI Journal* 9 (May 1984), p. 10.

[25]Linscott, *et al.*, "The MOD-2 Wind Turbine," pp. 19-20.

[26]Baldwin and Kennard, "Development of Large, Horizontal-Axis Wind Turbines," p. 5.

[27]Testimony of Lowe in U.S. Congress, *1982 DOE Authorization--Fossil, Solar*, pp. 494-495.

conservatism regarding alternative energy. While DeMeo stresses that no-one ever told his division to evaluate windpower negatively, he concedes that some inside the organization and among its clients "wouldn't have been upset if it didn't work." Later, a few utilities such as PG&E and Southern California Edison (SCE) developed genuine interest in windpower, and they encouraged EPRI to investigate its potential. EPRI's extensive research on wind resources and turbine performance included studies of BuRec's WTS-4 and the MOD-2 purchased by PG&E.[28]

DeMeo tells an intriguing story concerning EPRI's role in the last days of the large-turbine program. According to DeMeo, Boeing donated its in-house data to EPRI after ending its flyer in wind energy. Boeing, DeMeo affirms, had told the FWEP that they could produce large wind turbines for $900/kW. EPRI's interpretation of the Boeing data showed that they would only reach this level if production topped 50,000 MW--50 gigawatts!--per year. At a realistic rate of 200 MW per year, EPRI calculated costs at $3000/kW. DeMeo recalls that EPRI's figures "appalled" Divone. "He said, 'They slipped that one by me'" when confronted with EPRI's reworking of Boeing's data, recollects DeMeo, who terms this incident the "nail in the coffin" for the FWEP.[29]

Divone, for his part, concedes that "one problem NASA never really got fixed completely was that they were looking at mature product costs, the cost after a significant number produced. They never asked who was going to invest that money to get from here to there..." Divone recalls "massive" numbers of turbines, in the hundreds of thousands. "When you look at it, you say 'wait a minute, this isn't right.'" But in the FWEP's defense, Divone contends that later studies focussed on the cost of the 100th unit.[30]

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[28]Interview with Edgar A. DeMeo, Manager of EPRI's Solar Power Program, Generation and Storage Division, in Savannah, GA (4 October 1993). See also Piet B. Bos, "Introduction to Mission and Regional Analyses of Wind Energy Conversion Systems" in Eldridge (ed.), *Second Workshop*, pp. 79-81.

[29]Interview with DeMeo.

[30]Interview with Divone.

Published reports support Divone's claim that NASA eventually fixed the "production quantity" problem. For example, in 1981 NASA figured that "in mid-1977 dollars the estimated total turnkey cost of the 100th production unit for the [2500-kW] MOD-2 would be $1,720,000," or $688/kW. Given a 25% increase in prices due to inflation, this came to $2,147,000 in 1980 dollars, or $859/kW.[31] Similarly, Boeing reports from 1982 presented its 7200-kW MOD-5B in terms of the projected turnkey cost for the 100th unit. This came to $4.3 million, or $597/kW.[32]

But while NASA did consider costs for reasonable production quantities, they never told who they expected to pay the difference between the cost of producing the first ninety-nine units and their value to customers. The early Mission Analyses had calculated this "incremental revenue" for various scenarios,[33] and Lockheed had hoped that manufacturers would ameliorate the problem by pricing their products at the cost of, say, the 200th unit, and gamble on selling 500 units.[34] Manufacturers in a variety of fields routinely used such "loss leader" strategies to establish markets for new product lines. Even GE, one of the firms involved in wind turbine manufacture, intentionally took an enormous loss when selling its first commercial nuclear reactor.[35] But according to one independent wind developer who approached Boeing about the possibility of buying their machines for windfarm operation, the company insisted on selling each unit at its production cost.[36] No-

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[31]Linscott, *et al.*, "The MOD-2 Wind Turbine," p. 4.

[32]"MOD-5B Wind Turbine System Concept and Preliminary Design Report: Volume I--Executive Summary," Boeing Engineering and Construction, Seattle, WA, NTIS DOE/NASA-0200-1 (September 1982), p. 3/1.

[33]See, for example, GE, "Mission Analysis: Executive Summary," Table 4. Assuming reduction of capital costs by 25% due to R&D, GE projected reaching the breakeven point in the utility market after the 6300th unit, requiring $580 million in incremental revenue. Given the same 25% cost reduction, breakeven for units used in remote communities would follow the 15th unit, with an incremental revenue requirement of $13 million.

[34]Coty, "Mission Analysis: Final Report," p. 7/13.

[35]GE sold the 515-MW Oyster Creek plant to the Jersey Control Power and Light Company for $66 million, perhaps $30 million below its value. Ford, *Cult of the Atom*, pp. 62-63.

[36]Interview with Lotker.

one, it seemed, wanted to put up any "incremental revenue" to produce wind equipment, no matter what ultimate savings or earnings might accrue.

EPRI may indeed have found something in Boeing's proprietary data that damned large turbines as a practical commercial product. At any rate, the Institute altered its position on windpower. The *EPRI Journal's* first full-length piece on windpower in 1980 referred briefly to the potential of entrepreneurial windfarms, while scarcely mentioning the DOE's small-turbine program. Rather, the utility industry organ praised the amount of money, labor and analysis in the DOE large-turbine effort, and quoted with approval the rhetorical question posed and answered by Boeing's Lowe: "What is different about the MOD-2 project than the others? We've just done a whole lot more work more thoroughly."[37]

By 1984, however, in its second major article on windpower, the *EPRI Journal* changed its tune, reporting that "economic, technical, and political forces have combined to push further into the future the time when large, megawatt-scale wind turbines may be considered as a commercial generating technology." The EPRI author detailed with concern possible "diseconomies of scale" and the potentially substantial impact of operations and maintenance costs on the COE from large-turbines. "Increasing size implies increasing complexity," the author noted, because of the cost of additional controls and devices required to maintain reliability. "Investment risks increase significantly as one moves up the technological scale. A single large wind turbine may cost $10-15 million to install and have a projected reliability based entirely on estimates." In contrast to its earlier enthusiasm, EPRI argued that the optimal size for wind turbines lay in the intermediate range, which the DOE had long ignored.[38] EPRI may indeed have based this about-face on the acquisition of Boeing's production-cost data.

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[37] "Going With the Wind," *EPRI Journal* 5 (March 1980), p. 15.

[38] Moore, "A Question of Scale," p. 8.

The last giants: the MOD-5s

Following the advice of numerous witnesses in the 1979 Congressional hearings, NASA planned to develop the MOD-5, the third and projected final generation of FWEP multi-megawatt wind turbines, through parallel contracts designated the MOD-5A and MOD-5B. Both GE and Boeing won FWEP awards for individual designs intended to achieve COE of under 3.75 cents/kWh. GE's innovative 7.3-MW MOD-5A design incorporated a 400-foot, upwind, teetered rotor inclined 7 degrees off the horizontal. While the light blades included fiberglass and metal elements, wood represented their surprising primary material--specifically, Douglas fir laminate. To eliminate the problematic low-speed shaft, GE mounted the rotor directly on the three-step gearbox, which combined two innovative epicyclic speed increasers and one conventional parallel shaft increaser. Rather than full- or partial-span pitch control, aircraft-type ailerons maintained constant rotational frequency. GE predicted that the COE for the 100th unit would lie around 3.69 cents/kWh.[39]

Meanwhile, Boeing used MOD-2 technology in its MOD-5B, initially a 7.2-MW, 420-foot turbine. Its major advance over the firm's MOD-2 consisted of a variable-speed generator, allowing the rotor to turn at various speeds over a limited range, increasing efficiency by matching changing wind speeds. Boeing estimated the COE for the 100th unit at 3.24 cents/kWh.[40]

In 1983, cramped by Reagan Administration's budget cuts, the FWEP solicited cost-sharing proposals from its MOD-5 contractors, offering to fund the design process if the manufacturers took responsibility for funding the hardware. Both Boeing and GE refused. As an alternative, they opted to market the prototype MOD-5s as commercial products, and they sought a utility customer willing to purchase them. Each company pursued an

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[39]GE, Advanced Energy Systems Department, "MOD-5A Wind Turbine Generator Program Design Report: Volume I--Executive Summary," NASA N68-27708 (August 1984).

[40]Boeing, "MOD-5B Design Report: Executive Summary."

arrangement with the Hawaiian Electric Company, but in December of 1983, unable to negotiate satisfactory contract, GE abandoned its MOD-5A design and dropped out of the wind business altogether.[41]

Soon afterward, Boeing ended plans to mass-produce a 3.5-MW turbine with a 330-foot rotor, essentially an improved MOD-2. According to the FWEP's Dan Ancona, the company's windpower subsidiary, Boeing Engineering and Construction (BEC), had already assembled a design team consisting of hundreds of people, and it had planned dedicated production facilities. Denver's AeroTurbine Corp. had contracted to buy BEC's entire production run through 1985 and large portions of it subsequently; Aeroturbine intended to install the first machines near Fairfield, CA and sell the electricity to PG&E.[42]

Ancona estimates that the project came within six months of commercial production. "It probably would have worked," he recalls, "if OPEC hadn't become unglued and oil prices hadn't dropped to $12 per barrel." Ancona supposes that Boeing foresaw that utilities would not be beating the brush for generating options. "It was a business decision," he shrugs.[43] In 1982, Boeing announced that it would pursue no new windpower ventures, and it reabsorbed BEC into its Aerospace Division. At about the same time, Hamilton-Standard, Bendix, ALCOA and other large firms involved in the wind business pulled out as well.

However, even after announcing the end of its interest in windpower, Boeing opted to complete the MOD-5B project. Hawaiian Electric agreed to purchase the machine,

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[41]In explaining its decision, GE cited the expected expiration of Federal tax credits for windpower at the end of 1985, which they believed would dry up private sector interest and investment, making it unlikely that they could find customers for wind equipment. Baldwin and Kennard, "Development of Large Turbines," pp. 5-6.

[42]Ray Vicker, "PG&E Hopes to Be Buying Electricity From Biggest U.S. 'Wind Farm' by 1985," *The Wall Street Journal* (11 November 1982), p. 20; interview with Ancona.

[43]Telephone interview with Ancona.

provided that it successfully passed on-site tests.[44] Boeing shipped the giant--diminished from its projected dimensions to a 3.2-MW, 320-foot machine--from Seattle to Oahu in 1987. A 350-ton crane for installation accompanied it, since none large enough existed in the state. The MOD-5B project cost a total of $58 million: $42 million for design, $13 million for construction, and $3 million for testing.[45]

Despite optimistic initial reports,[46] the MOD-5B experienced nagging problems. HECo had difficulty securing spare parts for the Boeing machine and for fifteen 600-kW units, called WWG-600s, purchased from Westinghouse. "These machines were the only ones of their kind in the world," the president of HECo's renewable energy subsidiary later explained. "When parts were needed for these turbines, we frequently had to have them made."[47] Partly for this reason, HECo announced in 1992 the termination its wind energy operation, taking a substantial loss of cash reserves in the process.[48] Recently, the Macani Uwila Power Corp., a subsidiary of New World Power Corp., purchased the MOD-5B and the Westinghouse machines for the purpose of selling the power back to the Hawaiian utility, perhaps taking advantage of incentives not available to utility companies.[49]

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[44]Although HECo stipulated that the MOD-5B pass performance tests before they took possession, one developer charged that Boeing would not offer long-term performance guarantees with its products, making them a poor risk for independent investors. Interview with Lotker.

[45]Victor Laniauskas, "Letter from Hawaii," *Far Eastern Economic Review* 139 (21 January 1988), p. 76.

[46]"Hawaii's wind turbine," p. 36.

[47]Al Manning, President of Hawaiian Electric Renewable Systems, quoted in Leslie Lamarre, "A Growth Market in Wind Power," *EPRI Journal* 17 (December 1992), p. 11.

[48]"Hawaiian Electric Quits Business," *The Wall Street Journal* (8 October 1992), p. C18. By 1992, the Hawaiian Electric Company had become the diversified Hawaiian Electric Industries. Some observers speculated that the financial crisis occasioned by Hurricane Iniki, which scuttled a HEI subsidiary, the Hawaiian Insurance Group, forced HEI to cut loose all its marginal investments, including Hawaiian Electric Renewable Systems.

[49]Dan Ancona, Ron Loose and Jack Cadogan, "The United States Wind Energy Program in a Decade of Change," presented at the European Community Wind Energy Conference in Travemunde, Germany (March 1993).

Conclusion

The MOD-2 and MOD-5 projects addressed many common criticisms of the FWEP. For example, the purchase of the MOD-2s by the BPA and BuRec advanced windpower by using the Federal government's status as the country's largest consumer. The BuRec System Verification Project attempted to link windpower and pumped hydro-storage, proposed by windpower advocates since Palmer Putnam in the 1940s. The MOD-5 project instituted parallel contracts, giving purchasers a choice between two designs, and encouraging competition between the contractors. In addition, the FWEP made few constraints on the MOD-5 design other than requiring a final COE under 3.75 cents/kWh. And, when forced by funding cuts, the FWEP demanded a financial commitment by either the manufacturers or the users of wind technology. Finally, in one notable instance, described below, a private electric utility purchased a MOD-2 wind turbine developed as part of the FWEP. While many of these moves came late in the day, they might have encouraged a healthier program--if only the price of oil had remained high.

## PART III: The Oil Glut

In 1971, the price of oil sank to a nadir of $1.21 per barrel ($/bbl). Less than ten years later, during the supply crunch occasioned by the Iranian Revolution, panicked Japanese traders pondered quotes approaching $50/bbl for spot market purchases.[50] By then, to the average American, OPEC seemed to have an unshakable grip on the American economy, and worse, on the American lifestyle. OPEC's waxing power threatened the habits that Americans considered their cultural birthright--driving big cars, relaxing in air-conditioned homes and movie theaters, and leaving the porch light burning through the night. This attitude perhaps explains the appeal to millions of voters of Ronald Reagan's assurances that the "crisis" existed only in the mind of an ascetic and craven Democratic President. But large corporations such as GE, Boeing, Grumman and Kaman Aerospace, who had pursued windpower in the 1970s for purely economic reasons, apparently believed

[50] Yergin, *The Prize*, p. 702.

in the reality of the energy crisis. At least they found the threat of oil at $100/bbl lurking in the future real enough to consider developing products for an oil-scarce economy.[51]

From the very beginning of the corporate windpower experiment, the players used the rising price of oil as a rhetorical justification for the venture. The 1977 General Electric Mission Analysis assessed the breakeven costs of wind turbines (*i.e.*, the cost at which the price of turbines equaled their economic value to customers) given three fuel-price scenarios: rises in step with 6% annual inflation, rises of 50%, and rises of 100%.[52] Lockheed's 1976 Mission Analysis also noted the relevance of OPEC policies to windpower economics.[53] JBF's 1977 normalization study noted that anticipated rises in fuel prices would help windpower by increasing the cost of energy from conventional generating technologies, and predicted that oil prices hikes exceeding 9.3% annually would make windpower economically advantageous.[54] Oil prices clearly represented the standard against which turbine users and manufacturers measured their value.

To the shock of the world, the 1980s brought not higher but progressively lower oil prices. After peaking at $42/bbl in September of 1979, the world price for benchmark Arabian light oil plummeted to $10/bbl in the spring of 1986.[55] (See Tables 6 and 7 below.) Reagan took credit for making the energy-crisis bogey disappear, and he drew cheers by asking crowds whether they enjoyed watching gasoline pumps rack up the gallons

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[51]Or they may have found the alternative energy business a cheap public relations ploy, given that the Federal government funded much of the research. Any actual sales or valuable results would have been serendipitous extras. Nevertheless, GE probably shared the nation's shock at the oil embargo. Their mixed corporate motives presumably included a belief that oil prices might well soar out of sight, in which case the firm would benefit from having a substitute product ready. And companies such as ALCOA and Boeing did invest in their windpower initiatives.

[52]GE, "Wind Energy Mission Analysis: Executive Summary," pp. 14-15.

[53]Coty, "Mission Analysis: Final Report," Lockheed, p. 7/19.

[54]JBF, "Summary of Current Cost." pp. 2, 4-5.

[55]Fred Barnes, "Oil Together Now," *New Republic* 196 (9 February 1987), p. 12.

faster than the dollars. In submitting 1985's National Energy Policy Plan to Congress, the President wrote that:

> I am pleased to report to you that the state of our energy health is good, and the prospects for its future promising... Crude energy prices have declined... We have rightly placed our trust in our people, and in the belief that we were not running out of energy, only imagination... We stand at the beginning of a new era of energy strength.[56]

However, analysts derided his administration's "policy of benign neglect"[57] toward energy. Rather, they attributed the price-drop to the entry into the world market of new suppliers, primarily the British North Sea operation, Mexico and Alaska, and to the surprising impact of conservation.

**TABLE 6: Fossil Fuel Prices, 1970-1991, in cents per million British thermal units**

| YEAR | NOMINAL DOLLARS | | CONSTANT 1987 DOLLARS | |
|---|---|---|---|---|
| | Composite | Crude Oil | Composite | Crude Oil |
| **1970** | 31.7 | 54.8 | 90.3 | 156.1 |
| **1973** | 39.8 | 67.1 | 96.4 | 162.5 |
| **1975** | 82.1 | 132.2 | 166.9 | 268.7 |
| **1980** | 204.2 | 372.2 | 284.8 | 519.1 |
| **1983** | 270.1 | 451.6 | 309.7 | 517.9 |
| **1984** | 264.6 | 446.2 | 290.8 | 490.3 |
| **1985** | 251.2 | 415.3 | 266.1 | 439.9 |
| **1986** | 165.3 | 215.7 | 170.6 | 222.6 |
| **1987** | 170.0 | 265.5 | 170.0 | 265.5 |

[56]Ronald Reagan in "The National Energy Policy Plan," U.S. Department of Energy, DOE/S-0040 (1985), p. iii.

[57]James J. MacKenzie, "Lower Oil Prices Fuel Concern," *Technology Review* 89 (August-September 1986), p. 27.

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|---|---|---|---|---|
| **1988** | 153.3 | 216.9 | 147.5 | 208.8 |
| **1989** | 167.1 | 273.4 | 154.2 | 252.2 |
| **1990** | 184.3 | 345.3 | 163.2 | 305.8 |
| **1991** | 165.7 | 284.5 | 141.6 | 243.2 |

Data from U.S. Bureau of the Census, *Statistical Abstracts of the U.S.--1993*, 113th ed. (Washington, DC: 1993), no. 942. Composite price consists of crude oil, natural gas, and bituminous and anthracite coal prices, weighted by relative importance in total fuel mix.

| **TABLE 7: U.S. Crude Oil Prices in nominal dollars per barrel** | | |
|---|---|---|
| **YEAR** | **Domestic first purchase price** | **Composite refiner acquisition cost** |
| **1976** | 8.19 | 10.89 |
| **1977** | 8.57 | 11.96 |
| **1978** | 9.00 | 12.46 |
| **1979** | 12.64 | 17.72 |
| **1980** | 21.59 | 28.07 |
| **1981** | 31.77 | 35.24 |
| **1982** | 28.52 | 31.87 |
| **1983** | 26.19 | 28.99 |
| **1984** | 25.88 | 28.63 |
| **1985** | 24.09 | 26.75 |
| **1986** | 12.51 | 14.55 |
| **1987** | 15.40 | 17.90 |
| **1988** | 12.58 | 14.67 |
| **1989** | 15.86 | 17.97 |
| **1990** | 20.03 | 22.24 |

Data from *Energy Facts 1990*, Energy Information Administration (Washington, DC: U.S. Government Printing Office, 1991), p. 44. Refiner composite acquisition cost averages price of domestic and imported oil according to relative contribution to domestic market.

Conservation

Throughout the decades of economic growth in the middle of the twentieth century, most Americans assumed--if they considered the subject at all--the inelasticity of energy demand with respect to price. Electricity in particular seemed so basic to national comfort, progress and prosperity that no-one could imagine Americans using less of it, even if the price rose.[58] Yet, starting in the early 1970s, the nation cut its use of all forms of energy, including electricity, in response to a mixture of high prices, Federal incentives, and economic recession. During the decade before the embargo total American energy use had climbed 4% annually, but in the next eight years the curve flattened at less than 1% annual growth.[59] Pre-embargo use of electricity had grown even faster, at about 8% annually, but in the immediate wake of the oil shock, Americans lowered annual increases to under 3%.[60] From 1979 to 1984, 29 million Americans claimed conservation exemptions on their Federal income tax. And, contradicting those who assumed that economic growth followed energy use, energy consumption per unit of gross national product dropped 35% between 1973 and 1988.[61]

Slackening demand for electric power due to increased efficiency and conservation had a negative impact on the utility industry, and the wind industry suffered as well. In the late 1960s and early 1970s, American utilities had responded to growing demand and creeping brownouts by deluging their equipment suppliers with orders for new generators. The ordering spree reached such a magnitude that delivery schedules often included five-

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[58]See Hirsh, *Technology and Transformation*, pp. 127-128. Some economists argued for calculation of demand elasticity as a variable dependent on price. Andelman, for example, affirms that "the higher the price, the greater the response to a given price change." "OPEC at Thirty Years," p. 11. Alternatively, it may help to conceive of consumer response to price change in historical terms, by considering the population's expectations and current definition of reasonableness, as well as the perceived cause of the change.

[59]Eric Hirst, "Cutting into conservation," *Bulletin of the Atomic Scientists* 47 (May 1981), p. 10.

[60]Hirsh, *Technology and Transformation*, p. 128.

[61]"A light in the attic," *Commonweal* 115 (25 March 1988), p. 163. See also Eric Hirst, Robert Marlay, David Greene and Richard Barnes, "Recent Changes in U.S. Energy Consumption: What Happened and Why," *Annual Review of Energy* (1983), pp. 193-245.

year delays. But before these units came on line, soaring prices had stifled electricity demand.[62] Utility managers, worried that state regulators would disallow the recovery of costs from "unnecessary" construction, showed progressively less interest in buying new equipment, including wind turbines.

The tide turns against OPEC

The most effective strategy for the OPEC nations during their days of power might have been slowly to ratchet up prices, testing the waters at each step. Unfortunately, a majority of the organization's members depended almost completely on oil for income, and they felt unable to move slowly, especially those that had planned ambitious domestic development programs with their new wealth. In other cases, price hikes reflected sheer greed.

The continual price hikes--often resisted by the cautious Saudis--encouraged the fuel switching, conservation and market entry by new suppliers that eroded OPEC's market share. In 1977, OPEC's members produced two-thirds of the non-communist world's oil; after five years, their share had slipped to less than half. Although the war between Iran and Iraq applied upward pressure to prices, by the end of 1979, the trend clarified. In that year, some OPEC members cut prices in order to hold demand steady. In 1982, OPEC became a true cartel, setting production limits for its members as well as determining prices.[63]

The steady slide of prices presaged an irretrievable waning of OPEC's global power. The cartel trembled as members cheated on and then tossed aside their quotas, trying to protect individual revenues. Then, in 1986, the desperate and suddenly aggressive Saudis initiated an incredible game of chicken. In an attempt to force Britain and other non-OPEC producers to negotiate a price floor, the Saudis doubled production, flooding the world with cheap oil. Britain held firm, but Mexico reeled, as did the Saudis' debt-ridden OPEC

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[62]Hirsh, *Technology and Transformation*, pp. 100-102.

[63]Yergin, *The Prize*, pp. 744-768.

partners, Nigeria and Venezuela.[64] In America, prices fell so fast that even some free-market Republicans began quietly to fret. Speechwriter Patrick Buchanan admitted that the President no longer boasted about falling gasoline prices when he toured the stunned oil economies of Texas, Oklahoma and Louisiana. Vice President (and Texas oilman) George Bush chimed in with calls for "price stability."[65] Low prices also worried analysts with an eye to the long-term future, who foresaw resurgent demand and ebbing interest in conservation.[66]

## Conclusion

The collapse of the petroleum market ended or reduced investment in a number of energy projects, including the Exxon-Tosco oil shale initiative, the Alaskan gas pipeline and the Canadian Alsands project.[67] For the FWEP, under wilting attack by Stockman's OMB and conservative legislators, the glut provided a final obstacle; as one Federal wind administrator mournfully recalls, "with oil at ten dollars per barrel, who cared?"[68] Without the hullabaloo of an "energy crisis" riling voters, legislators allowed the Reagan Administration to transform the FWEP into a modestly-funded long-term research effort, a form more in tune with the fiscal philosophy of the President and his advisors. Those who doubted the wisdom of shutting down the government's commercialization-oriented renewable energy programs had only to reflect on the embarrassing mishaps experienced by FWEP turbines in the field, and consider the alternative to multi-megawatt utility-owned turbines then budding in California.

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[64]John Greenwald, "Awash in a Sea of Oil," *Time* 127 (3 February 1986), p. 52.

[65]Barnes, "Oil Together Now," p. 12.

[66]MacKenzie, "Lower Oil Prices," p. 27.

[67]Colglazier and Deese, "Energy and Security," pp. 423-424.

[68]Interview with Robert Thresher, Director of NREL's Wind Technology Division, in Savannah, GA (5 October 1993).

**PART IV: Utility Experiences: "We dynamited the sucker..."**

Only three American investor-owned utilities purchased megawatt-scale wind machines. Not coincidentally, all three depended heavily on imported oil. The Hawaiian Electric Company, whose home state had begun exploring the potential of windpower soon after the oil embargo,[69] hosted a MOD-0A and later purchased the largest Federal machine constructed, the 3.2-MW MOD-5B. In December of 1985, HECo also constructed the first, and in 1994 still one of the only, utility-owned windfarms, using Westinghouse WWG-600s. Although HECo later sold its machines, it continued to purchase wind-generated electricity from private windfarms.

In 1979, two-thirds of Southern California Edison's generating capacity burned oil. By the mid-1980s, SCE, lauded as "the most imaginative power company in the U.S.,"[70] boasted that it generated energy from nine separate sources. Much of the impetus for SCE's forays into non-conventional energy came from chairman William Gould, who bowed to the inevitable economic and political liabilities of nuclear power and announced in 1980 that SCE planned to install at least 2100 MW of alternative energy within the decade, including 43 MW of capacity displacement from wind.[71] Gould wrote that SCE had chosen "the least risky course of action... because it provides the best opportunity for SCE to continue as a viable business enterprise."[72]

Earlier, the FWEP had rejected SCE's proposal to host a Federal turbine. Piqued, the utility purchased a 500-kW Darrieus machine from ALCOA and a 3-MW unit designed by Charles Schachle for the Bendix Wind Power Products Co., and installed the turbines at a

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[69]Donald W. Grace, "The Potential of WECS for Hawaii," in Eldridge (ed.), *Second Workshop*, pp. 130-132. Hawaii used oil to fuel 93% of its generating capacity, and not even the archipelago's largest island used enough power to justify a nuclear reactor; hence HECo's early interest in windpower.

[70]Marc Reisner, "The Most Imaginative Power Company in the U.S.," *Science Digest* 94 (August 1986), p. 66.

[71]"Going With the Wind," p 9.

[72]Quoted in Reisner, "The Most Imaginative," p. 66.

site near Palm Springs, CA. The Schachle turbine differed from DOE designs in several respects, but proved operationally disappointing.[73] Due to a software bug, the ALCOA unit destroyed itself in a testing mishap.[74] Like HECo, SCE relinquished plans to own windpower capacity, and under the goading of Federal and state laws, came reluctantly to purchase large quantities of wind-generated electricity from California's windfarms.

PG&E represented the third private utility to explore the potential of megawatt-scale wind turbines. Also over-dependent on oil, the California utility in 1980 planned to bring 82.5 MW of windpower on line during the following decade.[75] Like SCE, PG&E participated in the FWEP site-selection program, but never received an experimental turbine. In 1980, after soliciting bids for a large wind turbine, the firm accepted Boeing's offer to construct the fifth (and, as it turned out, final) MOD-2, the only FWEP-designed machine fabricated under contract to an investor-owned utility. Construction began at a Solano County site in June of 1980, and PG&E took possession two years later.

As a "project," the MOD-2 met with reasonable success. By the time PG&E dismantled the MOD-2 in November 1988, it had produced more energy than any wind machine ever.[76] The BPA and BuRec had long since terminated their MOD-2 projects.

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[73]Robert L. Scheffler, SCE, "Status of the Southern California Edison Company 3 MW Wind Turbine Generator (WTG) Demonstration Project" in "Large Wind Turbine Design," pp. 355-359. The three-bladed Schachle unit transferred rotor power to the ground-based generator through a hydraulic linkage. Instead of a yawing nacelle, the entire turbine rotated on a track to face the wind. The DOE-based windpower community pooh-poohed these design decisions.

[74]James L. Schefter, *Capturing Energy from the Wind*, NASA SP-455 (Washington, DC: NASA, 1982), p. 75.

[75]"Going With the Wind," p. 9. In 1980, PG&E's resource mix included 44.5% oil and gas steam generation, 32.5% hydropower and pumped storage, 8.5% bulk power purchases, 5.5% geothermal, 5.3% nuclear, 2.5% gas turbines, and 1.3% cogeneration and solid waste conversion. PG&E, *1980 Annual Report*, p. 7.

[76]PG&E's MOD-2 generated about 5 million kWh of energy at its 18-mph Solano County site during the three-year period ending in spring of 1985. However, Boeing's original predictions of MOD-2 performance undermined this achievement; Lowe, for example, had suggested that MOD-2s in a 14-mph site could generate 10 million kWh *per year*. Quoted in Naar, *The New Wind Power*, pp. 171-172. For purposes of comparison, in 1985 PG&E purchased 379 million kWh from entrepreneurial windfarms in the Altamont Pass. Starrs, "Legislative Incentives," p. 121.

PG&E's machine served as the basis of a two-year EPRI-sponsored research project which produced upbeat conclusions regarding site wind resources, the turbine's performance, avian mortality rates ("bird strikes"), audible noise and television interference. Most important, the project provided data on the relationship between the wind resource and the utility's demand curves.[77]

PG&E found that Solano winds blew the strongest in the summer, when they topped the MOD-2's cut-in speed 96% of the time and surpassed its rated wind speed 48% of the time. During the winter, on the other hand, strong winds only occurred during infrequent storms. This pattern nicely matched PG&E's demand curve, weighted heavily toward the summer due to irrigation and air-conditioning loads. Daily wind patterns did not provide as fortuitous a fit. Solano winds built from a calm period in the late morning to a peak in the evening, when they began to die down. At the time of heaviest loads, summer afternoons between three and four o'clock, wind energy corresponded only to about two-thirds of the MOD-2's rated 2.5 MW.[78]

Nevertheless, PG&E estimated the load-carrying capability (LCC)[79] of the MOD-2 at a "surprisingly high" 80%. By examining the MOD-2's power production during hours of peak demand, PG&E's research branch calculated that a completely reliable power plant with a rating of about 2 MW would have had the same load-carrying capacity as the 2.5-MW MOD-2, assuming the MOD-2 had been available during all the times that the wind blew. Of course, neither wind, nuclear nor fossil plants are completely reliable; conventional facilities also spend time off-line due to routine maintenance and forced

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[77]William J. Steely, Mary Ilyin and K. Firor, "MOD-2 Wind Turbine Field Experience in Solano County, California," prepared by Pacific Gas & Electric Co. for the Electric Power Research Institute, EPRI AP-4239 (September 1985), *passim.*

[78]*Ibid.*, pp. 2/8-2/12.

[79]A generator's load carrying capability, or capacity credit, refers to the probability that it will be available to generate energy when needed. Dispatchers assessing a plant's contribution to their utility's total generating mix will count its LCC rather than its rated capacity. For example, a 100-MW plant liable to forced outages 10% of the time has an LCC of 90 MW.

outages. Because the MOD-2 suffered so many outages, it actually posted a LCC of 74%, still higher than expected, in part because it happened to run well during peak demand hours. This demonstration of windpower's potential to play a "responsible" role in utility operations surely won some converts in the firm, and it helped repair the unit's poor reputation.[80]

That reputation stemmed from continuous operational failures, compounded by what project manager Mary Ilyin remembers as a "lack of support" from Boeing.[81] Serious trouble spots included improper blade-tip lubrication and seal design, and cracks in what Joseph Iannucci, the executive in charge of PG&E's wind program, refers to as "that damned low-speed shaft."[82] In fact, a total of three shafts failed before PG&E gave up on its MOD-2. Because of these and other problems, the unit posted a mean operating time between failures of only 20.6 hours in its first year of operation, although that improved steadily to 129 hours in 1987.[83] From 1984 to 1987, capacity factor remained between 12 and 17% during a period when wind conditions would have allowed capacity factors between 34 and 38% had the turbine achieved 100% availability.[84]

Iannucci believes that in some ways Boeing designed the machine without consideration for utility operators. For instance, early in the MOD-2's history at PG&E, problems with the control system produced unstable frequency oscillations, provoking frequent automatic shut-downs. But the MOD-2 lacked a remote control switch, or even a remote indicator to tell dispatchers that the machine had turned itself off. The lack of remote controls, combined with safety regulations prohibiting a lone employee from working

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[80]Smith and Ilyin, "Solano MOD-2," pp. 3/1-3/3.

[81]Personal communication to Adam Serchuk from Mary Ilyin, Project Manager at PG&E (19 January 1994).

[82]Interview with Joseph Iannucci, Distributed Utility Associates, in Savannah, GA (3 October 1993).

[83]Steely, *et al.*, "MOD-2 Field Experience," p. S/5.

[84]Smith and Ilyin, "MOD-2 Operating Experience," p. 4/1.

on an "active powerplant," meant that "three or four people had to drive fourteen miles to hit a button."[85] Often, these people had conflicting responsibilities concerning much larger, more important facilities. This trifling design flaw had a severe impact on statistics tracking hours that the MOD-2 spent off-line.

While picayune, the bug indicates more serious problems, not only with Boeing's machine, but with PG&E's treatment of it. Although the PG&E press release announcing the retirement of the MOD-2 states that "the Solano turbine was installed and tested as a research project," the final report written by managers sympathetic to the project notes bitterly that "PG&E bought the turbine believing that it was ready for commercial use."[86] For that reason, perhaps, PG&E tried to run the MOD-2 as a working powerplant whose cost they could recover from ratepayers, rather than as an experiment. Iannucci is more expansive on this topic:

> It was the first one Boeing ever sold, and [PG&E] made it an operating powerplant in rate base? Big mistake! I don't think the [California Public Utilities Commission] ever disallowed any costs, but it was a mistake to assume that it could take care of itself without any tender-loving care. All of a sudden the Steam Generation Department has this thing, it doesn't produce any steam, and it's failing...[87]

Rather than handing the MOD-2 over to the company's conventionally-trained engineers, who may have lacked sympathy for the concept of renewable energy, Iannucci suggests that PG&E ought initially to have signed it over to the more flexible and innovative division of Research, Development & Demonstration.

Carl Weinberg, who managed PG&E's research activities at the time, agrees with Iannucci's assessment. He recalls arguing that

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[85]Interview with Iannucci. See also Smith and Ilyin, "MOD-2 Operating Experience," p. 5/1.

[86]"Retirement of PG&E's Solano wind Turbine," PG&E Fact Sheet (November 1988), reprinted in Steely *et al.*, "MOD-2 Field Experience," p. 5/2, and; Steely *et al.*, "MOD-2 Operating Experience," p. 5/1.

[87]Interview with Iannucci.

> ...we ought to approach it as a research project. But Boeing told us, "Sure, it's commercial. We can build them just like airplanes." Because one of the things in America is, if you can't promise that your next unit will be commercial, you don't get any more research funds. Once they plugged it in, they found out they didn't know how to operate it. My R&D group got the right to get data off it. The first few years it was terrible... Partly it was a new gadget, but it also had a low dispatch priority within PG&E. It could be a few days before a guy could be sent out there to replace a blown fuse. But for a while it operated better than any of the other Boeing MOD-2s...

Weinberg recalls that it became difficult to repair the MOD-2 once Boeing left the wind business, even after PG&E purchased spare parts off the BPA's three MOD-2s at Goodnoe Hills at that project's end.[88]

As PG&E lost money on the MOD-2, and as oil prices dropped, the company decided to take the unit out of commission. Weinberg received the option to run it out of his research budget. He recalls the decision's wrenching effect on some members of his division:

> My staff... went through soul-searching for six months. They concluded that we had learned as much as we could. Even though people loved it, and cried over it, I went to the operations people, and told them I couldn't justify keeping it... I think it was the right choice. In research you have the tendency to hang on, even though it isn't giving you anything of value...

In November of 1988, amid great festivities and to the apparent satisfaction of some of PG&E's more reactionary employees, the company destroyed the MOD-2. As Weinberg wistfully recalls, "we dynamited the sucker only a few years ago..."[89]

## Conclusion: The Lean Years

The Federal wind program has maintained a continuous administrative existence through the mid-1990s. Divone ascended the DOE hierarchy, and other staff disappeared, but Ancona, Thresher and a few other stalwarts weathered the lean years of the Reagan and

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[88]Interview with Weinberg.

[89]Interview with Weinberg. Like Weinberg, Iannucci remembers the incident with distaste: "It was blown up by Power Control... They went out with dynamite, gleefully took pictures and videos, invited the media, and blew it up, with great ceremony... That was disgusting." Interview with Iannucci.

early Bush Administrations. In fact, since 1990, the FWEP has seen a remarkable renaissance. But, when PG&E dynamited its MOD-2 in 1988 to a chorus of jeers and tears, the explosion seemed a grim punctuation to a well-intentioned but troubled program.

The FWEP manifested a number of internal problems. In particular, as a program founded on "technology push" rather than "market pull," the FWEP aroused no groundswell of enthusiasm for windpower among utilities. Few large manufacturing firms committed their own resources to turbine fabrication, and many small firms remained under-capitalized. Still, a few utilities in areas where fuel costs were high showed a real interest in wind, and EPRI blessed the concept. Among manufacturers, Boeing almost initiated a major fabrication venture, and many of the smaller firms proved themselves rabidly in favor of windpower for philosophical reasons. More important, as we will see in later chapters, some companies abandoned the FWEP altogether to establish a "windfarm" industry based on tax and other regulatory incentives.

The FWEP turbines themselves displayed troubling characteristics. EPRI backed off of its endorsement of the large-turbine concept, and while turbine engineers learned a good deal from NASA's large-turbine program, the machines themselves proved disappointing, as did large turbines built without FWEP funding. NASA's development style, based on high technology, lavish budgets and a guaranteed market, seemed ill-suited to building large numbers of cheap, dependable commercial machines. And, although some of the smaller turbines developed under the FWEP achieved success, the disastrous Field Evaluation Program sabotaged windpower's reputation among utilities, legislators and purchasers.

These troubles became apparent as early as in the late 1970s. As we have seen, the FWEP community might have overcome them in time. As it turned out, the FWEP did not have the leisure to reflect on and improve its operations. The Reagan Administration and Republican legislators elected during the "tax revolt" of the late 1970s and early 1980s pursued a vendetta against renewable energy technologies, including windpower. And, apparently shutting the door on further development with a bang, a dramatic collapse of world oil prices greatly reduced interest in alternative energy sources among potential customers and manufacturers of wind technology, electric utilities and lawmakers. Those who kept their commitment to the concept, however, soon made their way to the new windpower Mecca, California.

# CHAPTER EIGHT
# Political Winds in California

## Introduction: Why California?

Not until the early 1990s did utility-scale windpower evoke serious interest from utilities in geographically dispersed parts of the country. Until then, large windfarms remained a unique feature of the Californian landscape (although a few turbines also turned in Hawaii). Casual observers attributed California's leadership to an abundance of wind. To the contrary, a recent evaluation of national wind resources by Pacific Northwest Laboratories ranks California seventeenth in usable wind resources.[1] The survey demonstrates that California's leadership in the use of windpower (and alternative energy strategies in general) derives from a heightened sense of need and the political will to address that perceived need creatively.

The "energy crisis" in America's most populous state pre-dated the oil embargo and price hikes of 1973-74. Myriad responses to the perceived predicament even included an improved, FWEP-style wind energy program. This initiative proved as politically vulnerable as the Federal wind effort. Windpower, when it blossomed in California, took a completely different form. Inspired by a culture of creativity and compelled by a shared sense of urgency, California devised a decentralized, entrepreneurial model of electricity generation. To prepare for an explanation of how that happened, this chapter first explores California's political landscape and energy dilemma in the 1970s.

## PART I. Growth in the Land of Plenty

In 1970, approximately one American in ten--some twenty million--made their home between the Sierra Nevada Mountains and the Pacific Ocean. Benefitting from vast migrations of Asians and Mexicans seeking affluence and opportunity, as well as a flow of

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[1]Utility Wind Interest Group, "America takes stock of a vast energy resource," Electric Power Research Institute (February 1992), no pagination. On the other hand, California enjoys *concentrated* winds near population centers and transmission facilities.

sun-starved Easterners, California's influence in the Union waxed after World War II. The 1950 census awarded the nation's third-largest state seven new Congressional seats, followed by eight more in 1960 and five more in 1970. Only the United States itself, Japan, West Germany and the Soviet Union boasted gross products larger than California's. The state economy boomed; in fiscal 1970, the Department of Defense alone spent almost $10 billion on Californian contractors and military installations.[2] And, although the state's fecund agribusiness and thriving cities hid large numbers of migrant workers and urban poor, most Californians enjoyed affluence unknown in other countries.

Although the East Coast dominated the nation's finances, the Golden State emerged in the twentieth century as a cultural pacesetter. The state often demonstrated political shifts--to the left and to the right--in advance of the rest of the country. For instance, while Californian campuses such as Berkeley incubated liberal causes such as the anti-war and free speech movements, the state also hatched a set of culturally conservative politicians who articulated the mood of America's suburban middle class.

Thus, the state had the odd honor of contributing to the national scene both Ronald Reagan and Jerry Brown. Reagan, in the words of one caustic assessment, won his place in history by telling "the unpoor, the unblack and the unrebellious that their basic fears and impulses were well founded, that their way of life--whatever hippies and academics might think--was right."[3] Brown, by contrast, studied Zen, gallivanted with rock-and-roller Linda Rondstadt and told voters airily that he wanted to "re-equip human beings with the tools and

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[2]Michael Barone, Grant Ujifusa and Douglas Matthews, *The Almanac of American Politics--1972* (Publisher's location not identified: Gambit, 1972), pp. 40, 42.

[3]Barone, Ujifusa and Matthews, *The Almanac of American Politics--1978* (New York: E.P. Dutton, 1978), p. 47. Reagan governed California from 1967 to 1974. He failed to win the Republican nomination for President in 1976 before running successfully in 1980 and 1984. While these authors express their evaluation of Reagan in an uncomplimentary way, their phrase contains an element of truth, and applies equally to a host of other California politicians at the local and national levels from 1960 on.

skills by which they can enjoy the exercise of their own powers."[4] In California of the 1970s, both the ex-actor Reagan and the ex-Jesuit seminarian Brown represented large constituencies.

For many Californians, the debate between conservatism and change centered on how the state should react to growth. To some, catastrophe loomed. Smog had plagued Los Angeles since the 1950s, and air quality emerged as a "bottom line" in state planning. The scarcity of fresh water provided another worry. The arid south relied on an intricate web of aqueducts and an equally complex bureaucracy to deliver masses of water from the Colorado River Basin. Many Californians feared immigration, especially when combined with the growing militancy of the home-grown young. And, in 1971, a serious earthquake struck the populous San Fernando Valley. Confronted by an over-laden social and physical infrastructure, a few Californians began to reconsider the state's position on growth.

California's energy problems, and its electric utility industry in particular, provided a troubling example of the dangers of growth. From 1942 to 1972, electricity use in California increased by 8 to 9% annually. The nature of the industrial base changed, reducing that sector's electricity use, but the number of households multiplied, as did the percentage of homes using appliances such as space heaters and clothes dryers. Simultaneously, the commercial sector expanded, as did the size and energy intensity of commercial buildings, for example air-conditioned malls. Due to soaring electricity use in the residential and commercial sectors, California's electricity demand after World War II doubled at the terrific rate of every ten years.[5]

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[4]Brown, quoted in Neil R. Pierce, "Jerry Brown: Prophet of the Unconventional," *The Washington Post* (6 June 1977), p. A23. Brown governed California from 1975 to 1982, and sought the Democratic nomination for president in 1976, 1980 and 1992. He ran unsuccessfully for the Senate in 1982.

[5]W.E. Mooz and R.G. Salter, "California's Electricity Demand and Supply Characteristics: A Statement Before the Assembly Subcommittee on State Electrical Energy Policy, February 15, 1973," publication P-4981 (March 1973), pp. 3-9. While demand for electricity grew equally rapidly in other areas of the nation, few places suffered from the full range of problems that limited California's energy options, notably its over-dependence on imported oil and its unbalanced demand pattern caused by high residential and commercial loads.

The utilities

Sating this surging demand fell to two large and several smaller utilities. In the north, the Pacific Gas and Electric Company provided electric service to 2.8 million households in a 94,000-mile area centered on the San Francisco Bay Area. In 1972, the company posted a net income of $215 million, a 12% increase over the previous year.[6] To the south, in an area dominated by Los Angeles, the Southern California Edison Company served roughly the same number of homes and reported a 1972 income of $137 million, up 8% over 1971.[7] Smaller numbers of Californians purchased electric service from the San Diego Gas and Electric Company and the publicly-owned Sacramento Municipal Utility District and Los Angeles Department of Water and Power. The California Public Utilities Commission oversaw the utilities' operations. Like most regulators of the day, the CPUC commissioners tried to serve the public interest by cooperating with the utilities' own strategies for providing cheap, dependable service.[8]

At the end of 1971, California's electric generating capacity amounted to about 35,000 megawatts. This consisted of fossil steam plants (62%) and hydroelectric power (26.8%), supplemented by gas turbines (2.5%), nuclear plants (1.4%) and geothermal plants (0.5%). Purchases from utilities in other states made up the remainder (6.8%).[9] Utility planners expected the historical trend of 8% annual growth to continue, and they fretted over how to satisfy it. The only solution, most managers believed, lay in building more facilities as fast as possible. The CPUC agreed. After summing each utility's construction plans, the Commission reported that the state would need to supplant extant capacity with 80,000 to

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[6]Pacific Gas & Electric Company, *1972 Annual Report.*

[7]Southern California Edison Company, *1972 Annual Report*, p. 1.

[8]Barkovich, *Regulatory Interventionism*, p. 13.

[9]Mooz and Salter, "California's Electricity Demand and Supply," p. 24.

90,000 MW of new plant by 1991. This translated to about seventy new plants constructed in at least twelve sites over two decades.[10]

Nuclear plants, forecasters estimated, might provide half of that new capacity. Often, the utilities presented nuclear power as an environmentally-preferred technology. In 1973, PG&E called nuclear plants using the unlimited supply of cooling water available at coastal sites "the most promising long-range solution to the problem of meeting the major part of our growing power demands with a minimum impact on the environment."[11] They also hoped that giant nuclear facilities capturing economies of scale would generate cheaper power. Moreover, the powerful plants harmonized with utility managers' traditional preference for massive, complex technologies at the cutting edge of innovation. One set of consultants estimated in 1972 that if the utilities effected their building plans, and if they located the plants near the ocean as they preferred, California's striking Pacific coast would harbor a 1200-MW nuclear or fossil plant every eight miles by 2000.[12]

Yet the utilities had already met difficulties in implementing what they considered vital building plans. The CPUC generally acceded to utilities' construction proposals and allowed the utilities to pass on the costs to rate-payers. But before starting construction of a new plant, utilities also needed permits from up to fifteen other state and a dozen Federal agencies, as well as from local governments and air pollution control districts.[13] Sites appropriate for major hydroelectric development had grown scarce. Increasingly stringent air-quality standards impeded the combustion of coal or California's high-sulphur oil. In 1972 the California Assembly passed legislation limiting development of the state's coastal lands, which further reduced siting options. So did objections from citizens of neighboring

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[10]R.H. Ball, *et al.*, "California's Energy Quandary: II. Planning for Power Plant Siting," Rand Corporation R-1115-RF/CSA (September 1972), p. vi.

[11]PG&E, *1972 Annual Report*, p. 2.

[12]R.D. Doctor, *et al.*, "California's Electricity Quandary: III. Slowing the Growth Rate," Rand Corporation R-1116-NSF/CSA (September 1972), p. vi.

[13]Ball, *et al.*, "Planning for Power Plant Siting," p. vi.

states, who felt that sales of power to California left them bearing the air-pollution burden for that state's consumers. When, in 1976, the Assembly banned construction of new nuclear plants until a permanent solution to the problem of waste storage could be devised,[14] utility managers believed that unreasonable public fears and political opportunism had removed their final, best option.

As their range of choices narrowed, the utilities issued dire warnings, such as SCE's prediction in 1973 that Los Angeles would suffer brownouts within three years unless the company were allowed to proceed with construction of fossil plants in Huntington Beach and Long Beach.[15] At the same time, utility representatives lobbied the Assembly for creation of a "one-stop" power plant siting authority which, they believed, would not only simplify and accelerate the permitting process, but would also eliminate some access for "extremist" opposition. In 1973, Assemblyman Warren Alquist (D-Los Angeles) introduced a bill proposing the creation of such a commission.[16]

## PART II: The Need for Planning

As utilities lambasted the chaotic process regulating power plant construction, other voices expressed quite different grounds for dissatisfaction. Triggered by horror at the effect of massive power plant construction on California's natural environment, and by distrust of nuclear power, citizens groups and environmentalists called for coordinated planning. Lacking a formal long-term policy, they charged, the CPUC's *de facto* practice consisted of, in the words of one journalist, "demand accommodation."[17] Why, groups such as the Environmental Defense Fund asked, should the state endorse the utilities' never-ending race

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[14]California Public Resource Code, Section 25524.2

[15]Larry Pryor, "Energy Crisis--Hot Water for Legislature," *The Los Angeles Times* (4 March 1973), p. A1.

[16]Stuart A. Ross, "Organization Design in the California Energy Commission: The Adequacy of Alternative Design Perspectives," (Ph.D. diss., University of California at Berkeley, 1978), p. 63.

[17]Pryor, "Energy Crisis," p. A1.

to meet demand by expanding electricity supplies, when rigorous conservation, increased efficiency and the development of alternative sources could achieve the same effect?[18]

In late 1972, a Santa Monica think-tank, the Rand Corporation, released three reports commissioned by the State Assembly. Rand advised the creation of an agency to coordinate power plant siting, estimate future electricity demand, implement measures to slow the growth in electricity consumption, and manage an R&D program for new power technologies.[19] Rand questioned the magnitude of the utilities' growth forecasts, and their assumption (shared by the CPUC) that expansion of electricity supply constituted the only way to meet demand. The report suggested that future demand would "fall well below what might be anticipated from straightforward extrapolation from past consumption," due to saturation of the residential sector with major appliances and anticipated elasticity of demand with respect to price (*i.e.*, demand would drop as rates rose).[20] Instead of meeting this more modest demand by building new plants, Rand suggested that the proposed energy agency institute efficiency standards for appliances, eliminate utility rates that encouraged profligate use, and impose fuel-efficient building codes.[21]

The three Rand reports had an appreciable impact on the Assembly, particularly on Assemblyman Charles Warren (D-San Jose) of the Planning and Land Use Committee. Warren received responsibility for chairing an Energy Subcommittee and soon began hearings on long-term energy policy. (Later, Warren pointed out that unlike the Public Utility Committee, the Land Use Committee had few institutional or other ties to the

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[18]In fact, the EDF argued that by replacing traditional construction plans with a combination of alternative energy technologies and conservation, California utilities could lower rates, raise investor returns, *and* prevent further environmental degradation. See Roe, *Dynamos and Virgins*, p. 13.

[19]Ball, *et al.*, "Planning for Power Plant Siting," p. xiii.

[20]W.E. Mooz and C.C. Mow, "California's Electricity Quandary: I. Estimating Future Demand," Rand Corporation R-1084-NSF/CSRA (September 1972), p. vii.

[21]Doctor, *et al.*, "Slowing the Growth Rate," p. xiv.

industry in question, and therefore enjoyed greater freedom.[22]) From these hearings emerged a bill proposing the creation of a demand-side planning authority. Eventually, state lawmakers merged Alquist's supply-side bill with Warren's demand-side bill, and passed the resulting melange in September of 1973.

In early October of 1973, Governor Reagan vetoed the bill, stating that it duplicated existing state institutions.[23] The *Los Angeles Times* chided the governor for this "serious setback to efforts, already long overdue, to deal responsibly and comprehensively on a statewide basis with the problems created by the growing gap between energy demand and supply in California."[24] But the concept of a central energy planning commission might have died there, had not OPEC's petroleum price hikes and the Arab oil embargo surprised the nation a few days later. When the Assembly reconvened the following spring, all parties quickly compromised on the legislation. Reagan reluctantly signed Assembly Bill (AB) 1575, the Warren-Alquist State Energy Resources Conservation and Development Act,[25] which created the California Energy Resources Conservation and Development Commission, known after 1980 as the California Energy Commission. The Act called for the appointment of an economist, an environmentalist, a physical scientist, an attorney and a public advocate

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[22]Charles Warren, "The Soft Path to Water Policy Reform," presented to the California Water Policy Local Government Commission in Los Angeles (20 November 1992), p. 2. Warren attributes the state's energy problems in the late 1960s to the CPUC. The CPUC, he asserts, contented itself with requesting and then rubber-stamping the utilities' in-house projections of future need. After completion of a power-plant project, the CPUC passed on to rate-payers all building costs plus the allowed margin of profit. "Clearly," Warren charged in 1992, "the higher the utilities could project demand, the more capital-intensive power plants they could construct, the more profits they could earn (p. 1)." At least two of the Rand authors shared this cynical view, telling the Assembly that "although there is every evidence that [the utilities' demand forecasts] have been dispassionately prepared, questions might be raised about the adequacy for all state planning purposes of complete reliance on estimates prepared by those whose prime interests are the marketing of their product." Mooz and Salter, "California's Electricity Demand and Supply," p. 11.

[23]Jerry Gilliam, "Statewide Energy Board Vetoed, Vehicle Smog Inspections Okd," *The Los Angeles Times* (3 October 1973), pp. I1, I27.

[24]"A Serious Setback on Energy [editorial]," *The Los Angeles Times* (4 October 1973), p. II6.

[25]Cal. Pub. Res. Code && 25000-25968 (West. Supp. 1977).

to the Commission by January of 1975. This task fell to the incoming governor, Edmund G. "Jerry" Brown, Jr.

Jerry Brown

*The Washington Post* described Jerry Brown as "the strangest politician California has seen in a long time--the consummate outsider who has remained single, remote and seemingly ascetic."[26] After taking office in January of 1975, Brown announced that he would not live in the $1.3-million gubernatorial mansion built during the Reagan era. "Maybe," he cracked, "we can... make it into a halfway house for lobbyists."[27] Brown gained a reputation for goofiness, typified by his Zen retreats, and for appreciation of points of view out of the mainstream, exemplified by his state Office of Appropriate Technology to explore the potential of backyard organic farming and innovative building design.[28] Yet, his off-beat behavior appealed to many Americans. On impulsively entering the race for the Democratic presidential nomination in 1976, he beat front-runner Jimmy Carter in five head-to-head primaries, and might have won the nomination had he begun his campaign earlier.

Brown exhibited particular concern for California's energy predicament. In contrast to Democratic rival Jimmy Carter, Brown opposed nuclear power, and he sympathetically discussed Amory Lovins' "soft path" energy strategy:

> Well, [Lovins is] presenting ideas that are provocative and I find them interesting... [A]s we try to make for a more human quality of life, the source of energy, the amount of energy, the ways in which we use it, play a significant role. [Lovins] looks for a more benign energy future. What he says deserves to be heard. And in

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[26]Leroy F. Aarons, "Jerry Brown, the Loner, Seen Running Ahead in California," *The Washington Post* (1 November 1974), p. A2.

[27]Wallace Turner, "Brown, Stressing Change From Reagan Era, Sworn in as California Governor," *The New York Times* (7 January 1975), p. A7.

[28]Pierce, "Jerry Brown: Prophet," p. A23.

> California I'm trying to give maximum encouragement to diverse energy possibilities.[29]

At a more practical level, Brown's political appointments ensured a large role in his administration for environmental protection, for example by naming a former vice president of the Sierra Club to head the California Resources Agency.[30]

At first, the new energy commission fumbled in trying to knit its diverse missions of facilitating development, enforcing conservation and assembling plans for the long term. The young agency particularly frustrated environmentalist supporters such as Assemblyman Warren, who griped "Dammit, if the Commission is going to side with the utilities, the way the Public Utilities Commission does, I might as well repeal my goddamned act that created the thing."[31] Attorney David Roe of the Environmental Defense Fund remembers that the CEC's powers of enforcement seemed doubtful, and that its rules for conducting hearings discouraged factual cases. "Rigor," Roe wrote, "was almost inevitably drowned out by polemics." Roe remembers that the commissioners received presentations from outsiders, no matter what the content or the quality, with the standard comment, "Thank you for your views."[32]

Yet, as Brown's appointments to the CEC and (as Reagan's appointees vacated their seats) the CPUC became more astute, the state's energy policy became progressively more innovative. The CEC broadcast Brown's determination to reject the "business as usual" energy scenario when it rejected San Diego Gas & Electric's proposed Sundesert nuclear power plant, making California the first state to swerve from the nuclear path.

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[29]Burt Solomon, "California's Jerry Brown: There Is No Energy Crisis," *The Energy Daily* 6 (25 May 1978), p. 3. Brown also praised the potential of high-technology energy options that Lovins eschewed, such as the space power satellite concept, and when he railed at Federal regulation of the California oil industry, he sounded more like a free-market conservative than a hippie.

[30]"Woman, Brown Aides Get Key Ecology Posts," *The Los Angeles Times* (5 January 1975), p. I3, I21.

[31]Warren quoted in Ross, "Organization Design in the CEC," p. 78.

[32]Roe, *Dynamos and Virgins*, p. 39.

## PART III: The CEC Windpower Initiative

The supply-side provisions of the Warren-Alquist act focussed mainly on the siting issue, but legislators also perceived a need to explore new hardware. They gave hopeful mention to those technologies labelled "renewable," partly due to their potential to preserve California's fragile air quality. The law charged the Commission to

> develop and coordinate a program of research and development in energy supply, consumption, and conservation and the technology of siting facilities, and... give priority to those forms of research and development which are of particular importance to the state, including... exploration and accelerated development of alternative sources of energy, including geothermal and solar resources.[33]

Among the solar technologies discussed was windpower.

Obeying this directive proved easier in the 1970s than it might have at a later date. On taking office in 1975, Governor Brown had found himself perched atop a $4-billion budget surplus, the harvest of fiscal conservatism and hefty tax rates under his predecessor Reagan. In 1978, Brown proposed a five-year program to spend $200 million on energy conservation and retrofitting government buildings, and $230 million on energy R&D. This energy program, the biggest ever proposed by a state,[34] included a coal gasification power plant, three geothermal plants, a wood-burning plant, a methanol plant, and a windpower experiment. According to Brown's assistant Wilson Clark, the governor intended to diversify the state's energy supply options, and to identify the best mix by the only means possible--in Clark's words, to "buy technology and test it."[35]

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[33]The entire act appears in Dick Howard and James E. Jarrett, *State Energy Management: The California Energy Resources Conservation and Development Commission* (Lexington, KY: The Council of State Governments, 1976). For passages quoted, see pp. 34, 42.

[34]For other states' more modest plans, see "Renewable Energies: State Funded Programs," *Wind Power Digest* (December 1976), pp. 32-33.

[35]Lou Cannon, "The Puzzling Politics of Jerry Brown," *The Washington Post* (5 February 1978), pp. B1, B5; Richard Myers, "Gov. Jerry Brown Launches $500 Million Energy Program," *The Energy Daily* 6 (12 January 1978), pp. 1-2.

Wind energy comprised an important element of Brown's plan. The CEC had studied windpower since 1976, and it estimated that wind turbines could cost-effectively provide 10% of the state's generating capacity by 2000. In 1978, the Assembly endorsed the 10% figure. The CEC's Wind Energy Program subsequently set goals of 500 MW of installed windpower by the mid-1980s and 10,000 MW by the late 1990s. (Contrast the Federal Wind Energy Systems Act, which set a goal of 800 MW!) The California plan earmarked $60 million of the $80-million start-up cost for the critical task of identifying high-wind sites. The CEC envisioned eighty scattered windfarms by 2000, composed of a total of three-thousand 3-MW turbines. The state of California would partially fund the development of the turbines, but, according to the CEC's Matanius Ginosaur, the state would not enter the generation business. Rather, it hoped that the utilities would build, own and operate the windfarms. Ginosaur estimated windpower could save the state $27 billion by 2005.[36]

In many ways, the CEC's wind program responded to perceived shortcomings in the Federal Wind Energy Program. As the CEC's James Lerner told Congress, the California program devoted proportionally more funding to resource mapping than the FWEP; the utilities SCE and PG&E co-funded this effort, which identified and mapped high-wind sites such as San Gorgonio Pass outside of Palm Springs. In addition, the CEC's Ginosaur suggested, the FWEP program had increased rotor size on their experimental machines too fast to assure mechanical dependability; the manufacturers winning CEC contracts would engineer their products more conservatively. Ginosaur also pointed out that the FWEP had optimized their turbines to perform most economically in wind speeds substantially lower than those available in California. For this reason, he maintained, California should develop

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[36]Matania Ginosaur, "A Large Scale Wind Energy Program for the State of California," (Ph.D. diss., University of California, 1979), *passim*, esp. p. 16. Ginosaur includes the text of AB 2976, where the Assembly endorses windpower, on pp. 124-128. See also "California Assembly Committee Approves $80-million Wind Plan," *Solar Energy Intelligence Report* 4 (22 May 1978), p. 150; *Solar Energy Intelligence Report* 4 (3 July 1978), p. 199, and; "The California Wind Program," *Wind Power Digest* (Spring 1979), pp. 6-11.

its own turbines. Finally, Ginosaur and Lerner stressed that the California initiative aimed to give utilities a choice of products by accepting proposals from a variety of manufacturers.[37]

Nevertheless, the CEC plan resembled the FWEP in important ways. Ginosaur made explicit the assumption implicit in the Federal program, that wind energy should constitute simply another generating option open to utilities, implying no changes in the utility system itself. "While developing alternative energy supplies," he wrote, "no attempt should be made to purposely change the social structure of the state... This is why I do not advocate alternate ownership... of wind-electric energy systems, but ownership by... utilities."[38] More important, while the CEC attempted to stimulate utility participation and include utility funding in the wind project, it remained a government program, pushed by a state agency for reasons identified by politicians, and funded by tax monies.

Unfortunately, political events mooted the question of whether the CEC could have made centralized planning work where the FWEP had failed. In June of 1978, Californians approved Proposition Thirteen, which cut state property taxes by almost 60%, or about $7 billion.[39] Contrary to the ominous predictions of the law's opponents, the U.S. General Accounting Office (GAO) reported the following year that the cut had "no material impact" on local government programs and services. But the GAO imputed this to Governor Brown's decision to "bail out" threatened social service programs by redistributing the state's budget surplus to local governments. (In following years, the state lacked the funds to succor the municipalities, and social services indeed diminished.) The bail-out required Brown to suspend favored programs, including the ambitious windpower effort. Rather than

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[37]Testimony of Lerner in U.S. Congress, *Wind Energy Systems Act*, pp. 75-76, 87; Ginosaur, "Wind Energy Program for California," pp. 84, 89.

[38]Ginosaur, "Wind Energy Program for California," pp. 10-11.

[39]Robert Lindsey, "California City Growing Anxious as Layoffs Loom Under Tax Cut," *The New York Times* (23 June 1978), pp. A1, A12.

the $5 to 10 million that the CEC anticipated for the program's first year, the Assembly voted only about $800,000.[40] The program received no more money after that.

## Conclusion: An Energy Pioneer

In the 1970s, California emerged as a pioneer of revolutionary energy policy. Partly because the stresses on the nation's electric utility system took a virulent form in California, the Golden State commissioned a powerful energy agency, the CEC. Under the leadership of California's iconoclastic young governor, Jerry Brown, the CEC pursued a mandate to regulate supply, encourage and enforce conservation, and plan for the long term.

Among its many activities, the CEC prepared an aggressive windpower initiative that would have remedied some of the FWEP's serious flaws, while still locating authority in the state's central government. Although the passage of Proposition Thirteen dashed hopes for the CEC's windpower program, California lawmakers maintained their commitment to alternative energy. However, the startling boom in California windpower during the 1980s took a form quite different from that envisioned by central planners in the DOE and the CEC. In fact, emergence of California's windfarm industry hinged on a 1978 Federal law supporting decentralized energy production, President Jimmy Carter's Public Utilities Regulatory Policies Act.

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[40]Rankin, "The Effects of Proposition 13," D2; Lindsey, "California Finding Proposition 13 Less Potent Than Was Predicted," *The New York Times* (5 June 1979), p. A12; testimony of Lerner in U.S. Congress, *Wind Energy Systems Act*, p. 101.

# CHAPTER NINE
# Unintended Consequences: PURPA, Windpower and Deregulation

## Introduction: Unexpected Deregulation

For eight decades, government-sanctioned monopolies sheltered America's electric utilities from competition. Because the electric business requires massive capital, regulators believed that multiple firms duplicating the same front-end investment and competing for customers would produce higher, not lower, rates. In return for their monopoly status, utilities agreed to serve all citizens and to submit to regulation limiting their profits.

In the 1980s, the compact between regulators, utilities and customers mutated, and insiders acknowledged the "deregulation" of the electricity generation sector.[1] By 1990, utilities purchased much of the nation's power from entrepreneurs using alternative energy technologies such as cogeneration, windpower and biomass conversion. One new player optimistically suggested that independent power producers--not utilities--would supply half of the 100,000 MW of new capacity needed nationwide by 2000.[2]

In explaining these events, most analysts point to the Public Utility Regulatory Policies Act (PURPA), passed in 1978 as one element of Jimmy Carter's National Energy Act (NEA). Yet, its "deregulatory" effect notwithstanding, PURPA primarily addressed rate reform, not entrepreneurial power. The sections encouraging cogeneration and renewable energy comprise perhaps four pages of a sixty-page law, and their striking impact took most, if not all, players in the electric utility system by surprise.

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[1]Some analysts deny the "deregulation" of the electric utility industry, pointing to the countless regulations that continue to structure the market. Although literally inaccurate, the term is adequate for historical reasons. Events such as the passage of PURPA, while incomplete and perhaps unfair, signalled the dissolution of the *rationale* for regulation, *i.e.*, the belief that competition would drive up electric rates.

[2]Christine L. Nolin, "Competitive Juices," *Institutional Investor* 24, Utilities Forum (October 1990), p. 19. Nolin acts as the Executive Director of the Cogeneration and Independent Power Coalition of America.

This chapter recounts the genesis and reception of PURPA to illustrate three ironies in the development of American windpower. First, debates over PURPA, the legislation enabling the wind industry to coalesce, made little or no mention of windpower. Thus, the story of PURPA reinforces one of the main lessons of the preceding analysis of the FWEP; that windpower, lacking an influential constituency, floated on the tide of much larger historical movements. Entrepreneurial windpower represents an instance of sweeping changes in a large industry, rather than a self-contained drama.

Second, PURPA constitutes a story of unintended consequences. Not only did windpower materialize as a serendipitous winner from the changes wrought by the legislation. The changes themselves shocked both opponents and supporters of the law. PURPA's early critics did not cite the bill as an underhanded attempt to deregulate the electric industry; rather, they objected to its bold extension of Federal authority over rate-making. Thus, windpower (and entrepreneurial energy in general) may indeed symbolize a "natural" evolution of the electric system, as some advocates contend. It does not, however, result from conscious decision-making. Not only did windpower play a bit part in a larger play, but that play lacked a conscious author and intentional actors, at least in its early acts.

Finally, the relationship between PURPA and windpower undercuts claims that entrepreneurial windpower represents a triumph of decentralized, "hands off" governance. Later chapters illustrate that the California windfarmers indeed had greater control over technological development than the manufacturers and customers involved in the FWEP. But PURPA represents an unprecedented imposition of Federal control over utility regulation, previously in the hands of state public utility commissions. While windfarms constitute a market-based approach to generating electricity, the Federal government played a crucial role in forcing that model on the individual states and their investor-owned utilities.

## PART I: "The moral equivalent of war..."

Jimmy Carter, elected to the presidency in 1976, believed fervently that an "energy crisis" threatened America. In the Spring of 1977, he appeared on television clad in a sweater and seated in front of fire. He solemnly warned his constituents that hard times were upon them, and that conserving energy would bring hardship:

> Tonight I want to have an unpleasant talk with you about a problem unprecedented in our history. With the exception of preventing war, this is the greatest challenge our country will face in our lifetimes...

And then, borrowing a line from a 1902 speech in which William James had praised combat's capacity to mortify the flesh and so reduce human pride, the President defined his vision of America's energy struggle. "Many of the proposals will be unpopular," he warned viewers. "Some will cause you to put up with inconveniences and sacrifices... This difficult effort will be the *moral equivalent of war*."[3]

Carter identified three overall goals for his National Energy Act[4] (NEA): to decrease dependence on oil-exporting nations; to insulate America from reduced global oil production by lowering imports, and; to ready renewable, essentially inexhaustible sources for the long term. In an interview, the President bluntly declared that "this is a struggle that I don't intend to lose."[5]

The NEA relied on principles of marginal cost pricing to raise the cost of fuels, thereby encouraging conservation and efficiency. This economic theory taught that for markets to function correctly, the price of a given commodity should reflect the production cost of the next unit.[6] With regard to electric utilities, the NEA noted that current "rates

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[3]Stress added. Jimmy Carter, "President's Proposed Energy Strategy," *Vital Speeches of the Day* 43 (1 May 1977; delivered on television 18 April 1977), pp. 418, 420.

[4]As finally passed, the NEA comprised five bills: the Public Utility Regulatory Policies Act, the Energy Tax Act, the National Energy Conservation Policy Act, the Powerplant and Industrial Fuel Use Act, and the Natural Gas Policy Act.

[5]"I Don't Intend to Lose: Interview with Jimmy Carter," *Newsweek* 89 (2 May 1977), pp. 36-37.

[6]For example, consider an electric utility charging each of ten customers $250 per month, the average cost of providing their service. Suppose that adding an eleventh customer costs $400, perhaps due to the necessity of stringing a new transmission line to a remote location. If the utility averages costs among the (now) eleven customers, each pays $264, for a total of $2900. But suppose the eleventh customer, by opting to purchase utility service at $264, had foregone purchasing a free-standing wind-battery system for $300. If the utility had (continued...)

often do not reflect the costs imposed on society by the actions of utility customers," and it applied marginal-cost principles in its reform provisions. As proposed, the NEA required utilities to eliminate promotional declining block rates, devised in the days when steadily improving economies of scale prompted utility managers to encourage increased use of electricity. This and similar ratemaking standards, the President hoped, would discourage waste by showing customers exactly how much electricity cost to produce.[7]

Many citizens doubted the necessity for action. Only four years after the cold winter of the oil embargo, a Gallup poll found that less than half of Americans considered the energy problem very serious.[8] A speaker at an engineering conference sneered that

> I've read reports and bulletins, studies, speeches, all of them purporting to describe an unparalleled misfortune that exists--if it exists at all--at an imaginary point where six or seven lines intersect on a graph. The documents... raise questions about the political and financial interests of the people promoting the crisis... [but] the crisis has yet to take palpable form.[9]

While the nation's utilities approved of Carter's early emphasis on voluntarism, executives fretted during subsequent months as some members of the Administration pushed for rigorous enforcement of conservation--such a policy, one manager charged, "smacks of Soviet methods."[10]

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[6](...continued)
priced its product according to the true cost of marginal service (*i.e.*, $400), and thereby encouraged the prospective eleventh customer to buy the cheaper wind system, the group of eleven customers would pay only $2800 (10 x $250 + $300). Of course, this example settles no questions of equity; one might also classify electricity as a basic right, the costs of which should be averaged over the entire society. The example above is loosely adapted from Hyman, *America's Electric Utilities*, p. 180.

[7]"The National Energy Plan," Executive Office of the President, Energy Policy and Planning, Stock No. 040-000-00380-1 (29 April 1977), pp. 46-47.

[8]"Energy: Will Americans Pay the Price?" *U.S. News & World Report* 82 (2 May 1977), pp. 13-17; "People are Still Wondering--Is Energy Shortage for Real?" *U.S. News & World Report* 82 (2 May 1977), pp. 28-30.

[9]Lewis J. Lapham in "The National Energy Policy--Its Impact on the Electric Power Industry," Special Publication Number 14 of the Power Engineering Society, IEEE (presented 31 January 1978).

[10]"Utilities approve most of Carter's energy moves," *Electrical World* 187 (15 March 1977), p. 25.

Meanwhile, even before Carter released the NEA, flocks of earnest lobbyists descended on the rumored plan. Its voluntarism notwithstanding, some utilities reacted to the NEA with outrage. The Mississippi Power and Light Co., for instance, warned mayors in its service area that the package threatened "the very survival of the United States as a free nation."[11] Apart from such alarmism, the expensive prospect of having to re-convert their plants back to coal from oil and natural gas, fuels toward which previous anti-pollution legislation had pushed them, particularly irked the power companies. But the Administration lobbied, too, mailing 30,000 copies of the NEA to influential citizens, and occasionally taking obstreperous industry executives behind closed doors to explain bluntly how difficult business in a regulated environment might become.[12]

States' rights

The plan "went down with surprising ease"[13] in the House of Representatives. Speaker Thomas "Tip" O'Neill (D-MA) viewed the challenge of pushing it through in one piece as a test of Democratic party unity. The more conservative Senate, protective of its own prerogatives and of states' rights, proved less compliant. Against Carter's wishes, Senate leader Robert Byrd (D-WV) allowed individual votes on the five component bills. The tax and gas bills caused particular uproar. Senate Finance Committee chairman Russell Long (D-LA) held hostage such popular measures as tax credits for solar and wind energy, in an attempt to force his colleagues to compromise on less palatable sections.[14] The slow

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[11]Letter reprinted in U.S. Congress, *Congressional Record* 123, 95th Congress, 1st Session (5-6 October 1977), p. 32,937.

[12]"Carter Energy Bill Fails to Clear," p. 709. See also U.S. Congress, House of Representatives, *Congressional Record* 124, 95th Congress, 2nd Session (14 October 1978), p. 38,482.

[13]Allen J. Mayer, *et al.*, "The Battle Begins," *Newsweek* 89 (9 May 1977), p. 22.

[14]"Energy Bill: The End of an Odyssey," *1978 Congressional Almanac Quarterly* (Washington, DC: CQ Almanac, 1978), p. 640. Renewable energy advocates in Congress continually tried to launch a "solar breakout," but Democratic leaders held firm in trying to pass the NEA as a single package. Congress's dallying decimated the solar industry, as consumers postponed their purchases to see if the proposed tax credits would pass. Yet, few Senators opposed renewable-energy *per se*. Late in 1978, when solar advocates managed to append the renewable-energy credits to another bill, even the out-maneuvered Long gracefully added his affirmative vote. The credits eventually made their way back into the Energy Tax Act of 1978. "Senate Approves Long Awaited (continued...)

pace of the fractious Senate forced Congress to adjourn in December of 1977 without having reached closure on the NEA. The wrangle continued after Congress reconvened in 1978. One by one, legislators diluted the bill's strongest measures, converting it to a bill that rewarded conservation without punishing waste.[15]

Furor over energy taxes and natural gas drowned out the issue of utility rate reform. The debate that occurred on the utility bill focussed on the appropriate roles of Federal and state governments. The oil embargo had awakened Federal interest in the use of utility rates as tools for promoting conservation, but the Federal Power Act of 1935 (FPA) limited Federal regulation to wholesale power purchases across state lines, and gave control over utility rate-making to the individual states.[16] By 1977, frustrated Federal policy tinkerers had lost patience with what they perceived as foot-dragging on the part of state regulators. In PURPA, Carter proposed that the Federal Energy Regulatory Commission (FERC), which replaced the Federal Power Commission in 1974, mandate changes in the regulatory structures of the individual states.

In many ways, Congress endorsed the President's assertion of Federal leadership in establishing energy policy, including rate reform.[17] In the House, Rep. John Dingall's (D-MI) Commerce Committee had studied similar proposals in 1976 and included the President's strong stand in its version of PURPA. The newly formed Senate Energy Committee proved less familiar with the issues. The senior chamber also showed itself substantially less pro-consumer than the House, and warier of infringing on state autonomy. To Sen. J. Bennet Johnston (D-LA), Carter's plan "contemplated a radical extension of

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[14](...continued)
Tax Credits After Lightening Move by Solar Coalition," *Solar Energy Intelligence Report* 4 (28 August 1978), p. 260; *Solar Energy Intelligence Report* 4 (31 July 1978), p. 227.

[15]"Energy Bill: The End of an Odyssey," p. 639.

[16]See Paul L. Joskow, "Public Utility Regulatory Policy Act of 1978: Electric Utility Rate Reform," *Natural Resources Journal* 19 (October 1979), p. 797.

[17]U.S. Congress, *The 95th Congress and Energy Policy*, p. 27.

Federal authority," for which Johnston found "no justification."[18] Sen. Pete Dominici (R-NM) agreed, contending that the Senate should not "cause confusion and delays in an already fragilly-capitalized industry, where delays would amount to less development, less building, less construction."[19] Instead, the Senate wrote its own bill, S. 1469, authorizing the Secretary of Energy only to "advocate" conservation, efficiency and equitable rates. Most important, the Senate bill downgraded Carter's ratemaking standards to "guidelines"--in effect, polite suggestions from the Federal government to the states, with no enforcement mechanism.

The senators prevailed in the joint conference held to resolve differences between the House and Senate bills. Sen. Henry Jackson (D-WA), Chairman of the Committee on Energy and Natural Resources, reported to his chamber that

> ...the Conference bill leaves intact the authority and discretion of the State commissions... [which] would be required to examine a series of federally recognized ratemaking standards... Following such examination each State commission would be free to choose whether or not the standard would be put into effect.

Not all Senators greeted this announcement with enthusiasm. Sen. Howard Metzenbaum (D-OH) castigated his chamber for shying from the tough leadership the country needed. "The lobbies for the utilities did their work well," he chided. However, most senators accepted the "guideline" approach, and soundly approved the Conference Report.[20]

A "Silly bill"

As Congress approached its final vote on the NEA, few members expressed satisfaction with their work. Sen. Dewey Bartlett (R-OK) derided the rate-reform bill as "simply another item to make it look as though we are addressing the energy problem. In

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[18]Sen. J. Bennet Johnston in U.S. Congress, Senate, "Public Utilities Regulatory Policies Act of 1977," *Congressional Record* 123, 95th Congress, 1st Session (5-6 October 1977), p. 32,392.

[19]Sen. Pete Dominici in *Ibid.*, p. 32,394.

[20]U.S. Congress, Senate, "Public Utility Rates--Conference Report," *Congressional Record* 124, 95th Congress, 2nd Session (7 and 9 October 1978), pp. 34,558, 34,762, 34,780.

fact, this bill will produce no energy whatsoever." In the House, Rep. Clarence Brown (R-OH) captured the sentiments of many of his colleagues in sniffing that "this is a silly bill." But after almost eighteenth months of work, most members glumly equated a 'nay' vote to political suicide. One Representative reportedly told his colleagues that "I am going to put on a clothespin, and I am going to vote for this... I cannot go home and face my voters and say I did not vote for an energy policy." Others balked. Finally, Tip O'Neill rose to his feet with an impassioned plea: "I am asking you to put aside your parochial interests," the Speaker declaimed. "Now is the time to act with political courage, to act in a responsible manner. The art of compromise is the essence of the political process." Ultimately, O'Neill prevailed in the House, and, after a fifteen-hour filibuster, groggy opponents in the Senate capitulated as well. At 7:30 in the morning of October 15, 1978, the President finally received his energy package.[21]

## PART II: Cogenerators and QFs

PURPA's rate reform provisions, notwithstanding their non-compulsory nature, appreciably affected the electric utility industry. However, the material that occasioned the greatest institutional changes appeared in a few short pages of the law's Title II. These passages encouraged the use of decentralized, non-utility generation techniques.

In presenting his energy package to Congress in 1977, President Carter discussed the potential contribution of cogeneration to America's energy economy. The President noted, for example, that combined heat and electricity plants accounted for 29% of total energy in Germany, and only 4% in America.[22] But although increased cogeneration seemed able to enhance national energy efficiency, the technology faced three institutional barriers. First, cogenerators depended on electric utilities to purchase their power and then re-sell it on the

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[21]Comments from U.S. Congress, House of Representatives, "Conference Reports on National Energy Act," *Congressional Record* 124, 95th Congress, 2nd Session (14 October 1978), pp. 38,480-38,484, 38,487, 34,565.

[22]Jimmy Carter, "The Moral Equivalent of War," *Vital Speeches of the Day* 43 (1 May 1977; delivered before Joint Session of Congress 20 April 1977), p. 422. Cogeneration systems use industrial waste steam for electricity production, or, alternatively, use waste steam from fossil-fuel electricity generation for heating purposes.

grid. But utilities often refused to buy cogenerated power, or to offer a "fair" price for it. Second, some utilities charged cogenerators higher rates for back-up power than they asked of other customers. Finally, as electricity-producing facilities, cogenerators found themselves liable to the same complex regulation as electric utilities! The Public Utility Holding Company Act of 1935, intended to sunder the giant financial empires then dominating the industry, imposed particularly onerous conditions by threatening antitrust prosecution against electricity generators with another line of business.[23]

Utilities opposed decentralized generation for three basic reasons. First, since the time of Samuel Insull, utility managers (and regulators) had viewed the electric business as a "natural monopoly" in which competition between multiple suppliers raised, rather than lowered, costs.[24] Dismayed utility managers argued that adding a number of unruly suppliers to the grid could raise prices by requiring utility power during peak hours, and then producing their own electricity during the hours when utility equipment stood idle. Second, utility engineers feared that irresponsible outsiders might introduce unstable current and reliability lapses to the system. They also warned of risks to line workers should a decentralized facility suddenly feed current into a portion of the grid that utility workers had shut down at their end.

Management culture provided a third obstacle to PURPA's attempt to force the inclusion of non-utility generators in the national electric system. Utility officers contended that only the private sector, unhampered by the government, could provide efficient, reliable electric service, and they proudly viewed themselves as conscientious but unrecognized public servants. Throughout the century, the electric utility industry had met any attempt by

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[23]For more on cogeneration, see U.S. Congress, *Centralized vs. Decentralized Energy Systems*, pp. 198-257.

[24]Some recent analysts, while conceding the natural monopoly characteristics of transmitting and distributing electricity, suggest that generation never constituted a natural monopoly, or that changing market conditions removed the monopoly rationale. See, for example, Paul L. Joskow and Richard Schmalensee, *Markets for Power: An Analysis of Electric Utility Deregulation* (Cambridge, MA: The MIT Press, 1983), pp. 45-58, and; Bradford S. Gentry, "Public Utility Participation in Decentralized Power Production," *Harvard Environmental Law Review* 5 (1981), pp. 312-313. Note also that fewer analysts question the natural monopoly characteristics of power transmission and distribution.

Washington to meddle in its affairs with a combination of moral outrage and dogged antagonism. The Carter Administration's effort to foist cogeneration on the utilities seemed destined to meet the same resistance as had rural electrification and the breakup of the holding companies.

Nevertheless, the Administration remained convinced that wider use of cogeneration would benefit the nation. To promote it, Carter suggested a combination of tax breaks, exemption from state and Federal regulation, and permission to continue burning oil and natural gas.[25] These proposals met with general approval in Congress, and lobbyists representing large electric consumers such as the paper and pulp industry (the nation's third largest industrial consumer of electricity, and the source of 40% of American cogeneration) added their support.

Small Power

In the NEA, Carter suggested that the same institutional barriers hampering cogeneration impeded the emergence of small power facilities using renewable resource technologies, and he suggested that they receive equal protection. During their debates, members of Congress edited out the renewable energy clauses, perhaps doubting that the technologies' modest capacities merited special consideration. Renewables found a champion in Sen. Charles Percy (R-IL). As Percy recalls today, none of his Illinois constituents evidenced any particular interest in renewables; rather, he attributes his enthusiasm for the concept to "the political embarrassment... and the economic cost" imposed on America by the oil embargo.[26]

Before the Senate in August of 1977, Percy contended that renewable resources could help relieve the energy crisis, and that they suffered from the same restrictions as cogenerators. He argued strongly for re-insertion of the provisions, arguing that the

[25]"The National Energy Plan," pp. 45-46.

[26]Personal communication from Hon. Charles Percy to Adam Serchuk (23 June 1994).

economies of scale in the utility industry had ended. Percy suggested that "we may be at the beginning of a new era in electric power production," one which exploited "promising new small energy-producing technologies all of which would supply electric power in small amounts, be operated locally, and be owned by individuals or small companies." He mentioned wind, solar and small hydropower facilities, and asked how many senators realized that more than five dozen renewable energy systems currently fed small amounts of power back into electric company lines.[27] Percy succeeded in piggybacking the provisions to encourage renewable energy on the measures to promote cogeneration. These lines attracted little attention from members of Congress absorbed by the fireworks over natural gas and energy taxes.

The relevant material appeared as Sections 201 and 210 of Title II in the final version of PURPA. Section 201 amended Section 3 of the Federal Power Act[28] to define a "small power production facility" as one that "produces electric energy solely by the use, as a primary energy source, of biomass, waste, renewable resources, or any combination" of those, and whose total capacity fell under 80 MW. PURPA designated such facilities owned by persons not primarily engaged in the generation or sale of electric power (*i.e.*, electric utilities) "qualifying small power production facilities," or QFs.

Then, in under four pages, PURPA's Section 210 dropped the bombshell that allowed the FERC to completely change the nature of the electric generating sector:

> Not later than one year after the date of enactment of this Act, the [FERC] shall *prescribe*... such rules as it determines necessary to encourage cogeneration and

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[27]U.S. Congress, Senate, "Amendments Submitted for Printing: National Energy Policy--S. 1469," *Congressional Record* 123, 95th Congress, 1st Session (1 August 1977), pp. 25,948, 32,660.

[28]For the FPA as amended by PURPA, see: U.S. Congress, House of Representatives, Committee on Interstate and Foreign Commerce, *Compilation of Energy-Related Legislation: Volume II--Electric and Nuclear Energy*, 96th Congress, 1st Session (August 1979), Committee Print 96-IFC 27, pp. 5-74. For cogeneration and small power, see esp. pp. 10-11, 50-51, 53-54.

> small power production... [O]ne year after any rule is prescribed by the Commission... each State regulatory shall... *implement* such rule.[29]

Such language contrasted sharply with the "guideline" approach taken elsewhere in the act.

PURPA required that utilities purchase power from QFs and cogeneration facilities, and that such purchases be "just and reasonable" to ratepayers, while not discriminating against cogenerators or small power producers. Congress authorized the FERC to set the exact purchase price at any level up to the "incremental cost to the electric utility of alternative electric energy." That is, the FERC could not make utilities pay more for QF and cogenerated power than it would cost them to generate the power themselves. Sale of back-up power to QFs and cogenerators would meet similar criteria.

PURPA also directed the FERC to establish rules exempting cogenerators and small power producers from the Federal Power Act, the Public Utility Holding Company Act and State laws governing the rates, finances and organization of electric utilities. Although PURPA put no capacity cap on cogenerators, it limited QFs to 80 MW. Strangely, to qualify for the above exemptions, QFs other than those fueled by biomass had to fall under 30 MW, leaving an unexplained "no man's land" between 30 and 80 MW for windfarms and other renewable facilities.

By far the most striking aspect of the passages is the directive that the FERC "prescribe" its rules, and that the states "implement" them. While every other section of PURPA left latitude for state commissions to consider the proposed standards and then reject them if they wished, the House and Senate conferees agreed in this case to follow a more centralized approach. In doing so, Congress asserted the right of the Federal government to regulate electric utilities, hitherto responsible only to local authorities.

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[29]Emphasis added. P.L. 95-617, 92 Stat. 3117 (codified in scattered sections of 15, 16, 30, 42 and 43 U.S.C.). Portions quoted in the following paragraphs are Section 201, "Definitions," and Section 210 {a, b, e and f}, "Cogeneration and Small Power Production."

It is not clear whether members of Congress noted the change. Sen. Jackson, as recounted above, assured the Senate that "each State would be free to decide whether or not" to adopt PURPA's ratemaking standards. One guesses that Jackson himself knew of the exception to his resume, although he probably did not expect its consequences. Other members and their staffs, less familiar with the material and caught up in the frenetic debate over natural gas and energy taxes, may have missed the report's crucial phrases.

The FERC rules

In the FERC's 1980 ruling on the implementation of PURPA's Sections 201 and 210,[30] the agency chose to offer strong encouragement to small power and cogeneration. To the resentment of some observers, the FERC set the purchase price of QF and cogenerator power "at a rate reflecting the cost that the purchasing facility can avoid as a result of obtaining energy and capacity from these sources."[31] This rate, the "full avoided cost," represented the highest price allowed by Congress, and guaranteed to the QFs themselves the full benefits of their operation. (Alternative proposals had suggested splitting the savings between the QFs and ratepayers.) Requiring payment of full avoided costs also removed any short-term financial benefit to utilities from working with the entrepreneurs.

The FERC made other provisions to ease market entry by QFs and cogenerators. For example, because investors would base their decisions to buy into an independent energy project on the basis of the expected purchase price of its energy, the FERC required utilities to make available information concerning their marginal costs. The FERC required utilities to buy all power generated by the independent producers, whether they needed it or not. Finally, the FERC allowed (but did not require) states to implement standardized contracts

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[30]See FERC, "Small Power Production and Cogeneration Facilities--Qualifying Status: 18 CFR 292, Docket No. RM79-54," *Federal Register* 45 (20 March 1980), pp. 17,959-17,976, and; FERC, "Small Power Production and Cogeneration Facilities; Regulations Implementing Section 210 of the Public Utilities Regulatory Policies Act of 1978: 18 CFR 292, Docket No. RM79-55, Order No. 69," *Federal Register* 45 (25 February 1980), pp. 12,214-12,237.

[31]FERC, "Regulations Implementing Section 210," p. 12,215.

for the purchase of independent power, so as to lower the transaction costs of doing business with the utilities.

Conclusion: A historical riddle

A historical riddle lies at the center of PURPA, the most important piece of energy legislation since PUHCA. Why did the Joint Committee of Conference choose to couch Sections 210's provisions as requirements, while phrasing the ratemaking portion of the bill--ostensibly its main purpose--as non-binding encouragement? Certainly, some players acted intentionally, but their motives remain hidden. For example, the exemption of biomass from the 30 MW limit (for no obvious technical reason) suggests that the negotiations featured behind-the-scenes horse-trading by individual members protecting facilities in their home districts. Yet, other ambiguities in PURPA seem to reflect oversights made in the heat of the moment, such as the "no man's land" between the 80-MW limit on QFs, and the 30-MW limit on exemptions from utility regulation. One suspects that a certain element of sloppy staff-work enabled Congress to pass PURPA with little or no debate over its bombshell concerning non-utility generation.[32]

## PART III: Response to PURPA

Immediately after its passage, PURPA provoked dislike within the utility industry, but not outrage. A 1978 editorial in *Electrical World* bemoaned the law's "quicksands," such as the possibility that utilities might have to offer energy audits to customers requesting them, but the author sighed with relief in telling readers that

> ...utilities escaped relatively easily. Although the threat of prohibition on the use of natural gas and oil that had been hanging like the sword of Damocles was formally

[32]Current and as-yet unpublished research into the genesis of Section 210 reveals conflicting accounts which indicate key roles for Sen. Durkin, who may have been trying to protect a waste-to-energy company in his home state, and S. Lynn Sutcliff, a former Senate staffer who had worked with a law firm dealing with energy issues. Personal communication with Richard F. Hirsh concerning research for "Renegotiating the Social Contract: The 'Demand-side Revolution' and the Restructuring of the American Electric Utility Industry, 1978-1992," NSF Grant, NSF Office of Science and Technology Studies. These revelations underscore the questionable value of *ex post facto* appeals to intentionality as a historical tool. While Durkin may indeed have intended to protect a constituent's interests, Hirsh's research has uncovered no hint that Durkin or anyone else "intended" to deregulate the utility industry, or that anyone even realized the explosive potential of Section 210 after its passage.

> carried out... the Public Utilities Regulatory Policies Act appears to contain no nasty surprises.[33]

Other commentaries discussed the economic potential of cogeneration projects,[34] regretted that state commissions would slow or halt conservation efforts already underway while they awaited the FERC's rulings,[35] and criticized the FERC's understanding of marginal cost theory.[36] No-one cast PURPA as a deregulatory measure, or predicted the scale of its effect on the alternative energy industry.

As time passed, however, entrepreneurs and some members of the alternative energy community began to see the bill's potential. Utilities and state PUCs also saw what lay ahead, and they mustered opposition. They perceived even the requirement that states "consider" the new rate-making policies a burden, and most found Section 210 completely unacceptable. One observer charged that PURPA tried to "twist the arms" of state regulators by forcing them to consider Federal initiatives and justify any decision not to adopt them. While the states could consider and reject the guidelines, they could not ignore them, and the author lamented this pernicious instance of Federal encroachment.[37] In another response, a utility manager characterized PURPA's ratemaking reforms as redundant, since (he claimed) utilities had traditionally pursued conservation, efficiency and equitable rates on

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[33]William C. Hayes, "The National Energy Act isn't," *Electrical World* 190 (15 December 1978), p. 3.

[34]Scott A. Spiewak and Donald E. Kreps, "Cogeneration and Regulatory Uncertainty," *Public Utilities Fortnightly* 106 (20 November 1980), pp. 25-27.

[35]Joskow, "Public Utility Regulatory Policies Act," pp. 787-809.

[36]Dov Frishberg, "The FERC Rules on Marginal Costs," *Public Utilities Fortnightly* 104 (13 September 1979), pp. 26-30.

[37]Stanley A. Martin, "Problems with PURPA: The Need for State Legislation to Encourage Cogeneration and Small Power Production," *Boston College Environmental Affairs Law Review* 11 (1983), p. 169. Actually, Martin condoned PURPA's goals, but found counter-productive the use of Federal authority as a vehicle. He favored incorporation of PURPA's provisions in state codes to avoid the tangle of arguments over Federalism, and noted that seventeen states had already done so (pp. 171-172), for instance California in its Small Power Producers Act of 1976. Such state laws became known as "mini-PURPAs."

their own, with no prodding from the Federal government. The author petitioned the new Reagan Administration to block PURPA "by whatever means administratively feasible."[38]

In hindsight, such reactions seem predictable, given that, as one analyst put it, "PURPA contains no practical incentives for utilities, and is, in fact, contrary to their interests."[39] PURPA excluded from its protection facilities in which utilities owned a controlling interest. One cogenerator deplored that the best electrical engineers in the country "have chosen to focus their good minds on how to stop this whole thing rather than how to benefit from it,"[40] and suggested that utility involvement would improve the technologies. Although "enlightened" activists such as the Environmental Defense Fund argued that utilities could lower rates, avoid construction risks, and increase investor returns by encouraging independent power and renewable sources, most utility managers saw PURPA as a threat to their revenues and to their control over the national electric supply system.

Utility managers afraid of the breakdown of their monopoly soon allied themselves with state politicians apprehensive of Federal encroachment. Soon after issuance of the FERC rules, this alliance took its complaints to the courts. The Supreme Court heard "FERC v. Mississippi" in 1982, and "American Paper v. American Electric Service" reached the bench a year later.[41] The Supreme Court decided in these two cases to support the

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[38]Lamont K. Richardson, "Why PURPA's Title I Should be Repealed," *Public Utilities Fortnightly* 107 (12 February 1981), p. 14.

[39]Martin, "Problems with PURPA," p. 190.

[40]Testimony of Thomas Casten, President of Cogeneration Development Corp., in U.S. Congress, House of Representatives, Committee on Energy and Commerce, Subcommittee on Energy Conservation and Power, *Cogeneration and Small Power Production*, 97th Congress, 2d Session (15 June 1982), Serial No. 97-153, p. 45.

[41]The following accounts of the Supreme and lower Court rulings draw on: "Federal Energy Regulatory Commission, *et al.*, Appellants, v. Mississippi, *et al.*, No. 80-1749," *102 Supreme Court Reporter* 456 U.S. 742 L.Ed.2d 532 (1982), pp. 2126-2157, and; "American Paper Institute, Inc., petitioner, v. American Electric Power Service Corporation, *et al.* and Federal Energy Regulatory Commission, petitioner, v. American Electric Power Service Corporation *et al.*, Nos. 82-34, 82-226," *103A Supreme Court Reporter* 461 U.S. 402, 76 L.Ed.2d 22, pp. 1921-1933.

FERC's aggressive implementation of PURPA. By so doing, the Court reassured entrepreneurs considering renewable energy and cogeneration projects, and opened a floodgate of investment.

In the first case, the state of Mississippi argued before a District Court that Titles I and III and Section 210 of PURPA infringed on states' rights, protected by the Tenth Amendment and not included in the Commerce Clause of the Constitution.[42] The District Court agreed, roaring toward Washington that "the sovereign State of Mississippi is not a robot, or a lackey which may be shuttled back and forth to suit the whim and caprice of the federal government."

The Supreme Court unanimously rejected the District Court's use of the Commerce Clause, noting previous decisions establishing the interstate nature of the electric industry, and therefore the Federal government's authority to regulate it. The Court divided over the Tenth Amendment. Justice Sandra Day O'Connor, for instance, objected scathingly that PURPA's Titles I and III "conscript state utility commissions into the national bureaucratic army." But Justice Henry Blackmun, writing for the majority, noted that Congress and the FERC legally could have taken complete control of utility ratemaking. Given that, Blackmun found the "guideline" approach of Titles I and III rather restrained. In regard to Section 210's stronger language, the Justice pointed out that according to the FERC rules, state commissions might take no action on PURPA, and only adjudicate disputes arising between independent generators and utilities with regard to PURPA's edicts. Since regulatory agencies routinely performed this type of action, Blackmun reasoned in his majority decision, PURPA could not infract the Tenth Amendment. Although some observers found Blackmun's argument a bit strained, the law survived undiluted.[43]

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[42]Section Eight of the Constitution's Article One empowers Congress to "regulate commerce... among the several states." The Tenth Amendment reserves "powers not delegated to the United States by the Constitution... to the states respectively."

[43]For the remarks of O'Connor and Blackmun, see "FERC v. Mississippi," pp. 2137-2138, 2144-2157.

Soon afterward, in response to a challenge by a group of utilities, the District of Columbia Court of Appeals nullified two of the FERC's specific rules. The District Court objected to the FERC's award of "full avoided costs" to QFs and cogenerators, and to its requirement that utilities physically interconnect with independent power producers. The FERC and the American Paper Institute appealed the decision to the Supreme Court.[44] The Supreme Court acknowledged that while awarding the full avoided cost to independent generators might not directly benefit ratepayers, the nation as a whole would gain from encouraging these new technologies. In choosing full avoided costs, the Court believed, the FERC had interpreted Congress's wishes appropriately.

The interconnection issue proved a complicated legal mess. Section 210(e)(3) of PURPA subjects QFs to Section 210 of the Federal Power Act, which requires the Commission to hold a formal evidentiary hearing before ordering utilities to interconnect with any other facility. The FPA disallows such an order if it causes an uncompensated economic loss to the utility, or impairs the utility's reliability or quality of service (among other conditions). But Justice Thurgood Marshall, writing for the unanimous Court, noted that completion of a sale requires an interconnection; on those grounds, the Court found that the FERC had acted appropriately in pursuing its Congressional mandate to aid the emergence of independent power.[45] Again, PURPA survived.

## Conclusion: A Historiographic Enigma

PURPA represents a historiographic enigma. Passed as an energy efficiency measure, it evoked resistance to Federal encroachment on states' rights and on private

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[44]"High Court Upholds Utility Rules of U.S.," *The New York Times* (17 May 1983), p. D5. As the Supreme Court deliberated the "avoided cost" issue, Rep. Ottinger led an unsuccessful effort to pass the Cogeneration and Small Power Production Program Clarification Act of 1982, by which Congress would have specified the payment of full avoided costs by statute (rather than leaving the matter to the FERC). See U.S. Congress, *Cogeneration and Small Power*.

[45]In reaching its conclusions, the Court repeated the FERC's argument that FPA 212(e) qualifies FPA 210 by denying FPA 210 precedence over other existing laws. While PURPA 210(e)(3) can be interpreted in "its literal meaning" to require formal interconnection hearings to protect utility interests, Marshall opined, "the purposes of PURPA strongly support the Commission's contrary reading." Marshall also suggested that the cost of evidentiary hearings would inhibit QFs and cogenerators.

industry's "natural monopoly." In the end, it burst the traditional regulatory framework governing electricity generation. Its effect surpassed the imagination of both its proponents and its critics. In 1980, the FERC projected that PURPA would induce the development of 12,000 MW of independent power by 1995. As early as 1986, however, the FERC had received filings from entrepreneurs to construct 40,000 MW of capacity (although only half of that constituted already-constructed plants or firm commitments to build).[46] The nation saw 32,000 MW--about 5% of national capacity--on line by 1991.[47] These achievements paved the way for the passage of the National Energy Policy Act of 1992, which introduced even greater measures of competition into the electric utility industry. By 1994, PURPA's guarantees had brought 45,000 MW of capacity on line.[48]

By far, most of the independent plants brought on line in the 1980s in response to PURPA and related incentives used of cogeneration technology or burned natural gas. Yet, a number of facilities using renewable resources also got their start in this period. Of these, windpower proved the technology closest to commercial viability. In California, which chose to execute aggressively the FERC's rules, entrepreneurial windpower achieved a startling measure of success, and soon eclipsed the troubled Federal Wind Energy Program. On the down side, however, the circumstances of entrepreneurial windpower's birth ensured that the utilities perceived it as an unwelcome affliction symbolizing Federal high-handedness and anti-business philosophy.

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[46]"PURPA: Still Hazy After All these Years," *Public Utilities Fortnightly* 118 (10 July 1986), p. 33.

[47]Blair G. Swezey, "The Impact of Competitive Bidding on the Market for Renewable Electric Technologies," in *Proceedings: National Regulatory Conference on Renewable Energy*, in Savannah, GA (3-6 October 1993), p. 271. By 1992, non-utility generators, including those not considered qualifying facilities under PURPA, produced 15% of American electricity. Ann Crittenden, "Generating Competition: Electric Utilities Face a Host of New Rivals," *Barron's* (3 February 1993), p. 14.

[48]Yergin, Simon and Bupp, "Caught in the Muddle," p. 4. For purposes of comparison, at the beginning of 1993 American generating capacity equalled 752,000 MW, including 57,000 MW of decentralized generation. *Electricity Information: 1993* (Paris: Organization for Economic Cooperation and Development, 1994).

The story of PURPA also illustrates the irony of the windpower story. While California windfarmers often describe their success as a vindication of "decentralized" energy policy, their industry owes its existence to the controversial imposition of Federal power on local governments. Without the unexpected effects of Federal legislation, shored up by the conscious and aggressive support of the Federal Energy Regulatory Commission and the Supreme Court, windfarms could not have emerged.

# CHAPTER TEN
# Wind Wildcatters and the Shiny Shoes Crowd

## Introduction: More Than an Open Door

Although PURPA opened the door to independent wind development, it took juicy Federal and California tax incentives to attract investment to the new enterprise. These lucrative rewards threw together wind groupies and venture capitalists, a pair of odd bedfellows indeed. The wind industry of the early 1980s reeled from a bemusing "culture shock" as developers, manufacturers and investors elaborated a *modus vivendi*.

The "windfarmers" met various impediments, notably a predictably steep learning curve and unpredicted "environmental" opposition. The biggest obstacle, however, consisted of accusations that windfarms abused the tax credits themselves. But before tax reform eliminated the incentives in the mid-1980s, they attracted enough interest and cash to the windfarm industry to allow serious developers to get their start. This chapter describes the businesses that arose partly in response to the availability of tax credits. It also outlines their struggle against contemptuous Republican reformers opposed to the abuse of "loopholes" in the tax code, emerging "environmental" opposition to wind energy, and their own lack of expertise.

## PART I: The Stakes

As the 1980s opened, a confluence of regulatory factors at the Federal and state levels promised tempting financial rewards for Americans willing to gamble on a new, unexplored activity, "farming the wind." Section 210 of the Public Utility Regulatory Policies Act guaranteed interconnection, reasonable prices for energy produced and back-up power, and exemption from utility-style regulation to wind facilities up to 30 MW in capacity. While 30 MW seemed tiny by utility standards--new fossil and nuclear plants frequently exceeded 1000 MW in size--developers installing turbines as small as 17 kW found the niche positively roomy.

In a manner unplanned by Congress, the protections afforded by PURPA reacted synergistically with the incentives provided by a second component of Carter's National Energy Act, the Energy Tax Act of 1978.[1] The relevant sections of this statute amended the Internal Revenue Code to offer a 10% tax credit for investment in wind, solar and other innovative energy equipment; the credit augmented a standard 10% business investment credit. Congress intended the energy credit to expire after 1982. In 1980, however, the Crude Oil Windfall Profits Tax Act[2] extended the credit to the end of 1985, increased it to 15% and expanded it to cover other energy technology.

Additional legislation sweetened the pot for renewable energy. The Economic Recovery Tax Act of 1981 allowed investors to depreciate wind equipment at an accelerated five-year rate, compared to the ten years specified for many fossil fuel assets.[3] The Tax Equity and Fiscal Responsibility Act of 1982 exempted windfarm investors from the tax code's "at risk" provision, allowing them tax benefits greater than their investment, while limiting their liability to the sum at risk.[4] Taken together, these measures induced decisions that in the absence of overriding political goals might have been left to market forces.[5]

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[1]P.L. 95-618, 92 Stat. 3174 (codified in scattered sections of 19 and 26 U.S.C.). See "Congress Passes NEA with Several Solar Incentives," *Solar Energy Intelligence Report* 4 (16 October 1978), pp. 315-316.

[2]P.L. 96-223, 98 Stat. 229 (codified in scattered sections of 7, 19, 26 and 42 U.S.C.).

[3]P.L. 96-223, Sections 221-222, 94 Stat. 260-66 (codified in scattered sections of 46 and 48 I.R.C.). Depreciation refers to the assumption for tax purposes that an investor "loses" a certain fraction of material property each year due to normal deterioration. Whereas "straight line" depreciation assumes equal losses each year, accelerated depreciation stacks a greater percentage of the tax benefits into the first few years, allowing a quicker return on the investment. On the whole, the ERTA proved an overall disadvantage for renewables by granting a greater reduction in the effective tax rate for fossil energy capital equipment.

[4]Investors qualified for the credits provided that they had at least 24% of the funds at risk. Salvatore Lazzari and Jane Gravelle, "Effective Tax Rates on Solar/Wind and Synthetic Fuels as Compared to Conventional Energy Resources," Congressional Research Service, Report No. 84-85 E (16 April 1984), p. 25.

[5]See Starrs, "Legislative Incentives," pp. 116-117; Stephen L. McDonald, "The Energy Tax Act of 1978," *Natural Resources Journal* 19 (October 1979), pp. 859-869, and; "Energy Bill: The End of an Odyssey," pp. 641, 645-646. Of course, these laws extended their provisions to investments other than windfarms.

In addition to these Federal initiatives, a number of states enacted tax and other incentives to promote renewable energy. Their form varied. Some states adopted the Federal model by offering credits, which allowed investors to subtract a percentage of a wind system's cost from their total income tax. Other states offered tax deductions, which lowered the amount of income subject to tax. A third group absolved purchasers of wind equipment from property taxes. Other states offered no tax incentives at all.[6] However, while twenty states offered credits, all but six limited the portion of the project's cost that qualified for tax breaks, essentially ruling out large developments.[7]

In California, however, tax benefits decisively attracted investment to renewable energy projects. The State Assembly, after instituting a 10% solar tax credit in 1976, in the following year raised the ante to 25% for non-residential systems costing over $12,000.[8] Considered a temporary boost for a nascent industry, the credits later received two legislative extensions before expiring in 1986. Lured with such incentives, California soon outstripped the nation in installed renewable energy capacity.[9]

## PART II: Manufacturers and Machines--A Question of Scale

Some homeowners took advantage of Federal and state tax credits to buy wind systems with capacities of a few kilowatts, perhaps selling the excess electricity to the local electric company. But venture capitalists soon seized on the idea of grouping turbines into a

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[6]John H. Minan and William H. Lawrence, "State Tax Incentives to Promote the Use of Solar Energy," *Texas Law Review* 56 (1978), pp. 838-839, 843. These authors prefer tax credits to deductions, noting that credits allow the same incentive to all investors regardless of income level. See also "Wind Laws Enacted," *Wind Power Digest* (September 1976), p. 20, and; "New Wind Legislation," *Wind Power Digest* (December 1976), p. 18.

[7]Only California, Hawaii, Arizona, North Dakota, Ohio and Oklahoma allowed unlimited claims. "Solar and Wind Technology Tax Incentive Impact Analysis," prepared by Polydyne, Inc. & Associates for the California Energy Commission, P500-86-010 (May 1986), p. 2/7.

[8]See Assembly Bill 1558, codified in California Revenue and Taxation Code section 17052.5.

[9]"California's Solar, Wind, and Conservation Tax Credits," Tax Credit Committee of the California Energy Commission, P103-83-001 (December 1983), pp. 22-23.

"windfarm"[10] intended specifically to sell power to utilities. Unlike the clusters of multi-megawatt utility-owned machines envisioned by the Federal Wind Energy Program, windfarms incorporated intermediate-sized machines with capacities under 500 kW, owned and operated by entrepreneurs. The bulk of such projects took advantage of the favorable regulatory climate and strong winds in the high mountains of California, in particular in the Altamont, Tehachapi and San Gorgonio Passes; by 1985, installations in the three sites produced 89% of the world's wind-generated electricity.[11]

An attempt to use giant turbines

Although the FWEP had apparently demonstrated that multi-megawatt wind turbines offered economies of scale over smaller machines, few windfarm developers could raise the capital to purchase them. One notable but unsuccessful bid to develop farms of giant turbines involved a San Francisco company called Windfarms Limited. Founded by Wayne Van Dyke, who left a position as a venture finance specialist in 1978 to pursue large-scale wind projects, Windfarms Ltd. raised $17 million and contracted with the Hawaiian Electric Company to construct an 80-MW facility on Oahu. The installation would have supplied 9% of Honolulu's power from farms of 4-MW "WTS-4" turbines built by Hamilton Standard, a subsidiary of United Technologies. Negotiations alone cost the firm $600,000; Van Dyke estimated the cost of the project itself at $360 million.[12]

HECo would have paid Windfarms Ltd. the utility's "avoided cost," as the FERC required. Van Dyke estimated the average cost of his windpower at seven cents/kWh; HECo projected that the cost of generating its own electricity would rise above that level by

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[10]As recognized in Chapter Five, note #1, the origin of the term "windfarm" remains obscure. In 1981, the Department of Energy (DOE) referred to a cluster of three 2.5-MW MOD-2s owned by the Bonneville Power Administration as the first windfarm.

[11]Don R. Smith, "The Wind Farms of the Altamont Pass Area," *Annual Review of Energy* 12 (1987), p. 146.

[12]Testimony of Wayne Van Dyke, President of Windfarms Ltd., in U.S. Congress, *Cogeneration and Small Power*, p. 83.

1986, perhaps sooner.[13] Windfarms Ltd. soon approached other oil-dependent utilities, whose avoided cost Van Dyke hoped would rise equally high. In 1981 the Pacific Gas and Electric Company agreed to purchase the energy from Windfarms Ltd.'s planned 350-MW facility in California's Solano County; the state's Department of Water Resources agreed to buy the electricity generated during off-peak times for pumping purposes.[14] The future seemed to beckon for Van Dyke's ventures.

The outlook soon soured. Hamilton Standard's prototype WTS-4, installed by the U.S. Bureau of Reclamation, proved a lemon, and the firm left the wind business.[15] At the same time, the Reagan administration slashed funding for the FWEP, making it unlikely that the other players in the large-turbine business, Boeing and General Electric, would commercialize their multi-megawatt designs. Indications that Congress wanted to halt tax incentives for wind technology added to the manufacturers' chariness.

In collaboration with two prestigious investment banks, Merrill Lynch & Co. and the First Boston Corp., Windfarms Ltd. doggedly arranged $105 million for its own R&D program, but this impressive deal collapsed as the price of oil fell from over $40 to under $30 per barrel. Toppling oil prices dealt the final blow to the giant-turbine manufacturers and to Windfarms Ltd.'s plans; Van Dyke estimated the cost of electricity from the first phase of the yet-unbuilt Hawaii project at 11 cents/kWh, but HECo's avoided costs soon fell to 5 cents/kWh. By 1982, Van Dyke mournfully informed a Congressional subcommittee that his company had spent over $12 million, held contracts with three utilities for over 450 MW worth $1 billion, but lacked a technology.[16]

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[13]Naar, *The New Wind Power*, p. 151.

[14]"World's Largest Wind Cluster Planned by Windfarms, PG&E, California," *Solar Energy Intelligence Report* 7 (30 March 1981), p. 132.

[15]"Hamilton Standard Backs Out of 80-MWe Hawaiian Windmill Project," *Solar Energy Intelligence Report* 7 (5 October 1981), p. 326.

[16]Testimony of Van Dyke in U.S. Congress, *Cogeneration and Small Power*, p. 83.

Van Dyke's experience seemed to indicate that, although large machines promised theoretical advantages, they did not fit the emerging windfarm market. Even if they had demonstrated reliable performance during development--which they did not--few entrepreneurs could muster the capital to purchase large turbines. (Of course, the technical risk added to the difficulty of securing investment.) Likewise, producing enough giant turbines to achieve economies of mass production required an enormous investment by the manufacturing firms, which made them even warier of committing themselves.

Intermediate turbines

Lacking the clout to employ the 4-MW Hamilton Standard WTS-4 or the 3.2-MW Boeing MOD-2,[17] developers relied on smaller machines. For instance, Renewable Energy Ventures (REV), founded by a former utility employee and a financially-minded surgeon, settled on 17-kW turbines made by the wind industry's illustrious septuagenarian, Marcellus Jacobs. After locating a financial backer to provide start-up capital and guarantee the performance of the units, REV went to work selling interests in Hawaiian and Californian windfarms. The company soon found the Jacobs machine too small for profitable development and switched to a 50-kW machine made by Energy Sciences, Inc.[18]

In fact, "intermediate" machines between 50 and 500 kW edged out very large machines such as the WTS-4 and very small machines like the Jacobs unit. In the early years, developers seeking intermediate turbines found this niche empty. But the small-turbine community, sparked by the prospect of selling more profitable intermediate units to a thriving new industry, scrambled to scale up, as the large firms considered scaling down.

For example, the 50-kW Energy Sciences, Inc. machine adopted by REV resulted from the work of five former employees of the FWEP's small-turbine center at Rocky Flats,

[17]According to the executive in charge of the PG&E's wind program, the firm paid $14 million for its MOD-2, the only giant turbine purchased by an investor-owned utility. Interview with Iannucci.

[18]Interview with Lotker, co-founder of REV.

who caused a small flap in 1980 by quitting to form their own firm. Some members of the wind community complained that ESI had profited from publicly-funded research. When quizzed, company president Jim Alexander, who had directed field operations at Rocky Flats, replied testily that "we were in an ideal spot to know what the market needed and to supply the technological answers as well as having excellent capitalization and solid manufacturing capacity backing us up."[19] He also pointed out that anyone could have obtained the data used to design the popular ESI-54 through the Freedom of Information Act. The 54-foot turbine met with considerable success, due to its simplicity and its use of off-the-shelf components, and equally important, to the scarcity of machines appropriate to windfarm use.

Some large corporations tested the intermediate market as well. In some cases, they waited for a small firm to build a good machine, and then offered to purchase the company. For example, Carter Wind Turbines (CWT) of Burkburnett, TX, headed by former Bell Helicopter engineer Jay Carter, Jr., and his father, posted admirable availability and energy production figures with its 25-kW machine, the Carter-25. In 1982, Hamilton Standard offered to buy out CWT contingent on the performance of CWT's next machine, a 250-kW model. The speed with which the small, under-capitalized firm completed its second effort surprised the industry and impressed Hamilton Standard.[20]

Unfortunately for CWT, their prospective parent bolted after problems cropped up with the WTS-4. Hamilton Standard soon left the wind business altogether. (The younger Carter explains their decision to jilt CWT by crowing that "they didn't want to be seen in the industry as being rescued by a three-man outfit in Burkburnett, Texas!") CWT narrowly missed the chance of a similar arrangement with Electricité de France, the French utility giant, when fire razed the CWT fabrication facility, but eventually they found a godfather in

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[19]Quoted in Naar, *The New Wind Power*, p. 91.

[20]Interview by Kahn of Carter.

the German manufacturer of diesel equipment (and high-quality but economically uncompetitive wind turbines), Maschinenfabrik Augsburg-Nuernburg.[21]

Vertical Integration

Of the dozens of wind turbine companies emerging in the 1970s and 1980s, U.S. Windpower received the most acclaim. By many measures, it also experienced the most success. Founded in 1974 by Stanley Charren and a coterie of tinkerers in a Massachusetts garage, U.S. Windpower immediately dismissed the manufacture of megawatt-scale machines as beyond their capabilities. Charren and his team gambled instead that the shorter interval needed to achieve economies of mass production with intermediate-sized turbines priced under $50,000 apiece would outweigh their theoretically higher cost of energy. After erecting twenty 40-foot, 30-kW turbines in New Hampshire as the nation's first PURPA-protected windfarm in 1979, the company produced a disappointing 50-kW machine. But the next effort, a 56-foot 100-kW unit, became the company's workhorse. In 1980, U.S. Windpower moved to California, where they eventually installed 4200 dependable "56-100s," mostly in the Altamont Pass. These machines frequently surpassed other brands in fulfilling their energy-capture goals.[22]

Although U.S. Windpower eventually produced solid wind turbines, its early technology arguably represented nothing special. In explaining the firm's success, most observers refer instead to its concurrent manufacturing and development operations, which made it the world's only vertically-integrated wind enterprise. Typically, U.S. Windpower sold interests in the projects it developed (often retaining a small equity interest), leased back the machines, and pocketed the revenue from energy sales. The company found that by designing, manufacturing, installing, operating and maintaining its turbines, it efficiently

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[21] *Ibid.*

[22] Jonathan Marshall, "Power Firm Races Into the Wind," *San Francisco Chronicle* (29 August 1994), p. 9; Kenetech Corp., *Prospectus* (28 April 1994), pp. 43-44; "Going With the Wind," p. 15; Christopher Flavin, "A Renaissance for Wind Power," *Environment* 23 (October 1981), p. 37; Smith, "Wind Farms of the Altamont," p. 168; Naar, *The New Wind Power*, p. 162.

recycled knowledge gained in the field back into the R&D process, and thus won an edge over the competition.

U.S Windpower's oldtimers boast that they aimed all along to dominate the wind business, and that this distinguished them from other firms. "We never saw ourselves as a cute little windmill company," says Glenn Ikemoto, now retired from the company's financial end. "We always envisioned ourselves as a generating business."[23] Other executives agree. William Holley, director of the firm's R&D division, contends that other wind concerns shied from hard-nosed business tactics. "They didn't want to grow," he asserts. "They wanted to maintain their independence, to be green... They didn't want to sacrifice their principles to become a major industrial company." Holley demurs from the question of whether his firm sacrificed anything in its drive to shape windpower as a "generally accepted utility generating technology."[24] However, he unapologetically dismisses the concept of "soft technology" as a fiction, and chalks up U.S. Windpower's success to its willingness to adapt to mainstream America's business culture.[25] Outside observers sometimes chuckle at U.S. Windpower's assurances that they planned it all, but no-one presents evidence to the contrary.[26]

Variety

As the industry gathered speed, developers installed a plethora of different model turbines. In 1994, one source counted no less than sixty-five different types under 500 kW in commercial service, made by thirty-seven different manufacturers, most installed in the

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[23]Interview with Glenn Ikemoto, retired, in San Francisco, CA (21 July 1994).

[24]Kenetech Corp., "Prospectus." This phrase continually recurs in U.S. Windpower rhetoric, and represents to the company its determination to move windpower from the counter-culture fringe to the utility boardroom.

[25]Interview with William E. Holley, Director of R&D for Kenetech Windpower, in Livermore, CA (22 July 1994).

[26]For example, interview with Thresher.

1980s.[27] These included upwind, downwind and Darrieus machines; machines with two, three and four blades; machines on tubular shell and lattice towers; free-yaw machines and those with yaw motors; machines with stall control, full-span pitch control and partial-span pitch control; machines with fiberglass, aluminum, carbon graphite and wood blades--in short, a tremendous variety of wind turbines that explored every imaginable variation on the basic themes available. While cynics attributed this technological variety to the availability of tax credits which allowed anyone to make money, even if their machines failed to perform, the optimists point out that the tax credits allowed the emerging companies to do R&D in the field--a socially-expensive process, perhaps, but a unique opportunity to develop the best technology possible.

Its variety notwithstanding, the development of wind technology showed some clear trends. Most noticeable, the average capacity of newly-installed units rose each year, from 49 kW in 1981 to 191 kW in 1992, so as to increase energy production per unit of ground area and per unit of fixed-cost investment.[28] The growth in machine size showed clearly that the success of intermediate machines derived not from superior physics but from the giant machines' incompatibility with the existing market. As the windfarm infrastructure and financial backing grew capable of absorbing larger machines, capacities increased.

Why intermediate machines?

Questions of scale dominate most comparisons of the FWEP and the entrepreneurial windfarms. Indeed, the importance of intermediate machines caught most people by surprise. Louis Divone of the FWEP recalls the problems his people had generating interest in the medium sizes during the 1970s. To the utilities, he recalls, even a 3-MW machine was "peanuts," and a 100-kW machine made no sense to them at all. On the other hand, such a unit dwarfed residential turbines by a factor of twenty. While FWEP managers talked up the advantages of intermediate-sized wind machines for industrial and agricultural

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[27]Appendix C in Spera (ed.), *Wind Turbine Technology*, pp. 612-624.

[28]Lynette and Gipe, "Commercial Wind Turbine Systems" in Spera (ed.), *Wind Turbine Technology*, p. 180.

use and for remote communities, the FWEP did not envision the major market for intermediate machines that emerged in California. "We missed the boat on that," Divone concedes, "and, in fact, so did everyone else."[29] Neither the FWEP, the aerospace firms involved in giant-turbine manufacture, the smaller firms pursuing residential machines, nor the American Wind Energy Association foresaw an important market for intermediate-sized wind turbines.

In retrospect, intermediate turbines offered clear advantages. First, against the expectations of the large-turbine community, rotors two to three hundred feet in diameter proved difficult and disconcertingly expensive to build. (Recall the failed fiberglass blade that delayed the MOD-1 project.) The intermediate machines, often a fifth or less the diameter of the MODs, reduced developmental risks and lowered installed costs per unit of swept area, a major determinant of energy capture. Second, the intermediate machines' economies of mass production outweighed the large machines's economies of scale, especially since manufacturers purchased most components off the shelf. Third, transportation and installation proved easier and cheaper; windfarm developers used standard trucks, smaller cranes and less skilled labor.

And fourth, the modularity of small machines allowed a number of advantages. They had shorter lead times, so that manufacturers could incorporate operating experience into future models more quickly, thus speeding the pace of technological development. Smaller modules also meant greater reliability; a miscalculation in siting or a malfunction in an intermediate turbine reduced a windfarm's total capacity by that much less. Finally, smaller machines required less capital investment in production facilities. Thus, while less cost-efficient on paper than the Federal giants, the intermediate machines proved cheaper and less chancy in the field. Like the FWEP giants, they too experienced operational

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[29]Interview with Divone. The FWEP spent a good deal on this size range (25% of its budget, according to Divone), but the FWEP's intermediate models--the 100-kW MOD-0 and the 200-kW MOD-0As--served as studies for the multi-megawatt machines, rather than as ends in themselves. Neither the intermediate horizontal-axis MOD-4 and the MOD-6H, nor the intermediate vertical-axis MOD-6V ever passed the proposal stage.

problems; their advantage derived not from superior hardware, but from better compatibility with the economic environment.

## PART III: Wind Groupies and Venture Capitalists

The windfarm business married members of the small-turbine industry to financial schemers. To the manufacturers, often motivated by ideological opposition to the established electric system and fixed on technological development, the legislative initiatives outlined above seemed daunting; one author concluded despairingly that "a tax lawyer may be necessary to unravel these complexities for a particular" facility.[30] On the other hand, while experienced financiers often identified the synergy between the Energy Tax Act's incentives and PURPA's protections before the nuts-and-bolts turbine manufacturers, they knew little about the technology itself. At first, this mutual ignorance produced friction, but the firms that managed to knit innovative expertise to business savvy thrived.

### The boom

Windfarm developers obtained financial backing through two principle paths. Some, such as Windfarms Ltd., solicited funds from a number of investors in the upper-income brackets, each seeking a write-off on their Federal and state income taxes. Apart from the tax credits, each investor stood to gain from the farm's energy sales in proportion to their investment. Other developers, such as U.S. Windpower in its early years, sold single units to investors, which the owners then commissioned U.S. Windpower to operate. The proud owners received photos of their machines, and earned returns according to its energy production. Because imperfect siting techniques precluded accurate prediction of a given unit's energy yield and opened the developer to investors' lawsuits, the former approach won out. U.S. Windpower, for example, soon shifted to the more common debt-and-equity financing.[31]

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[30]Randi Lornell, "A PURPA Primer," *Solar Law Reporter* 3 (May-June 1981), p. 65.

[31]Frederic March, *et al.*, *Wind Power for the Electric Utility Industry: Policy incentives for fuel conservation* (Lexington, MA: Lexington Books, 1982), pp. 20-21.

The influx of cash into a capital-starved industry stimulated an era of exhilarating growth. As the financiers assembled their deals, they swarmed windpower trade shows--previously of interest to only the dedicated few--in search of hardware. The manufacturers responded by enlarging and improving their machines, and turning out as many as possible. The California Energy Commission estimated that the state's turbine manufacturing sector hosted 441 jobs in 1983, up from 250 in 1981, while the development sector employed 270, up from 30. Construction and installation put 1050 state residents to work in 1983, up from 49 two years before. The Commission speculated that an active wind industry could employ 50,000 Californians by 2000.[32]

Janice Hamrin, founder of the Independent Energy Producers Association (IEPA), compares the California windfarmers to the early Texas wildcatters prospecting for oil. The boom, she reminisces, had a cowboy feel to it. Yet, perhaps unlike the Texan oil community, the "wind wildcatters" viewed themselves as idealists, combining capitalism and sustainable energy development. Of course, they had other motivations. Many viewed the boom as a chance to embarrass the FWEP, which, they charged, had erred in ignoring the counter-culture in favor of its aerospace contractors. But as Hamrin recalls, "they thought they could make money doing something good."[33]

In some cases, the "wildcatter" mentality combined with untested technology to yield dangerous risks and accidents. Each winter, developers struggled in the snow and winds of the California mountain passes to ready their machines by January 1, so as to qualify for the annual tax credit. In one notable tragedy, turbine designer Terry Mehrkam, founder of the Energy Development Company, fell to his death in the winter of 1981 while trying manually to shut down a malfunctioning unit. Hamrin recollects that "we knew within a few hours.

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[32]"California's Tax Credits," pp. 94-96. The study notes that most turbines installed in California came from out of state.

[33]Interview with Janice Hamrin of Hansen, McOuat, Hamrin and Rohde, in Savannah, GA (4 October 1993).

We were shaken, because everyone was cutting corners to get these things up. It happened every year."[34]

The accident struck such a chilling note partly because the early wind industry formed a tight community. Most of the work occurred in a few highly visible locations, and developers and manufacturers alike shared information on how best to use certain machines, and they worked together to develop new siting and negotiating techniques. Often, the meetings of the American Wind Energy Association provided a more-or-less formal community, but an informal subculture grew up among the "roustabouts" of the California wind fields as well.

As usual, U.S. Windpower diverged from the rule. The emerging leader in the field, Hamrin recalls, treated communitarian information-sharing almost as industrial espionage.[35] Company engineers rarely attended technical meetings, or shared the results of their research, and soon gained a reputation for arrogance. William Holley, later U.S. Windpower's manager of R&D, remembers that when he left Oregon State University in 1985 to join the firm's technical team, he encountered myopia, and even ignorance. U.S. Windpower employees, he recalls, felt that "the rest of the industry was Mickey Mouse, that [they] had nothing to learn by interacting with them."[36]

Although Holley believes that the company benefitted from his contacts in the domestic and European wind industries, it did not grant him complete freedom to share his experiences with outsiders. Had U.S. Windpower chosen a more open corporate personality, Holley speculates, he might today be broader and better informed about the wind industry. "But would it be better for the company?" He shrugs. "I don't think so." Other wind

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[34] *Ibid.*

[35] *Ibid.*

[36] Interview with Holley.

companies, Holley surmises, alienated potential financial backers by flouting the etiquette of the business world.[37]

The "tax farms"

As Donald Bain of the Oregon Department of Energy remembers, in the early 1980s the wind industry reeled from an invasion of

> ...promoters and money men, people with slick suits and shiny shoes, who were basically packagers and developers of capital intensive projects... They didn't give a damn about the health of the industry, or any of the values of the industry up to that time.[38]

A few developers demonstrated a strong commitment to windpower as a viable, long-term energy industry, and some investors drew satisfaction from their socially-acceptable application of venture capital. It seems clear, however, that some developers and many investors knew little and cared less about windpower *per se*. Often, they seemed more interested in making deals than in building a business.

Because the tax credits accrued according to money invested, rather than energy produced, speculators could make a bundle without producing a single kilowatt-hour of electricity. As one utility executive sniffs, "it could have been a wind turbine, it could have been a hippopotamus... If you wanted a million-dollar tax credit, you got a million-dollar hippopotamus."[39] So, from the beginning, windfarms carried an unsavory reputation. While a journal called *Medical Economics* approvingly reported one doctor's experience investing in windfarms as "How I Built a Better Tax Shelter,"[40] the financially conservative *Forbes* sneered at the "The great windmill tax dodge."[41]

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[37]*Ibid.*

[38]Interview with Bain.

[39]Interview with Iannucci.

[40]Raymond M. Chaitin, "How I Built a Better Tax Shelter," *Medical Economics* 62 (9 September 1985), pp. 107-116.

[41]Ellen Paris, "The great windmill tax dodge," *Forbes* 133 (12 March 1984), pp. 39-40.

Consider the following simplified illustration involving an upper-income California resident in the 50% Federal marginal tax bracket (*i.e.*, after allowed deductions, she must pay half of her last earned dollar as tax). Presumably, she seeks to "shelter" her money in an investment that will relieve her Federal and California tax burden. Suppose that the general partner[42] of a wind project buys and installs a wind turbine for under $100,000 (a typical price for an intermediate machine). He then sells it to our investor--who becomes a limited partner--for a nominal price of $400,000, and receives from her in return $100,000 in cash. They agree to treat the outstanding $300,000 as a "non-recourse" loan, carrying no personal obligation of payment. For example, they may consider it a long-term, low-interest note with no restitution for the first ten years.[43] Regardless of when the investor pays, she receives the same tax benefits. Such financing encouraged highly leveraged deals, in order to create higher potential returns.

Since our investor bought the windmill for $400,000, she receives a 25% Federal credit, lowering her Federal income tax by $100,000. This approach pays back her up-front investment. The state of California also reduces her income tax by $100,000. The investor then writes off her $400,000 investment over a period of five years. This deducts the equivalent of $80,000 from her taxable income per year, depending on what depreciation schedule she chooses; as a member of the 50% tax bracket, she saves the equivalent of another $40,000 annually. Of course, she pays taxes on any income she receives from energy sales.[44] In sum, our investor instantly doubles her $100,000 investment, and secures

[42]Limited partners in wind projects received tax benefits that could exceed their investment, and bore liability only up to the amount invested. They also received payments from energy sales. The general partner, who organized the project, assumed responsibility for project management and bore potentially unlimited liability in the case of a calamity. By siphoning off management fees, general partners often had the opportunity to make tidy profits even when their projects proved unable to distribute energy earnings to the limited partners.

[43]The IRS required that non-recourse financing take the form of level-payment loans repaid in equal installments including principal and interest. Lazzari and Gravelle, "Effective Tax Rates," p. 25.

[44]For more on windfarm financing, see "Solar and Wind Tax Analysis," Polydyne, pp. 4/16-4/18.

hefty deductions each year for five years. As one developer reminisces incredulously, "there were deals that were that outrageous!"[45]

Even friends of windpower agree that fraud existed, perhaps even abounded, although few point to specific cases. Michael Lotker, co-founder of REV, recounts a common (and perhaps apocryphal) story of turbines with plywood blades, erected solely to earn a tax credit, and recalls a set of blue towers erected in Altamont Pass by a company called Turbo Wind, on which he never saw a blade or gearbox. Lotker maintains that

> ...there was out-and-out fraud during that period. If the Internal Revenue Service even gave it a cursory review, the fraud would be obvious. But people who did this were playing the lottery, because the IRS doesn't audit every one.[46]

Other observers compared two farms of rickety-looking Darrieus machines to "clotheslines strung with sails," implying that the units could not represent serious generating equipment.[47] Perhaps realizing the currency of such stories, Angus Duncan, representing the FloWind Corporation and the AWEA, admitted to Congress in 1985 that "there have been isolated instances of abusive tax farm activity," but stressed the AWEA's willingness to cooperate with the IRS in rooting out the rascals.[48]

But at the time, most windfarmers hotly denied charges of fraud, and they cast their business as the legal exploitation of provisions intended to reward risks taken while developing a socially-desirable new industry. They noted that while some turbines produced less energy than expected, very few--one in a thousand in the Altamont Pass, for example--

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[45]Interview with Lotker. Thanks to Mr. Lotker for what he jokingly calls a "two minute primer in tax fraud" on which the above example is based.

[46]*Ibid.*

[47]Solomon, "Windmillers Clean Up Act," p. 3.

[48]Testimony of Angus Duncan, Vice President of FloWind Corp. and Legislative Director for the AWEA, in U.S. Congress, House of Representatives, Committee on Energy and Commerce, Subcommittee on Energy Conservation and Power, *Renewable Energy Incentives*, 99th Congress, 1st Session (20 June 1985), Serial No. 99-25, p. 190.

never generated power at all.[49] They also complained bitterly that tax loopholes had become untouchable institutions in the conventional energy industry. The "depletion allowance," for example, encouraged oil drilling by permitting investors to list the gradual exhaustion of an oil well as "depreciation," even though the term generally refers to deterioration of capital equipment rather than depletion of natural resources. Consultants to the CEC reported that the oil industry had received $14.5 billion in incentives in FY 1978 alone.[50]

By contrast, tax incentives for wind technologies from 1981 to 1985 cost the Federal and California governments $774 million and $634 million respectively.[51] While not a negligible sum, especially considering the small contribution made by renewables to the national energy economy, defenders justified the incentives by pointing to their function in stimulating an embryonic industry. In the case of the established fossil fuel industries, they complained, the incentives amounted to subsidies; in the case of nuclear, they propped up an economically-inefficient energy option that had withered despite prolonged coddling.

Nevertheless, the fat and apparently unproductive rewards earned by the windfarmers irked many observers. Congressional and Californian legislators had approved the tax credits as an acceptable price to pay for the socially-beneficial development of an alternative energy technology. But, critics accused, the system apportioned munificent benefits to investors regardless of energy generated; no-one in the process had any incentive to make electricity, or even to purchase or design better machines. Windfarming's most implacable

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[49]Gerald W. Braun and Don R. Smith, "Commercial Wind Power in the United States," *Annual Review of Energy and the Environment* 17 (1992), p. 109.

[50]"Solar and Wind Tax Impact," Polydyne, p. 1/12.

[51]*Ibid.*, p. 5/25. To estimate of the cost of wind credits to Federal and state treasuries, the Polydyne report calculates gross revenue lost over the system's fifteen-year investment lifetime due to energy tax credits plus depreciation and interest deductions, minus the impact of alternative investments had the energy credits not been available. The figure for Federal cost refers only to systems installed in California, which of course constituted the mammoth portion of the Federal total. Figures in 1984 dollars. See also Starrs, "Legislative Incentives," p. 140.

foe, Rep. Fortney "Pete" Stark (D-CA), whose district included the Altamont Pass, carped that "these aren't wind farms, they're tax farms," but he sighed that "if you criticize the tax credits, people think you're unpatriotic."[52] Indeed, Congressional supporters of windpower repelled a number of attempts by the Reagan administration to kill the tax credits in the early 1980s, in advance of their scheduled expiration at the end of 1985.

Actually, windfarm tax shelters represented one instance of a larger trend in financial planning during the 1980s. In 1973, the IRS processed about 400 tax returns utilizing shelters, distributed among oil and gas partnerships, and real estate, farming and movie deals. In 1984, the agency struggled to decipher 350,000 returns involving twenty-five or thirty additional schemes. Some analysts estimated the revenue lost to the government from tax shelters at billions of dollars annually.[53] Not only the rich, but increasing numbers of middle-income Americans risked substantial fines on such dodges.[54] The pervasive tax shelters provoked President Reagan's pitched campaign for tax reform, which advocated eliminating the business investment tax credit and lengthening depreciation periods.[55]

Although windfarms represented only one option for a society turning in large numbers to complicated tax schemes that perhaps skirted the intent of the law, they aroused more virulent reactions than similar hustles. The explanation for this lies in the cultural conflicts of the 1970s and 1980s. As Hamrin pointed out, windfarmers often promoted themselves as a new breed of capitalists, using the market to propagate an environmentally-sound and virtuous energy option--and to enrich themselves in the process. Supporters of

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[52]Rep. Stark, quoted in Paris, "The great windmill tax dodge," p. 40.

[53]John S. DeMott, "Of Windmills, Cattle and Form 1040," *Time* 123 (19 March 1984), p. 48; Stanley H. Breitbard, "Shelters: Still alive and well?" *Financial World* 154 (6 March 1985), p. 106.

[54]Roscoe Egger, "The IRS Versus the Tax Shelter," *Best's Review: Life/Health Insurance Edition* 86 (October 1985), p. 78.

[55]Egger, "Egger says reform will curb shelters, aid investment," *Tax Notes* 27 (10 June 1985), p. 1280.

renewable energy such as Amory Lovins[56] often cast wind energy as a sagacious alternative to nuclear power. Claims by the renewable energy community to the ethical high ground provoked the ire of fiscal conservatives and of the established energy community, who remembered occupying that moral space not long before. The windfarmers' assertions of sainthood help explain why the use of questionable financial techniques, common in other spheres, evoked such a vinegary response.

## PART IV: Environmental Objections and Shaky Performance

Apart from battles with fiscal and cultural conservatives, windfarmers also skirmished with critics who deplored the environmental impacts of wind installations. In most respects, the incorporation of windpower into the electric utility system represented a triumph for environmentalism, demonstrating that "society," supported by sympathetic state and Federal regulators, could nudge the system onto an environmentally-sustainable "soft path." Unfortunately, as one critic noted, "a soft energy path can affect the environment in ways as complex as those of any coal or nuclear plant."[57] In some cases, homeowners used the vocabulary of environmentalism to justify their opposition to the strange-looking machines, while rejecting the aspects of the environmentalist agenda that praised windpower for its cleanliness. (Sociologists classified this as a case of the not-in-my-backyard, or NIMBY, syndrome.) For other Americans, windpower's trade-offs constituted an unsettling dilemma.

"Environmental" objections to wind turbines took various forms. When windfarms sprouted near towns and cities, residents objected to noise, visual clutter, television interference and bird kills, and they voiced concerns over safety. *Forbes* reported that "thanks to the thousands of tax-sheltering windmills that now call Palm Springs [CA] home, the area... offers dead birds, noise pollution and a potential, if unlikely, threat of

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[56]See Amory B. Lovins and John H. Price, *Non-nuclear Futures: The Case For an Ethical Energy Strategy* (New York: Harper Colophon Books, 1975).

[57]Henry Petroski, "Soft Energy Technology Is Hard," *Technology Review* 85 (April 1982), p. 39.

dismemberment."[58] Palm Springs residents demanded that developers paint the machines to blend with the desert, post a hefty bond to insure removal in case of bankruptcy, and dismantle those units near centers of activity. (Unmollified, Palm Springs residents led by celebrity mayor Sonny Bono opposed the turbines throughout the late 1980s.[59]) In other areas, skeptics fretted over the farms large land-use requirements.

Some problems had technical solutions, while others prompted agonizing reassessment of priorities. Television interference and noise represent two of the former; windfarm manufacturers soon produced less objectionable models. Fears over land-use conflicts proved exaggerated. Developers emphasized that America's best winds often blew far from the centers of human habitation. In fact, at the beginning of the wind boom, the fields of the Altamont sold for a meager ten dollars per acre.[60] Developers noted that windfarms coexisted quite well with activities such as farming and ranching, and they pointedly circulated publicity photographs of cows placidly munching and white-tailed deer cavorting under the merry turbines.[61]

The question of visual pollution proved less tractable than that of land use, and it demonstrated the dilemma of environmentalists who supported both renewable energy and landscape preservation. While most Americans indeed live far from constant, gusty winds, those same winds often blow in highly visible and beautiful parts of the country. One writer for *Audubon* magazine evoked the Altamont Pass, increasingly shadowed by long lines of turbines:

> A grand, splendid sense of loneliness dominates this place... In most years, the rains trail off in early March, leaving the grasses to wither and ripen by May, so that all

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[58]Ellen Paris, "Palm Springs and the wind people," *Forbes* 135 (3 June 1985), p. 170.

[59]Paris, "Turbine Renewal," *Forbes* 144 (7 August 1989), p. 112.

[60]Janet L. Hopson, "They're harvesting a new cash crop in California hills," *Smithsonian* 13 (November 1982), p. 123.

[61]See, for example, Utility Wind Interest Group, "Wind power and the environment," Electric Power Research Institute (August 1993), no pagination.

> summer the rounded hills seem in certain light to be molded of dark gold... There are other pollutants besides smoke and oil, however. Noise is one... The visual pollution is another question.

The author pleaded for a realignment of aesthetic sensibilities by the environmentally-conscious to accomodate windfarms; he compared the lines of turbines against the sky to the artist Christo's ambient sculpture. But the realignment, he conceded, would be difficult.[62]

An equally perplexing dilemma which continues to divide environmentalists in the mid-1990s concerned bird kills. Migratory birds and raptors compete with windfarms for the same resource, the wind, particularly where it cuts through mountain passes. During the 1980s, many supporters of windpower denied that bird kills represented a major problem,[63] and implied that some professed ornithologists merely used the label of environmentalism to keep windpower out of their areas for selfish reasons.[64] But avian advocates adamantly maintained that the spinning turbines threatened raptors such as red-tailed hawks and especially golden eagles, only a few hundred breeding pairs of which remained in California. A two-year study released in 1992 by the California Energy Commission tallied over 500 raptors killed, including 78 golden eagles.[65] As a result, most developers altered their position to one of accommodation. U.S. Windpower, for example, has spent a considerable sum researching ways to prevent collisions.

The problem remains unresolved. Far from being universally praised, the wind industry today contends with opposition from organizations that once represented staunch

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[62]Wallace Turner, "Energy: *Whoosh* Go the Giant Windmills of Altamont Pass, But Does Anyone Hear?" *Audubon* 85 (July 1983), p. 126.

[63]For example, see Smith, "Wind Farms of the Altamont," p. 167.

[64]Research conducted in the late 1980s indicated that members of national environmental groups such as the Sierra Club often opposed windpower while conceding its advantages as a clean energy source. By contrast, community-based activists living near wind installations often claimed to see no advantages at all to windpower, and pointed to visual pollution as its prime disadvantage. They also often doubted that windpower "worked" and denied that it represented a low-cost supply option. See P.B. and K.W. Bosley, "Risks and Benefits of Wind Generated Electricity: Facts and Perceptions," *Energy Sources* 14, (January-March 1992), pp. 1-9.

[65]Theresa Tamkins, "Tilting at Windpower," *Audubon* 95 (September-October 1993), p. 24.

allies. For instance, the chief scientist of the Audubon Society has called for a moratorium on wind power where it overlaps with migration paths.[66] Some birders, pointing to the Eagle Protection Act and the Migratory Bird Treaty Act, have asked that the Department of Justice bring criminal charges against windfarms, although Federal prosecutors seem disinclined to cooperate.[67]

Conflicts over the impacts of windpower demonstrate the expansion in recent decades of the term "environmental." Legally, at least, the environment encompasses not just the non-human world of wildlife and landscape, but also any activity that affects human quality of life. Even citizens uncommitted to the environmentalist agenda have access to the powerful legal vocabulary of environmentalism. In some cases, analysts argued, community opposition reflected developers' failure to inform and involve the communities they neighbored.[68] At any rate, events in the 1980s belied the claims of early advocates that windpower presented "zero environmental impact."

Performance

Critics of windpower found it easy to designate the new technology a "failure." In the early years, many windfarms performed poorly. Even in 1985, the windfarms of Altamont Pass generated only 57% of their projected output. At any given moment 25% of the machines in the Pass might not function. Most wind industry insiders ascribed poor performance partly to the vagaries of their progress along a learning curve; as the AWEA's Duncan put it, "many of the earliest turbines didn't work very well, any more than did the earliest computers or automobiles."[69] And since developers found it cheaper to leave old, broken or uneconomic models to rust in the ground than to remove them, their idle capacities deflated the wind region's overall statistics. In addition, as windfarmers explored

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[66]Jan Beyea, quoted in Tamkins, "Tilting at Windpower," p. 28.

[67]Peter Asmus, "Who Owns the Wind?" *E Magazine* 4 (May-June 1993), p. 18.

[68]Bosley and Bosley, "Risks and Benefits," pp. 7-8.

[69]Testimony of Duncan in U.S. Congress, *Renewable Energy Incentives*, p. 190.

and defined their new business, unexpected problems cropped up. For instance, maintenance crews found that build-up of dead bugs on the blades of stall-control turbines could reduce power by up to 40%![70] Finally, 1985 saw less energetic winds than usual, due to the El Niño-Southern Oscillation, a large-scale meteorological phenomenon.

But contributing to the industry's poor achievement in these years, many developers played what the FWEP's Divone calls "liar's poker"[71] by exaggerating their turbines' capacities. Many unwitting customers bought machines fitted with an unrealistically large generators (which raised the turbine's rated capacity), not realizing that energy capture depends more directly on the area swept by the rotor and the machine's aerodynamic and mechanical efficiency. Thus, the official rated capacity of many windfarms indicated only poorly the energy capture one could reasonably expect.

The immature craft of wind resource assessment, practiced initially by only a handful of firms,[72] provided a major source of problems as well. Siting turbines proved a difficult art that few practitioners mastered early on. Developers found that identical wind turbines within a few hundred yard of each other might vary in output by a factor of two.[73] "Array effects," or the interference from one machine on its neighbors also lowered energy capture, as well as increasing turbulence, which could drastically shorten a wind machine's life.

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[70]Smith, "Wind Farms of the Altamont," pp. 162, 168. Stall-control turbines feature fixed-pitch blades, the shape of which creates turbulence in high winds. This effect spills the excess energy, avoiding dangerous overspeed and voltage fluctuations. Bug gunk changes the shape of the airfoil and interferes with the stall-control process.

[71]Interview with Divone.

[72]See Naar, *The New Wind Power*, pp. 210-212.

[73]Smith, "Windfarms of the Altamont Pass," pp. 168-169.

The Independent Energy Producers Association's Hamrin recalls questionable wind prospecting as "the area that caused the biggest problem, whether it was purposeful or not."[74] In some cases, the assessment firms themselves seem to have incorrectly assumed that contiguous sites enjoyed similar wind conditions. In other cases, to attract financing, developers inflated estimates of annual wind energy at a site under consideration for a windfarm, particularly if nearby sites had already obtained funding on the basis of higher winds.

While statistics reporting anemic electricity generation prejudiced some energy industry insiders against windpower, dramatic stories of turbine failure captured the general public's attention. Numerous models experienced problems, ranging from fatigue-induced tower failure for an Enertech model in San Gorgonio Pass, to a large 330-kW Howden machine that "threw a blade" in the Altamont Pass. U.S. Windpower reported in 1984 that 179 (out of 557) of its "56-50s" manifested problems in the blade-pitch mechanism and failed in the field; the company removed an additional 352 from service to avoid similar problems. Such reports evoked understandable concern; residents of Palm Springs, for example, fretted over the machines built within 300 feet of a major thoroughfare, especially after one machine in the region threw a blade 400 feet.[75]

<u>Progress, nevertheless</u>

With all these problems, wind technology nevertheless progressed in the early 1980s. The industry's performance record improved as well. By 1985, the AWEA's Duncan forcefully testified to Congress that windpower could provide the "lowest cost source of electricity available to a utility by 1990."[76] Indeed, by the mid-1980s, the machines installed in American windfarms had improved their performance in a number of ways. In

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[74]Interview with Hamrin.

[75]Smith, "Wind Farms of the Altamont," pp. 160-162; Paris, "Palm Springs," p. 171.

[76]Duncan in U.S. Congress, *Renewable Energy Incentives*, p. 192. Duncan noted that the California Energy Commission endorsed the feasibility of this goal.

California, energy production increased from an average of 38,000 kWh per unit of capacity in 1983 to over 100,000 kWh in 1986. Average capacity factors rose from 8% to 17%, and by 1985 some large arrays demonstrated capacity factors of 25% over long periods. Many developers achieved availabilities over 95%. Installed costs declined to from $3100/kW in 1980 to $1600/kW in 1986[77] to $1100/kW in 1990,[78] a cost far lower than nuclear or fossil plants. (For example, the Shoreham nuclear plant on Long Island, NY, came in at $5200/kW.[79]) In short, wind technology had improved considerably.

**TABLE 8: Growth of California Windpower, 1981-1986**

| YEAR | MW of new capacity installed | New turbines installed | Million kWh generated | Million dollars invested | Thousand bbl. of oil saved |
|---|---|---|---|---|---|
| **1981** | 7 | 144 | 0.01 | 21 | na |
| **1982** | 64 | 1145 | 6 | 139 | 11 |
| **1983** | 172 | 2500 | 49 | 326 | 86 |
| **1984** | 325 | 4700 | 195 | 680 | 340 |
| **1985** | 485 | 5000 | 632 | 750 | 1120 |
| **1986** | 240 | 2300 | 1200 | 290 | 2127 |
| **1987** | 154 | 1392 | 1700 | 177 | 3014 |

Data from Paul Gipe, "Maturation of the U.S. Wind Industry," *Public Utilities Fortnightly* 117 (20 February 1986), p. 68, and; Thomas A. Starrs, "Legislative Incentives and Energy Technologies: Government's Role in the Development of the California Wind Industry," *Ecology Law Quarterly* 15 (1988), p. 109. Figures denote annual totals.

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[77]Fred Sissine and Michele Passarelli, "Renewable Energy Technology: A Review of Legislation, Research and Trade," Congressional Research Service, Report No. 87-318 SPR (March 1987), p. 9.

[78]Braun and Smith, "Commercial Wind Power," p. 105.

[79]Paul Gipe, "Maturation of the U.S. Wind Industry," *Public Utilities Fortnightly* 117 (20 February 1986), pp. 71-75.

## PART V: The End of the Tax Boom

Windpower's gains at the cost of uncollected tax revenue stretched the patience and sympathy of many Americans and their representatives in Congress. At best, critics cast it as an economic failure, unable to survive without the crutch of tax credits; at worst, they painted it as an unsavory swindle. The perception that the wind industry produced nothing of social value led to an abrupt withdrawal of tax credits at the end of 1986, rather than the gentle phase-out suggested by compromisers.

On May 29 of 1985, after stumping the country to build support for income tax reform, President Ronald Reagan delivered his proposals to Congress. The tangled tax code, he wrote in his transmittal letter, had come to violate

> ...our Nation's most fundamental principles of justice and fair play. While most Americans labor under excessively high tax rates that discourage work and cut drastically into savings, many are able to exploit the tangled mass of loopholes that has grown up around our tax code to avoid paying their fair share--sometimes to avoid paying any taxes at all.[80]

Rather than loopholes, Reagan proposed to encourage venture capitalism by cutting the capital gains and corporate taxes, and cropping the top personal income tax rate to its lowest level in fifty years.

In subsequent speeches, the President gave frequent examples of the type of abuse he hoped to eliminate. He charged that "our present tax code diverts too many of our precious resources into wasteful loopholes and tax dodges like jojoba bean shelters, windmills, race horse writeoffs, and Cayman Island trusts."[81] Public mention in such dubious company sounded an ominous note for wind developers who needed tax credits to attract investment.

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[80] Ronald Reagan, "Message to the Congress Transmitting Proposed Legislation: May 29, 1985," *Weekly Compilation of Presidential Documents* 21 (3 June 1985), pp. 707-708.

[81] Reagan, "Remarks at the Great Valley Corporate Center: May 31, 1985," *Weekly Compilation of Presidential Documents* 21 (3 June 1985), pp. 723-726.

As the months ticked down toward the tax credits' expiration, the wind industry undertook to police itself and salvage its reputation. In January of 1985, the American Wind Energy Association approved a code of ethics and endorsed the IRS's drive to scrutinize windfarm investments.[82] Some of the industry's allies kept the faith, for example Rep. Edward Markey (D-MA), who chaired hearings on alternative energy at which he demanded to know "why this administration is abandoning energy conservation and renewable sources."[83] But as the Reagan Administration fought to shrink the size of the Federal government, the wind credits, with their image of promoting greedy and unproductive speculation, seemed doomed. *Inc.* magazine chortled that "Uncle Sam isn't smiling anymore," and voiced the common supposition that the impending end of the tax boom would scuttle the wind industry for good.[84]

The Tax Reform Act of 1986 proved calamitous for windpower. Some provisions enhanced the tax advantage of fossil fuel, in keeping with the President's belief that the energy "crisis" consisted of a short-term supply problem best addressed by escalating domestic fuel production. The law also eliminated the 10% business investment tax credit, although it created a new R&D tax credit. Most important, while the act prolonged the energy tax credits for renewable technologies such as solar and ocean thermal, it ended them for wind technology. Completing the disaster, California's Governor Deukmejian (who replaced Jerry Brown in 1983) repelled attempts to extend his state's wind energy credits past their scheduled termination at the end of 1986.

Shakeout

Investment in windpower ground to a halt in the mid-1980s, and the wind industry underwent a chilling shakeout. Of over forty developers installing machines in California between 1982 and 1984, only a half-dozen remained in the field by 1987, led by Fayette

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[82]Solomon, "Windmillers Clean Up Act," p. 1.

[83]U.S. Congress, *Renewable Energy Incentives*, p. 1.

[84]"Living and Dying at the Federal Trough," *Inc.* 6 (December 1984), p. 40.

Manufacturing, Zond Systems and U.S. Windpower.[85] During that period, domestic manufacturers lost their dominance of the American market, as developers settled increasingly on European and Japanese machines. Danish models proved particularly successful.

This shift reflected a number of factors. On paper, the Danish units cost more per kilowatt of capacity, but in the field they cost less per kilowatt-hour of energy generated, due to their dependability. Their superior performance derived from conservative engineering; American manufacturers, while less ambitious than the designers of the FWEP's giant turbines, pursued aerodynamically-efficient, low-weight designs using innovative concepts. The Danes, by contrast, preferred heavy machines using theoretically less-promising concepts such as stall control, which regulated rotation speed without moving parts. Danish manufacturers such as Vestas offered performance guarantees unavailable with American units, cementing their dominance.

The exchange rate of the 1980s also aided the Europeans; one could buy more Danish capacity per dollar. And, while the Reagan Administration opposed government funding for short-term research, Danish companies (and those of Japan and other European countries) won commercialization subsidies from their governments. Finally, some observers suggest that Danish investors accepted lower profit margins than Americans.[86] For these reasons, Danish manufacturers increased their share of the American turbine market from one-third in 1984 to one-half in 1985. By the early 1990s, Danish machines comprised 41% of California's cumulative capacity, and 61% of newly installed capacity.[87]

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[85]Gipe, "Maturation of the U.S. Wind Industry," p. 68.

[86]Interview with Holley.

[87]Robert R. Lynette and Paul Gipe, "Commercial Wind Turbine Systems and Applications" in Spera (ed.), *Wind Turbine Technology*, pp. 161, 173; Sissine and Passarelli, "Renewable Energy Technology," pp. 11-12.

## Conclusion: A Revenue Stream

The tax credits lured a nourishing stream of investment capital to the infant wind industry. An indeterminate but substantial fraction of that investment represented frivolous speculation, intended to shelter taxable income, rather than to nurture an industry. Such schemes represented nothing uncommon in the mid-1980s. Besides, some of the money flowed to reputable wind firms, determined to improve their technology and to develop the windfarm concept into a long-term business. In this sense, the tax credits fulfilled their purpose.

Unfortunately, the tendency of investment credits to encourage construction of wind turbines rather than the generation of kilowatt-hours drew the wrath of Republican reformers, who gleefully exposed the seamy maneuvers of an industry known for self-righteous rhetoric. Against expectations, the wind industry did not collapse with the evaporation of the tax incentives. Its unanticipated staying power stemmed from a third element of the windpower story, the availability in California of standardized contracts guaranteeing favorable prices. In concert with PURPA and the tax incentives, these "Standard Offers" sheltered the wind industry during the remainder of the decade.

# CHAPTER ELEVEN
# Vital Time and Financial Space: California's Standard Offers

## Introduction: Unexpected Tenacity

In the early 1980s, critics of California's windfarms characterized them as a shady tax dodge offering the society underwriting it no tangible benefits. *Forbes* magazine, for instance, scoffed that "the windmill industry would disappear into desert sands without the credits."[1] In fact, the Federal tax incentives expired after 1985, and the California credits a year later. Simultaneously, as America cavorted in a flow of cheap oil, the Reagan administration slashed budgets for alternative energy research. Although this congeries of factors devastated the FWEP, the windfarms hung on tenaciously during the late 1980s, and seemed poised for a renaissance in the early 1990s.

Wind energy's tenacity derives in part from technological progress made by windfarm operators and turbine manufacturers. Yet, it depended also on the California Public Utilities Commission's determination to control negotiations between the state's electric utilities and facilities qualifying for PURPA's protections. Through a quirky combination of foresight and oversight, the CPUC armed the windfarmers with standardized long-term contracts known as Interim Standard Offer #4 (ISO4) that insulated them from political opposition and the falling price of competing energy sources. While many utility executives complained that ISO4 forced them to purchase power they did not need at vastly inflated prices, it provided vital time and financial space for the adolescent wind industry.

This chapter recounts the story of ISO4, which, alongside PURPA and the tax credits, comprised the final leg of an institutional tripod supporting early windpower. It ends by summarizing the history of U.S. Windpower (later Kenetech Windpower), the wind firm that seems to have best exploited the time and financial space provided by ISO4.

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[1]Paris, "The great windmill tax dodge," p. 40.

Kenetech diverged in its goals from some other wind companies; rather than an environmentally-sound soft energy technology, Kenetech aimed to provide a generally accepted utility supply resource. This chapter depicts the company's strategy as an attempt to lessen windpower's vulnerability to the changes in the energy market and the political environment. Significantly, this has entailed repudiation of regulatory supports such as ISO4.

## PART I: The CPUC and Radical Interventionism

Most states established their regulatory agencies in relatively mutable legislation. The CPUC, however, drew its vigorous mandate directly from the state constitution.[2] During the long decades of stability in the electric utility industry, the agency used its broad power to support California's investor-owned utilities in policies that they themselves defined. By the end of Ronald Reagan's governorship (1969-1974), however, changes in the economic and political climate roiled the calm industry. Groups of consumer advocates and environmental activists coalesced to protest rising rates and ambitious construction plans. CPUC Chairman John Vukasin and the other four Reagan-appointed commissioners seemed to ignore, or at least miscalculate, the importance of these constituencies. Instead, the agency tried to "hold the line" on change, and protect consumers by protecting the utilities.[3]

Under Vukasin, the Commission focussed its efforts on eliminating "regulatory lag," the delay between a rise in fuel prices and a ruling by the CPUC permitting utilities to include the higher costs in customer bills. In this period, the CPUC allowed utilities to raise rates in response to rising fuel prices with no public hearing at all. Vukasin justified this agenda by pointing to the precarious financial position of the state's electric companies and

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[2]California State Constitution, Article XII, Section 22. *Constitutions of the United States, National and State* 3rd cumulative supplement, 1 January 1961 to 31 December 1967 (Dobbs Ferry, NY: Oceana Publications, Inc., 1969), pp. 81-84.

[3]Anderson, *Regulatory Politics*, pp. 139-143.

to the complex evidentiary hearings clogging the CPUC's docket.[4] To many ratepayers and some legislators, however, the CPUC's solicitude indicated its "capture" by the very companies the Constitution directed it to monitor. Assemblyman Charles Warren, for example, retrospectively excoriated California's "congenial and compliant regulatory structure"[5] for passively accepting the utilities' demand forecasts and construction plans.

As the Reagan appointees completed their staggered terms, Governor Jerry Brown (1975-1980) named commissioners of a more interventionist bent to the CPUC. As chairman, he selected Leonard Ross, an economist and lawyer interested in the new wave of marginal-cost pricing theory. Brown flanked Ross with Robert Batinovich, a businessman who had tithed generously to Democratic campaign funds. Reagan-appointee David Holmes soon evinced interest in Ross's proposals. His swing vote gave the Brown commissioners a majority at the five-seat table on many issues.[6]

In this period the CPUC delved into the utilities' selection of supply resources, their lukewarm support of conservation, and their forecasting methods, which previous Commissioners had accepted as an undecipherable "black box." The CPUC's determination to transform the state's electric system came to a head in 1979 when the Commission levied an unprecedented $7-million fine on the Pacific Gas & Electric Company for failing to pursue cogeneration opportunities.[7] Most important to the emerging wind industry, the CPUC endorsed the FERC's concept of "full avoided costs," and pushed to ensure that independent energy producers received the price that utilities would otherwise have had to pay to generate their own power. The CPUC also adopted the principle of "rate

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[4]*Ibid.* See also Scott M. Lewis, "Pacific Gas and Electric Company," *International Directory of Company Histories* 5 (Detroit and London: St. James Press, 1992), p. 686.

[5]Warren, "The Soft Path to Water Policy," p. 1.

[6]Barkovich, *Regulatory Interventionism*, pp. 69-70.

[7]Redburn, "Utility Penalized," pp. I/1, I/27.

transparency," requiring that the incorporation of non-utility generators into the electric system not increase (or decrease) consumers' bills.[8]

Such activities reflected the Commissioners' concerns and Governor Brown's ideological agenda. In explaining the CPUC's interventionism, however, some observers posited a fear among CPUC staff that the new CEC had appropriated their control over the state's energy industry.[9] While the CPUC retained ultimate authority for approving utility actions reflected in rates, the CEC bore responsibility for long-range energy planning, among other roles. The CPUC's interventionism thus represented, in addition to a policy agenda, an institutional struggle over jurisdiction. While the CPUC shied from some of the CEC's more radical positions, such as the claim that windpower could supply 10% of the state's generating capacity by 2000,[10] it increasingly acted to promote an alternative energy sector.

## PART II: Negotiating Against "The Stonewall"

By the end of 1983, the Supreme Court had sustained the FERC's aggressive interpretation of PURPA, and the tax credits had pumped half a billion dollars in venture capital into California's wind fields. Yet, PURPA and the tax incentives appeared insufficient to induce maturity in the juvenile wind industry. California's Altamont, Tehachapi and San Gorgonio Passes sported perhaps 3800 wind turbines, giving a combined generating capacity under 250 MW.[11] These figures represented three years of learning and hard work, but they paled in comparison to the capacities of competing sources of

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[8]William R. Ahern, "Implementing Avoided Cost Pricing for Alternative Electricity Generators in California," in Harry M. Trebing and Patrick C. Mann (eds.), *New Regulatory Strategies in a Changing Market Environment* (East Lansing, MI: Michigan State University, 1987), pp. 405-406.

[9]For example, in explaining the CPUC's support of conservation programs, Barkovich asserts that "the CPUC did not want the CEC to become too involved in *utility* conservation programs since this meant an incursion into the CPUC's jurisdiction over ratemaking... The new CPUC commissioners wanted to demonstrate that the Commission was not a moribund agency and wished to contradict the sentiments that had led to the creation of the CEC." Emphasis in original. Barkovich, *Regulatory Interventionism*, p. 74.

[10]See *Solar Energy Intelligence Report* 4 (22 May 1978), p. 150.

[11]Gipe, "Maturation of the U.S. Wind Industry," p. 68.

energy. For example PG&E designed its troubled Diablo Canyon nuclear facility to generate 2190 MW. While PURPA ordered the utilities to interconnect with qualifying independent facilities and to pay them "just and reasonable"[12] rates, the legislation left open myriad questions of detail separating the two parties. The wind community argued, and the newly truculent CPUC came to accept, that the primary obstacle to significant windpower development lay in the utilities themselves.

To some extent, the difficulties of hammering out a contract reflected two communities deeply suspicious of each other. Utility managers thought of themselves as public servants, and took they exception to implications by regulators that they constituted the weak link in the nation's electric system. The managers also feared that ceding some control over the system to politicians and entrepreneurs would result in higher rates, increased operating problems, and escalating inefficiency. Furthermore, regulators had begun to penalize utilities for what they considered "imprudent" management decisions, intensifying the industry's traditionally risk-averse management culture.[13]

All told, the utilities' reluctance to dabble in renewables constituted "an understandable viewpoint," according to Edgar DeMeo, director of solar and wind projects for the Electric Power Research Institute. "They had a system that worked, they had a responsibility to keep it working, and they didn't want people messing with it."[14] When approached by windpower developers hawking an imperfectly-developed technology, the utility managers naturally resisted.

For their part, the windfarmers suspected the utility managers of inherent conservatism, self-serving obstructionism, and blatant disregard for social welfare. They believed the national energy dilemma so dire as to justify risk-taking and slight temporary

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[12]PURPA, Section 210(b)(1).

[13]For prudence and management culture, see Hirsh, *Technology and Transformation*, pp. 151-154.

[14]Interview with DeMeo.

inefficiencies. Even where the two sides tried to come to terms, neither appreciated situation the other. This impasse became painfully obvious when the entrepreneurs, juggling banks and multiple potential investors, ran up against the utilities' torpid legal officers, who saw their mission as protecting a stressed system from additional trauma.

Negotiations between Renewable Energy Ventures and the Hawaiian Electric Company over that state's first independent energy project, a 300-kW windfarm, illustrate this problem. REV's co-founder Michael Lotker, who had worked for Northeast Utilities before striking out as a windpower entrepreneur, recalls that HECo insisted on building its own substation for the PURPA-mandated interconnection. HECo also required REV to pay for the construction in advance. As one line-item, the estimate submitted by the utility to REV included AFUDC ("Allowance for Funds Used During Construction"), a piece of utility accounting jargon used in rate cases to denote the interest owed by ratepayers to utilities who advance funds for construction projects.

> I asked how they could charge us for that... If anything, I said, you should pay us! [*I.e.*, because REV rather than HECo supplied the money.] The guy says, we've put in generation for sugar plantations for fifty years, and we've always done it this way. He shows it to the senior accountant, who says, "Oh, my god." It was the first time anyone had complained. You see, the two parties didn't know how to deal with each other on these issues. I worked for a utility, so I knew what AFUDC was. The average wind developer thought it was some kind of relay or something.

Not all obstacles consisted of regrettable misunderstandings. Lotker bitterly recalls the day when HECo switched contracts at the last moment, forcing REV either to accept the changes or to refuse and lose its place in the lengthy queue of projects seeking an interconnection. A smug HECo representative told Lotker that in the preceding months, the two sides had not really been negotiating. Rather, Lotker had been "commenting" on HECo's standard contract, and the utility had rejected his comments.[15]

California's windpower developers encountered similar problems. In 1981, after negotiating individually with little success for over a year, a set of entrepreneurs using a

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[15]Interview with Lotker.

variety of technologies launched a trade group to represent them in talks with Southern California Edison. To direct the group, dubbed the Independent Energy Producers Association, they secured Janice Hamrin, who had managed energy extension services for the University of California and later headed the CEC's solar programs. When she started the IEPA in 1981, Hamrin reminisces, she had about a dozen clients. These included cogenerators, biomass concerns supported by timber companies, and perhaps half-a-dozen windfarms. However, because none had a firm contract with the utility, no-one had yet built anything.[16]

When asked to explain the difficulty experienced by windfarmers in nailing down contracts with California utilities in the early 1980s, Hamrin replies firmly that "it was just stonewall." Hamrin points out that in some cases the utilities had legitimate grounds for uneasiness. For example, fearing that the CPUC would refuse to include the cost of "imprudent" alternative energy purchases in rates, the utilities balked at considering a contract valid until the CPUC had explicitly approved it. In response, the IEPA cooperated in passing legislation that validated any contract for which the CPUC had already approved the price. But Hamrin also charges that the utilities prolonged the negotiations by any means possible, often switching negotiators, and including clauses that effectively made the projects non-financable, for example claiming the right to interrupt power purchases at their discretion. She speculates that the utilities wanted to raise transaction costs, leaving the undercapitalized windfarmers, at that point lacking both projects and revenue, no choice but to abandon the venture.[17]

## <u>PART III: The Standard Offers</u>

Negotiations between California's electric utilities and its struggling windfarmers represented an abnormal and unequal business relationship, in that the two sides lacked common interests. The utilities perceived no financial incentive in cooperating, but since

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[16]Interview with Hamrin.

[17]*Ibid.*

they represented the only buyer for the independents' electricity--a condition known as monopsony--all the bargaining power remained on their side of the table. As David Morse, Chief of the CPUC's Energy Resources Branch, explains, "it's the difference between someone you want to do business with, and someone you have to do business with."[18] The CPUC increasingly came to believe that only regulatory intervention could level the playing field and give the small energy producers the clout they needed to negotiate.

The CPUC made clear to the utilities that it intended to punish evasion of its edicts to encourage alternative energy. The 1979 fine imposed on PG&E shocked the state's utility industry, and the Commission seemed poised to levy similar penalties on other equivocating firms. In this way, the CPUC supplied an "artificial" interest impelling the utilities to the negotiating table, and it partially countered their monopsony power.

The threat of financial loss had a definite effect on SCE, which, under the leadership of Chief Executive Officer William Gould, began to present itself as a leader in commercializing windpower and other forms of alternative energy--a valid claim in comparison to its laggard sister firms, but also a slick public relations move.[19] Wind developer Lotker recalls hearing from a senior manager that SCE did not really want windpower, but with the CPUC threatening to force it on them, they had decided to "smile and get the kudos."[20] In mid-1981 one hopeful environmentalist depicted SCE and PG&E as "playing a game of leapfrog" in their race to associate themselves with ever-larger

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[18]Telephone interview with David Morse, Chief of the CPUC's Energy Resources Branch (15 July 1994). Morse arrived at the CPUC in 1985 from the CEC; the CPUC solicited the services of Morse and two other CEC staffers to shore up their weak grasp of long-term energy planning.

[19]Reisner, "The Most Imaginative Power Company," pp. 63-87; Sebastian J. Nola and Fereidoon P. Sioshansi, "The Role of the U.S. Electric Industry in the Commercialization of Renewable Energy Technologies for Power Generation," *Annual Review of Energy* 15 (1990), p. 104. Nola and Sioshansi, engineers at SCE, praise their employer for incorporating nine primary sources of energy in its operations, and for an "all-out RD&D effort that catapulted it to the forefront of [renewable and alternative technology] commercialization world-wide."

[20]Interview with Lotker.

projected wind programs, and thereby win popular acclaim.[21] Public approval had provided at least a partial substitute for financial incentives.

Nevertheless, the CPUC believed that utility recalcitrance to negotiating "fair" contracts had stymied many wind developers capable of providing the state with clean electricity. According to the CPUC's Morse, the Commission wished to put the independent energy producers "on an equal footing with the utilities."[22] Specifically, the Commissioners wanted to make the dickering process cheaper and simpler, and to allow would-be windfarmers to calculate future revenue with greater precision and confidence, in order to expedite project financing. To do so, the CPUC determined to introduce generic contracts, a measure recommended but not required by the FERC's 1980 rules implementing PURPA.[23]

Regulatory agencies in some other states ordered their utilities to negotiate avoided-cost contracts, but the CPUC opted to take the matter directly into its own hands. As one observer notes, "the utilities were not trusted, at all."[24] Instead, the Commission required that the utilities craft standard contracts applicable to four basic cases, and make them available to all takers.[25]

The first three of these "Standard Offers" concerned short-run avoided cost contracts, based on the cost to the utility of generating its own electricity during any given three-month period. Standard Offer One (SO1) applied to intermittent sources of electricity such as wind

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[21]Christopher Flavin, *Wind Power: A Turning Point*, Worldwatch Paper 45 (July 1981), p. 30.

[22]Telephone interview with Morse.

[23]FERC, "Regulations Implementing Section 210," p. 12,235. The FERC required standard rates for QFs under 100 kW in capacity, and suggested that such rates could also aid larger facilities, provided they exceeded the utility's avoided costs. See CPUC decision 82-01-103 on the need for standard offers.

[24]Ahern, "Implementing Avoided Cost Pricing," p. 406.

[25]See CPUC decision 82-01-105.

and solar power, and provided for energy and capacity payments "as available." That is, the facility received capacity and energy payments only when it delivered electricity. Standard Offer Two (SO2) applied to facilities with more predictable ("firm") capacity, and included fixed capacity payments for up to thirty years, in addition to the floating, short-term energy payment.[26] Standard Offer Three (SO3) applied to facilities with capacities under 100 kW, and provided as-available energy and capacity payments in the manner of SO1.

An entrepreneur could request one of the Standard Offers from a utility, complete it, and return it, secure that the CPUC would obligate the utility to honor it. If the project delivered the energy, the entrepreneur would receive the energy and capacity payments specified in the contract. (If the project never produced energy, the entrepreneur suffered no penalty.) By the end of 1982, California utilities had signed 1511 MW worth of such contracts, a sizable fraction of the state's 40,000 MW of total generating capacity. However, less than a third of this capacity had come on line.[27] At the time, windfarmers had installed only about 70 MW of capacity, some of which represented non-standard contracts.

<u>A long-term standard offer</u>

Short-run avoided costs initially seemed to offer an adequate incentive to windfarmers and other independents, especially as war between Iraq and Iran drove up fossil fuel prices. When oil prices began to drop in 1983, avoided costs fell from about 7 cents/kWh to under 5 cents/kWh, damping interest in independent energy projects. In addition, PG&E announced in 1983 that it lacked the transmission capacity to handle new generating facilities in the north of its service area. The company proclaimed that the

[26]To qualify for capacity payments under S02, a QF had to deliver power at least 80% of the time during summer peak hours. To calculate avoided capacity costs, the CPUC assumed that the utility would build a natural gas combustion turbine if the QF capacity were not available. The Commission re-figured avoided energy costs every three or four months, according to changes in fuel prices. Ahern, "Implementing Avoided Cost Pricing," p. 406.

[27]Jeffrey Dasovich, William Meyer and Virginia A. Coe, "California's Electric Services Industry: Perspectives on the Past, Strategies for the Future," a report to the CPUC by the Division of Strategic Planning (3 February 1993), p. 66; Ahern, "Implementing Avoided Cost Pricing," pp. 407-408.

independents would thereafter have to pay a large but unspecified fee for upgrading the grid. Added to the erratic oil market, this threat caused investment in energy projects to stumble.

Many independent producers complained that the short-term standard offers had not resolved the financing problems caused by an uncertain revenue stream. Instead, they lobbied the CPUC for the creation of a standard offer based on the long-term cost of energy. The Commissioners, like most other people at the time, considered the drop in oil prices a momentary glitch before the inevitable rise re-commenced, and they agreed with the independents that the existing Standard Offers, based on fluctuating short-run costs, did not reflect the long-term value of QFs in utilities' resource plans.[28] The utilities argued in response that short-term avoided costs would eventually equate to long-term avoided costs. Nevertheless, the CPUC determined in the spring of 1983 to develop Standard Offer #4 as a long-term avoided-cost contract.

The chief difficulty lay in determining the long-run cost of electricity. Such a calculation required comparison of possible generating mixes some fifteen or twenty years in the future. Rather than await the outcome of lengthy proceedings over such controversial estimates, the CPUC opted to issue an "interim" standard offer as a "fair bet" contract, with the understanding that a final offer based on evidentiary hearings would eventually supersede it.

To devise ISO4, the CPUC hosted negotiating sessions in late Spring of 1983. The endeavor encompassed energy entrepreneurs utilizing a variety of technologies, Jan Hamrin's IEPA (now comprising dozens of members), representatives of the state's three investor-owned utilities, and the staffs of the CEC and CPUC. The process provided the independents an opportunity to confront the utilities in a semi-public forum. Hamrin recalls bringing a list of the paragraphs that the utilities had rejected in previous negotiations, and going over them one by one.

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[28]12 CPUC 2d 604, Decision 83-09-054 (7 September 1983), p. 22.

> I'd ask what it was about each paragraph that was keeping them awake at night, what they were trying to protect themselves against. There were other people in the room, so they couldn't say that they had written the stupidest thing they could think of, to keep us from signing, even if that was true... We went back, line by line, and negotiated the whole thing.[29]

The participants bickered especially over the inclusion of an "out-clause," which would have allowed utilities to halt purchases at their discretion. In return for rejecting the out-clause, the entrepreneurs agreed that the regulators would not be able to cancel the contract, either.

While "perhaps not the perfect preferred solution" from each participant's individual perspective, the CPUC hoped that this procedure would produce a contract that each could "comfortably tolerate while refinement and 'perfection' could be pursued in subsequent evidentiary hearings." And indeed, under the watchful eye of Administrative Law Judge Sara Myers, the parties to the process arrived at a compromise contract, which the CPUC approved in September of 1983.[30] The CPUC planned to open ISO4 for one year, and then to evaluate its success.

Energy producers could sign ISO4 contracts lasting up to thirty years. To avoid nullification of the contract, ISO4 required them to begin delivering electricity within five years from the date of signing. Thirty-year contracts specified energy prices for each utility during the first ten years. (Shorter contracts had shorter periods of guaranteed prices.) For instance, the price schedule obligated PG&E to pay 5.55 cents/kWh in 1985, rising to 11.39 cents/kWh ten years later. After that point, prices reverted to the current short-term avoided cost--which, participants agreed, would by then have reached astronomical levels.[31]

Most parties to the definition of ISO4 considered its price schedule fair. According to Gerbux Kahlon, who attended the proceedings as a junior CPUC staff member, some

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[29]Interview with Hamrin.

[30]CPUC decision 83-09-054.

[31]ISO4 also offered the option of a levelized payment stream, which increased revenue in the project's early years, at the expense of later years.

negotiators representing independent producers even advised their clients wait for Final SO4, as the prices indicated in the interim offer seemed too low. "It didn't seem like we were just giving it away," she insists. "By nobody's estimate were those prices high."[32] Glenn Ikemoto, who analyzed the proceedings for U.S. Windpower, confirms that some wind companies expected oil prices to rise even higher, and they rejected ISO4 in favor of the short-term SO1 contracts. U.S. Windpower, by contrast, welcomed the guaranteed revenue stream, and the firm signed all the ISO4 capacity it could. "We weren't walking out of there saying that this was a great deal," Ikemoto stresses. "We thought it was an acceptable deal. If you want to speculate on energy prices, there are easier ways to do it than building windmills!" U.S. Windpower's refusal to play guessing games with oil futures gave it a safe base of ISO4 contracts, which served it well during the years of falling oil prices that followed.[33]

ISO4 met a sluggish response throughout late 1983 and 1984, corroborating Kahlon and Ikemoto's denial that the offer represented an obvious victory for alternative energy at the time of its approval. Indeed, few Americans in 1983 foresaw the imminent oil glut. Disappointed in ISO4's modest success, the CPUC elected in August of 1984 to extend the contract's availability indefinitely.[34] In late 1984, however, interest in the interim offer quickened.

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[32]Interview with Gerbux Kahlon, Regulatory Programs Specialist for the CPUC's Financial and Economic Analysis Branch, in San Francisco, CA (25 July 1994).

[33]Interview with Ikemoto.

[34]CPUC decision 84-08-035.

## PART IV: The Gold Rush

Several factors accounted for accelerating interest in ISO4. First, it became clear that the energy tax credit would expire at the end of 1985. Second, cogeneration technology had improved considerably, attracting investment to that area. Third, a market had developed in "enhanced oil recovery," whereby drillers injected cogenerated steam into depleted wells to force out the remaining oil; by late 1984, perhaps 3000 MW stood ready to come on line from this source. Fourth, in December of 1984 the CPUC ruled that PG&E's grid indeed suffered from transmission constraints. After finding that the system could handle only 1000 additional megawatts without upgrades, the Commission established a queue (known as the Qualifying Facility Milestone Procedure) which independents could enter on a first-come, first-served basis, providing they had a contract in hand.[35] Fifth and finally, oil prices continued to fall.[36]

As the CPUC's Scott Cauchois recollects, "people began to sign up, and the Commission began to talk about suspending it. Then people *really* began to sign up. It was a gold rush."[37] In late 1984, in response to the enhanced oil recovery issue, the CPUC suspended ISO4 for large cogenerators. Spooked, other qualifying facilities snapped up even more ISO4 contracts, and in April 1985 the CPUC withdrew the offer for all potential takers.[38] By that time, entrepreneurs had signed ISO4 contracts totaling 16,000 MW worth of capacity. Of that total, 3500 MW represented renewable energy projects; natural gas-fired cogeneration accounted for the rest.[39] In 1986, viewing with astonishment the

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[35]See 17 CPUC 2d 87, 64 P.U.R. 4th 537.

[36]Dasovich, Meyer and Coe, "California's Energy Services Industry," p. 69; Ahern, "Implementing Avoided Cost Pricing," p. 412.

[37]Interview with Scott Cauchois, Project Manager for the CPUC's Division of Ratepayer Advocates, in San Francisco, CA (26 July 1994). Cauchois had transferred with Morse from the CEC to the CPUC in order to supply expertise in long-term planning.

[38]CPUC decision 85-04-075. See Dasovich, Meyer and Coe, "California's Electric Services Industry," p. 69; Ahern, "Implementing Avoided Cost Pricing," pp. 410-411.

[39]Dasovich, Meyer and Coe, "California's Electric Services Industry," p. 70.

backlog of ISO4 contracts, the CPUC conceded that a capacity shortfall no longer threatened the state, and suspended SO2 (which offered fixed capacity payments) as well.

No capacity limit

In 1988, partly due to the surprising "success" of ISO4, the CEC reported that the state enjoyed "a comfortable surplus of electrical generating capacity."[40] Only five years earlier, however, the threat of shortages had bedeviled policy-makers. ISO4 reflected a concern to ensure adequate supply in an envisioned era of energy scarcity. In issuing ISO4 in 1983, the Commission declaimed that

> We would rather err on the side of trying to have QF steadily come on line over time, than that of ultimately risking a critical capacity shortage because we did not take reasonable steps...[41]

Significantly, the CPUC's ruling contained no estimate of the total capacity additions that might result from ISO4. The Commission appears to have believed that the small amount of electricity generated by the offer would represent a drop in a distressingly empty bucket.

Indeed, most Californians considered rolling blackouts an imminent possibility. The utilities fed this fear, perhaps to bolster support for their construction plans. PG&E in particular sought regulatory approval to bring on line its delayed nuclear plant at Diablo Canyon in order to start recouping its cost. In that context, it seemed silly to worry about adding too much capacity, and no-one did. As the CPUC's Morse recalls, "our attitude was that we had a shortage of supply. ISO4 would produce some power, and the more, the better." Morse confesses that he "never dreamed" that ISO4 would draw the market response it did.[42]

According to the CPUC's Morse, most estimates of potential renewable energy and cogeneration ranged between 2000 and 4000 MW. The CEC claimed that wind alone could

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[40]CEC, "Electricity: 1988 Report" (June 1989), p. 1/2.

[41]12 CPUC 2d 604, decision 83-09-054 (7 September 1983), pp. 25-26.

[42]Telephone interview with Morse.

supply 10% of California's electricity needs by 2000, but, Morse shrugs, "non-one believed that one."[43] William Ahern of the CPUC asserted in 1987 that the Commission had expected perhaps 1000 MW of capacity from ISO4.[44] Even Jan Hamrin of the IEPA, professionally optimistic concerning the potential of alternative energy, affirms wonderingly that "never in my wildest dreams did I expect as much in California as there was."[45] Scott Cauchois, who represented the CEC during the proceedings, explains that although oil prices had already begun to slide in 1983, most people supposed that oil's real cost would rise by 2-3% annually. "We assumed those prices would go through the roof," he says. "People just ignored the relationship between supply and demand."[46] U.S. Windpower's Glenn Ikemoto sounds off more bluntly. "They screwed up," he says. Not only did the CPUC neglect to put a ceiling on the amount of capacity that could sign ISO4 contracts; when the rush began, the CPUC "went into panic mode." Their dithering over whether to suspend the offer, Ikemoto asserts, only increased the magnitude of the gold rush.[47]

Ironically, participants at the ISO4 conference apparently discussed and discarded the notion of a capacity cap. CPUC staffer Gerbux Kahlon, then fresh out of graduate school, remembers the controversy well. "I cringe every time I think of it," she sighs. In a brief position paper written as part of an exercise during the meetings, Kahlon contended that ISO4 would artificially raise supply, which the CPUC should counter by imposing an artificial limit on demand. Her audience objected that a capacity limit would necessitate rationing the available contracts between competing firms and technologies. "They said I was opening up a can of worms," Kahlon says, and she underscores that even the utilities thought a limit unnecessary. "The feeling was that the prices were not that attractive, and

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[43]*Ibid.*

[44]Ahern, "Implementing Avoided Cost Pricing," p. 411.

[45]Interview with Hamrin.

[46]Interview with Cauchois.

[47]Interview with Ikemoto.

that nobody was going to jump to take the offer."[48] Indeed, the CEC reckoned later that when the long-term offer opened, the avoided cost specified in SCE's ISO4 contracts exceeded the company's real avoided cost by only 0.5 cents/kWh, while PG&E actually paid a tad less than true avoided cost.[49] Meanwhile, the independent energy producers opposed any measure to limit the amount of ISO4 capacity, and the CPUC chose not to push the issue.

Utility protests

As they weathered the effects of the gold rush, however, utility managers complained bitterly of the absent capacity limit. They pointed out that the CPUC had sought to make the offer "transparent" to consumers, writing in the original decision that

> ...if we do a reasonable job of valuing and pricing QF power, the ratepayers should be indifferent as to whether eventually needed capacity is to be supplied by QFs or electric utilities.[50]

As it turned out, oil prices plummeted toward $10 a barrel in 1986, and rose only sluggishly in subsequent years. Real avoided costs stayed far below the energy prices guaranteed by ISO4, which rose each year according to gloomy but inaccurate forecasts of oil prices. In 1990, the CEC estimated actual avoided costs for PG&E and SCE in the neighborhood of 3 cents/kWh, but ISO4 bound them to payments of over 8 cents/kWh. In 1995, PG&E would have to pay QFs holding IOS4 contracts 11.4 cents/kWh.[51] Utilities that opposed ISO4

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[48]Kahlon carefully explains that her position paper did not propose a numerical limit. "It was part of my theoretical accuracy bent," she says. But, corroborating participants' recollections that a capacity limit represented a minor issue, Kahlon neglected to save the paper. "I wish I had kept it," she shrugs. Interview with Kahlon.

[49]Dasovich, Meyer and Coe, "California's Electric Services Industry," pp. 67-68.

[50]12 CPUC 2d 604, decision 83-09-054 (7 September 1983), pp. 25-26.

[51]Dasovich, Meyer and Coe, "California's Electric Services Industry," pp. 67-68.

(and PURPA in general) plausibly argued that the measures compensated cogenerators and renewable facilities at the expense of ratepayers.[52]

In the late 1980s, some utilities came to accept the restructuring of their industry engendered by PURPA as a *fait accompli*;[53] deregulation and competition, they decided, had come to stay. But, as Vice President Greg Rueger of PG&E explained to Congress, although his firm had no beef with PURPA itself, its implementation in California via ISO4 had led to "too much, too soon, and at too high a cost." At the time, PG&E had signed Standard Offer contracts totaling 8400 MW, of which 1800 MW had already come on line; the company expected eventual development of an additional 2500 MW. PG&E estimated that customers would pay 10% more due to the Standard Offers, for an "overpayment" of $850 million.[54] SCE estimated an even greater "overpayment" of $1.3 billion.[55] Both firms also objected that most of the contracts represented natural gas cogeneration; while this technology increased overall system efficiency, it ignored PURPA's goal of reducing reliance on fossil fuel.

Naturally, the independents often denied that a problem existed. According to the IEPA's Jan Hamrin, PURPA was "working beautifully."[56] Others argued out that ISO4 represented a "fair bet" contract, which only appeared favorable to them because the utilities had bet wrong. Because of PG&E and SCE's extensive oil-fired capacity, the drop in oil

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[52]For instance, "PURPA: Still Hazy," pp. 33-35. In fact, in 1987 Californians paid an average retail price for electricity of 7.96 cents/kWh, compared to a national average of 6.35 cents/kWh. *Electric Power Annual: 1988* (Washington, DC: Energy Information Administration, 1989), p. 43.

[53]See, for example, the surveys of utility executives in "1987 to spotlight competition and deregulation," *Electrical World* 201 (January 1987), pp. 15-20; "The big issue is deregulation," pp. 11-20, and; "The political train is on the track," *Electrical World* 204 (January 1990), pp. 11-15.

[54]Testimony of Gregory Rueger, Vice President for Electric Resources Planning and Resources at PG&E, in U.S. Congress, House of Representatives, Committee on Energy and Commerce, Subcommittee on Energy and Power, *Electric Powerplant Construction*, 100th Congress, 1st Session (7 May 1987), Serial No. 100-63, pp. 109, 111-114.

[55]Nola and Sioshansi, "The Role of the U.S. Electric Industry," pp. 110-113.

[56]"PURPA: Still Hazy," p. 35.

prices in fact benefitted ratepayers. "Would they have rather had fossil fuel prices go higher, so they got killed on their base system?" asks U.S. Windpower's Glenn Ikemoto. "The Standard Offers turned out to be a great deal for the developers, but it was still better for [the utilities] than if the oil prices had gone the other way."[57] Proponents of windpower pointed out that cogeneration plants, not windfarms, held the majority of ISO4 contracts. (See Table 9 below.)

**TABLE 9: Percentage of Total Installed Alternative Energy Capacity by Type for California Investor-Owned Utilities in 1988**

| TYPE | PG&E | SCE | SDG&E | Total |
|---|---|---|---|---|
| **Solar** | 0% | 6 | 0 | 3 |
| **Small hydro** | 7 | 3 | 3 | 5 |
| **Biomass** | 10 | 7 | 4 | 7 |
| **Geothermal** | 5 | 12 | 0 | 9 |
| **Wind** | 26 | 19 | 1 | 21 |
| **Cogeneration** | 52 | 55 | 92 | 55 |

Data from Sebastian J. Nola and Fereidoon P. Sioshansi, "The Role of the U.S. Electric Utility Industry in the Commercialization of Renewable Energy Technology for Power Generation," *Annual Review of Energy* 15 (1990), p. 111.

## Conclusion

After discontinuing ISO4, the CPUC doggedly worked on its final standard offer. With no apparent threat of capacity shortages, and with the perceived shortcomings of ISO4 still evoking complaints, the Commission worked deliberately until 1993 on its new procedure. Significantly, the final policy (officially called the Biennial Resource Plan Update) limited capacity additions to 1500 MW, based on the CEC's forecast of each utility's needs during a two-year cycle. Moreover, to avoid overpayments, the offer took the form of an "auction," with different energy entrepreneurs bidding to provide capacity at the

[57]Interview with Ikemoto.

lowest cost; the Commission set aside a portion of each utility's block for bidding only by renewable generators.[58] One wind company, Kenetech Windpower (formerly U.S. Windpower), did especially well in the auction. Due to utility objections to the process, the bids may not lead to actual installation.[59] Whatever the result of current negotiations, however, the structure of the auction indicates that the CPUC tacitly accepted the common criticisms of ISO4.

## PART V: A Generally Accepted Utility Supply Option

To a casual observer in the mid-1980s, U.S. Windpower appeared well-positioned as a viable business enterprise. Some developers preferred Danish turbines, but U.S. Windpower had brought its workhorse, the 56-100, to an adequate level of sturdy dependability. Good hardware alone did not explain the company's success; the performance of company windfarms indicated careful siting, operation, and maintenance, all controlled by vertically-integrated U.S. Windpower. Nor, for that matter, did the 56-100 represent the populist "Model T" sought by early manufacturers.[60] Rather than a "soft path" energy technology, facilitating community decision-making and decentralized energy production, U.S. Windpower marketed the 56-100 as a "generally accepted utility supply technology"[61] capable of competing on its economic merits when installed in large numbers as part of the utility grid. Indeed, providing energy at a cost of 9 cents/kWh, the 56-100 compared reasonably well with short-term avoided costs in 1983.

### Strategic planning

Problems loomed, however. By 1986, the 56-100's cost of energy lagged behind that of powerplants burning unexpectedly cheap fossil fuels. Only a cushion of ISO4 contracts insulated the company from disaster. Some within the company warned against

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[58]Interview with Cauchois.

[59]Kenetech Corp., *Prospectus*, pp. 35-36.

[60]See, for example, "Small Wind Focus Group," p. 18.

[61]Kenetech Corp., *Corporate Overview*, (San Francisco, no date), p. 8

complacency; favorable prices for 70% of the company's 56-100s would expire between 1994 and 1997, and the rest by 2000.[62] The contracts would subsequently revert to short-term avoided cost, which the 56-100 probably could not best. Although some financial executives disagreed, U.S. Windpower's technical personnel doubted that they could lower the 56-100's cost of energy.[63] The old workhorse could buy time for the company, they argued, but it should cease to figure in strategic planning. These engineers urged management to prepare for the disintegration of the "protective space" provided by ISO4.

U.S. Windpower's managers took rhetorical, financial and technological steps to address such concerns. Publicly, they attempted to distance the firm from the image of dependency plaguing the industry. After 1985, a shakeout of firms reliant on the expired tax credits and lacking sound technology seemed inevitable, but as financial officer Margaret Rueger recalls, "we didn't want our name associated with that."[64]

Rather, the company depicted windpower--their own version of windpower--as a competitive utility supply technology, capable of standing on its own. As Robert Guertin, Vice President for Engineering, explained, "we do not go to a utility and say you should buy this because it keeps the air clear," but rather that "wind is cost-competitive. It makes sense to have it as part of your mix."[65] Guertin implied that environmental benefits, while important, represented lagniappe.

Yet Guertin's stance merited some skepticism. Perhaps Kenetech did not carp at utilities to cooperate with windpower because of its environmental or political benefits (*i.e.*, its capacity to advance America's energy independence). But regulators often required that

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[62]Kenetech Corp., *Prospectus*, p. 44.

[63]Interview with Holley.

[64]Interview with Margaret Rueger, Kenetech Corporation, in San Francisco, CA (21 July 1994).

[65]Quoted in James Glanz, "High Tech Windmill's Future Burns Bright," *R&D Magazine* 34 (August 1992), p. 38.

the utilities do so, for example by insisting that renewables represent a percentage of each new block of capacity. In their frequent Congressional testimony, Kenetech executives emphasized the environmental and political advantages of their technology, reinforcing the rationale for such "set asides."[66] In short, Kenetech could rhetorically present windpower as a smart business investment, knowing that regulators often insisted on its use because of its political and environmental advantages. And of course, the company intended to exploit to the fullest any incentive available.

In fact, over the years, U.S. Windpower's spokespeople sometimes argued against the provision of government assistance to alternative energy, for instance the 1.5 cent/kWh tax credit extended for the production of renewable energy by the National Energy Policy Act of 1992.[67] Their stance combined political ideology and perceived short-term business interest. Considering the firm's philosophical orientation, General Counsel James Eisen remarks that "there are a lot of Republican-minded people in management who think it's important that a private company succeed on its own."[68] At the same time, U.S. Windpower argued that subsidies only impaired windpower's credibility. Director of R&D William Holley, for example, asserts that "renewables are helped more by utility acceptance than by a 1.5-cent credit."[69] Company managers also believed that their firm, alone among alternative energy technology manufacturers, had attained economic parity with conventional generating resources. Given that conviction, U.S. Windpower's managers reasonably believed that they needed a resurrected tax credit less than did competitors.

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[66]For example, see: U.S. Congress, House of Representatives, Committee on Energy and Commerce, Subcommittee on Energy and Power, *PURPA: Renewable Energy Programs*, 101st Congress, 2d Session (14 June 1990), Serial No. 101-160, p. 37, and; U.S. Congress, House of Representatives, Committee on Energy and Commerce, Subcommittee on Energy and Power, *Renewable Energy Technologies*, 100th Congress, 2d Session (27 April 1988), Serial No. 100-199, p. 109.

[67]Credit specified in U.S. Congress, Committee of Conference, *Energy Policy Act of 1992: Conference Report to accompany H.R. 776*, 102d Congress, 2d Session, Serial No. 102-1018 (Washington, DC: U.S. Government Printing Office, 1992), p. 257.

[68]Interview with James Eisen, General Counsel for Kenetech Windpower, in San Francisco, CA (21 July 1994).

[69]Interview with Holley.

At the financial level, in 1986 U.S. Windpower formed a Delaware holding company, the Kenetech Corporation, as a base from which to diversify. Although wind operations (under the new name of "Kenetech Windpower") provided the company's revenue base, Kenetech expanded into other "environmentally preferred" energy technologies, including biomass conversion, fossil-fueled cogeneration facilities, and conservation services.[70] In 1987, Kenetech Corp. raised $100 million in "junk" bonds and acquired a powerplant construction company, CNF Industries, presumably in order to minimize reliance on outside expertise. The creation of Kenetech Corp. indicates the seriousness of the firm's desire to hedge against fluctuations in the economic and political environment.

Meanwhile, at Kenetech Windpower, engineers mulled technological responses to the impending phase-out of ISO4's favorable rates. To beat utilities' short-term avoided costs in the 1990s, they conjectured, a "third generation" machine should generate electricity at 5 cents/kWh. One option consisted of variable-speed operation. Like other turbines, the 56-100 rotated at a constant speed to avoid introducing fluctuating current into the grid. The 56-100 regulated rotation by pitching its blades in high winds. By contrast, "stall control" units featured fixed blades, shaped to spill excess wind energy. In both cases, the quantity of wind energy converted to electrical energy suffered.[71] Still, Kenetech engineers lacked confidence that they could design a competitive variable-speed machine.

As Kenetech's engineers pondered their options, engineers at EPRI, the utility industry's R&D branch, investigated a new type of transistor-based power electronics. The new technology seemed suited to managing the current of a variable-speed wind turbine; it could take "dirty" alternating current, convert it to direct current, smooth out the frequency instabilities, and then turn it back into clean, 60-Hz alternating current. EPRI believed that the utility industry would profit from further development of the converter concept, and it

[70]Kenetech Corp., *1994 Corporate Overview*, pp. 2-5; interview with Ikemoto.

[71]By contrast, Boeing's MOD-5B turbine generated stable current while adjusting rotation to the prevailing wind speed, but the single MOD-5B turning in Hawaii hardly represented a commercial technology.

agreed to allow Kenetech Windpower to use it in an advanced wind turbine.[72] Kenetech and EPRI formed a consortium, which also included PG&E (encouraged by Carl Weinberg, the same executive who had mercifully terminated PG&E's MOD-2 project) and the Virginia Power Company. Virginia Power later backed out, to be replaced by New York's Niagara Mohawk Power.

Kenetech contributed the lion's share of the funding for the new thirty-three meter, variable-speed turbine, perhaps $70 million out of $75 million. (In 1993, the firm went public to raise $92 million for developing and marketing the "33M-VS."[73]) But through frequent technological reviews, EPRI and the utility partners helped Kenetech design a customer-friendly product, for example by providing frank feedback on design trade-offs such as reliability versus cost. Equally important, Kenetech's partners contributed their credibility, encouraging some utilities still skeptical of windpower to take Kenetech's new technology seriously. For their part, Niagara Mohawk and PG&E received a chance to recoup their investment, pleasantly favorable publicity and, at least in the case of PG&E, a measure of control over a technology that state regulators might force it to use anyhow. EPRI was able to represent itself as an arbiter of utility supply technology and as a conduit through which utilities and energy entrepreneurs could cooperate.

By the early 1990s, Kenetech had begun to take orders for the 33M-VS, rated to produce between 300 and 400 kW (depending on wind speed) and priced at about a third of a million dollars. Journalists gushed over the new technology, and crowned Kenetech--by then a $250-million company with 1000 employees--the king of the wind industry.[74] Nevertheless, some analysts contended that the company had quickly burned through the

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[72]Moore, "Excellent Forecast for Wind," *EPRI Journal* 15 (June 1990), pp. 11-23.

[73]Kenetech Corp., "Kenetech Corporation Launches IPO of 6 Million Shares on NASDAQ," press release (22 September 1993).

[74]For example, Mary B. Regan, "The Sun Shines Brighter on Alternative Energy," *Business Week* (8 November 1993), reprint; Douglas Gantenbein, "Something in the Wind," *The Atlantic* 272 (October 1993), pp. 36-42, and; Matthew L. Wald, "A New Era for Wind Power," *The New York Times* (8 September 1992), pp. D1, D4.

capital from its initial stock offering, and wondered whether it could get machines in the ground fast enough to generate a revenue stream. Others charged that Kenetech's vaunted $600-million backlog of orders comprised some fairly shaky contracts, that major stockholders lacked long-term commitment, and even hinted at the existence of photographs showing 33M-VSs twisted by disasters.[75] Other turbine companies complained bitterly that their machines compared quite favorably with the 33M-VS. Nevertheless, Kenetech seemed well ahead of potential competitors. This apparent lead perhaps reflects Kenetech's pluck in investing heavily in new technology in the late 1980s, while other firms pursued conservative strategies and nursed lucrative ISO4 contracts.

Insulation

U.S. Windpower/Kenetech Windpower distinguished itself from other wind firms by continually seeking to insulate itself from an uncertain environment. By refusing to speculate on rising oil prices by signing short-term SO1 contracts, and instead taking all the ISO4 capacity possible even when the offer's guaranteed long-term prices seemed unexciting, the firm assured itself an acceptable revenue stream. Creation of Kenetech Corp. and subsequent diversification made the firm less vulnerable to shifts in the wind business. At the same time, Kenetech planned for a post-ISO4 future by entering a consortium with two potential customers to design an economically-competitive wind turbine. This move aimed at relieving the company from dependence on special allowances and mutable political sympathies.

Also unlike many renewable energy concerns, U.S. Windpower/Kenetech Windpower sometimes seemed to ignore windpower's image as an environmentally-sound generating option. Of course, Kenetech presented windpower as an "environmentally

[75]See, for example, Marshall, "Power Firm." The price of Kenetech's stock dropped alarmingly in 1994. A querulous President and CEO Gerald Alderson attributed his firm's difficulties to bad weather, CPUC "prevarication" concerning implementation of the final SO4 process, technical problems in ramping up production of the new 33M-VS machine, and innuendo spread by short sellers "who have a significant financial interest in seeing our stock price decline." Kenetech Corp., *1994 Third Quarter Report*, San Francisco, CA (18 November 1994).

preferred" generating option, but the firm stopped short of arguing that it should therefore be permitted less stringent economic goals. In a manner reminiscent of the Environmental Defense Fund's representation of alternative energy and conservation as *business* strategies capable of benefitting both ratepayers and utility investors, Kenetech marketed windpower as a sound utility investment, while (rhetorically, at least) rejecting the taint of a technology dependent on legislative environmentalism. This stance, too, represented an attempt to reduce vulnerability by avoiding an ideological stance that company managers perceived as politically risky.

While U.S. Windpower/Kenetech Windpower executives challenged some industry assumptions about the role of renewable energy in utility operations, they judiciously forbore from challenging the culture or practices of the financial community. Their conservative mien paid off. Kenetech Corp. lists the Allstate Insurance Company, the F.H. Prince Companies and the Hillman Companies as major investors. Although PURPA prohibits utilities from owning windfarms, corporations providing debt or equity to Kenetech included subsidiaries of the Florida Power and Light Co., Niagara Mohawk Power, PacifiCorp and the Iowa-Illinois Gas & Electric Co., in addition to AETNA, John Hancock Insurance, Chrysler Financial, the Security Pacific Bank and Westinghouse.[76]

In sum, rather than pursuing a "counter-culture" image and practicing gentle business tactics, the firm staked its future on adapting to America's mainstream business culture. Kenetech negotiated toughly, guarded its proprietary rights, and aimed to bury its competitors. Ikemoto captures the company's chutzpah by comparing it to the goliath of the computer chip industry; Ikemoto forecasts that if the firm accomplishes the mission symbolized by the 33M-VS, "we will be an Intel... one of those names in America that get identified with a new business sector."[77] Clearly, the success--or good chance of success--

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[76]Testimony of Robert T. Boyd, Director of Regulatory Affairs for U.S. Windpower, in U.S. Congress, *PURPA: Renewable Energy Programs*, p. 35.

[77]Interview with Ikemoto.

of Kenetech Windpower's corporate vision indicates that windpower has developed far differently than envisioned by early proponents such as R. Buckminster Fuller and Amory Lovins.

## Conclusion: Three Legislative Events

Previous chapters describe three legislative events central to the emergence of entrepreneurial windpower. Jimmy Carter's Public Utility Regulatory Policies Act of 1978 impelled balky state regulators and intransigent utilities to encourage a non-utility generation sector relying on alternative energy technologies. Federal and state tax incentives, in place from the late 1970s through the mid-1980s, ensured a healthy stream of investment capital. And in California, the CPUC promulgated generic contracts based on forecasted oil prices, insulating the wind industry from the shockingly low oil prices of the mid-1980s and the antagonism of Republican politicians.

To some extent, these governmental actions shaped windpower. Unlike the policies of the FWEP, they did not seek to determine the nature of the emerging wind industry, nor did they succeed in doing so. Instead, they provided the vital time and financial space in which the wind industry developed. Those manufacturers and developers still in business survived largely through their canny exploitation of the legislative environment.

This success can best be seen in the story of U.S. Windpower, which so far has managed, better than any of its competitors, to insulate itself from the vagaries of the energy market and American politics. Company executives believe that they are succeeding, in the terms that they have defined for themselves, namely to become a provider of a "generally accepted utility supply technology." One might question the construction of this version of "success," but given Kenetech's definition, their success indicates an ability to use regulatory protections and then to replace and repudiate them as soon as practical.

# CHAPTER TWELVE
# Assessments and Conclusions

## Introduction: The Construction of Success

According to the simplest gauge of success, the large-turbine component of the FWEP failed miserably. Out of perhaps a dozen large machines built, only the Oahu MOD-5B turns today. Significantly, the program lost the war after the war; those who remember it at all dismiss it as expensive, muddle-headed and naive. Other components of the FWEP--for example, wind resource mapping and airfoil research--built better records, but today's California windfarmers use technology and techniques that they claim owe little to the FWEP. Considered in the same way, the entrepreneurs have succeeded. The remaining players seem able to adapt to a changing environment and ready to expand in the face of newly-abundant resources.

But the history presented here begs a more sophisticated analysis. "Success" itself constitutes a problematic concept. The players in this drama fought among themselves to shape a "windpower" according to their preference; in addition to disagreeing over how to achieve success, they diverged in describing what success would look like. In this story, both success and failure reflect the compatibility of the actors' goals with factors outside their control. Looked at in this way, the FWEP "failed" because the future that it *identified for itself* proved unattainable in the face of institutional obstacles. Companies such as U.S. Windpower, by contrast, defined a version of success that resonated with larger trends.

Complicating the picture, many actors in the drama and the outsiders who review it depict it as a bipolar contest concerning scale and ownership. According to this reading, the protagonists collided over the merits of multi-megawatt turbines owned by utilities and manufactured by diversified aerospace corporations, versus hundred-kilowatt machines owned by entrepreneurs and built by smaller, one-product firms. Indeed, this reading captures much of the story's crucial tension. Yet, the bipolarity results not from the "natural" landscape of the events, but from a historical process that, by combining the participants' acts of will with institutional factors that had little to do with windpower *per se,* winnowed the diverse possible forms that windpower could have taken down to two.

To give the most obvious example of this winnowing, some players, such as Amory Lovins, pled with diminishing impact for a decentralized, community-based windpower unlike either utility-owned giants or entrepreneurial windfarms. Neither the FWEP managers nor the windfarmers accepted this "soft path" version of windpower. Instead, they concurred in preserving the established electric system, in which utilities produce or purchase power from large facilities and sell it to customers to whom the mechanics of generation remain, in the CPUC's phrase, "transparent."

Evidence for the negotiated nature of "success" appears throughout the preceding material, as does analysis of the effectiveness of the participants' decisions for their own versions of success. The following chapter considers, instead, two questions. First, how much "play," or room for alternate choices, did the web of historical causality constructed during the recent history of windpower contain? Could the FWEP have survived, spreading its version of large-scale, utility-owned windpower as the norm?

Simultaneously, we consider how much historical causality we can attribute to human intentions, by asking whether one could reproduce the windfarm model. The discussion focusses on the decisions made by "policy makers," some--but not all--of whom bore a formal charge to act for the public good. The analysis does not presume that human intentionality represents the only meaningful causal agent in the story. To the contrary, the human actors' efforts often appear laudable but puny in the face of larger institutional movements. But human actors merit attention because we need to know the limits of human will in shaping a technological system for social or political purposes. More important, as members of a technological society, we need insight on how to knit our own themes into the weave of an existing technological system.

## **PART I: The Received View**

Today, many members of the windpower community, particularly those with no connection to the FWEP, dismiss the Federal effort as a wrong-headed, unsuccessful attempt to design giant turbines. For example, windfarm developer Michael Lotker derides its products as "engineering accomplishments, not reliable wind turbines," and maintains that there was "nothing very subtle about [the FWEP's] original direction. They wanted the biggest and most exciting."[1] Don Smith, a long-time member of the windfarm industry, affirms that "the federal wind R&D programs, despite their cost of about $400,000,000 dollars [sic], have had little effect on the designs of the turbines in Altamont Pass or the other major wind farm areas now in operation."[2] Thomas Starrs contends that "from its inception, the focus of the Federal Wind Energy Program was on the development of large-scale wind-electric generation," and denies that the FWEP played a role in developing the technology used in California's successful windfarms.[3]

A recent publication of the Electric Power Research Institute implies that the FWEP represented a large-turbine program, and informs readers that "because of their imposing size and complexity, these machines proved costly to build, operate, and maintain. Moreover, potential manufacturers displayed little interest in commercializing the turbines."[4] Edgar DeMeo, Manager of EPRI's Solar Power Programs, calls the FWEP the best-managed of the Federal R&D programs with which his organization dealt, but recalls that Federal wind administrators "set a path in the early 1970s, and they followed it. Unfortunately, it was the wrong path."[5] Such accounts contribute to a "received view" of the FWEP as an aggressive pursuit of large turbines that resulted in an unfortunate dead end.

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[1]Interview with Lotker.

[2]Smith, "Wind Farms of the Altamont," p. 151.

[3]Starrs, "Legislative Incentives," p. 113.

[4]"Electricity from Sun and Wind: Perspectives and Activities of the EPRI Solar Power Program," (Palo Alto: EPRI, 1991), p. 13.

[5]Interview with DeMeo.

**PART II: Insiders Defend the FWEP**

FWEP veterans defend it as a well-intentioned, almost noble effort to conjure a commercial technology out of thin air during a period of political and fiscal turmoil. They decry the contentious ideologues from opposing ends of the spectrum who harassed the program. National moods concerning energy ran quickly from Jimmy Carter's "moral equivalent of war" to Ronald Reagan's conservatism. Circumstances saddled the FWEP with a top-heavy primary contractor in NASA and forced it to rely on large defense contractors with dubious commitments to alternative energy. FWEP insiders Louis Divone, Robert Thresher and Daniel Ancona contend that they did their best in the midst of this politicized environment.

Divone, in particular, bridles at suggestions that the FWEP aimed purely at producing giant turbines. "Don't ever trust anyone, not even me," he says, "because we all have our own biases." The winners have written the standard history, Divone warns, and they paint themselves as insightful innovators of an "alternative" technology. In fact, Divone finds the rancorous fragmentation of the wind community into separate camps remarkable, and unlike, say, the photovoltaic community, which seemed to march in step:

> The wind industry was always fighting each other. So you need to look at budgets to see what was really being done. Even on my own staff, size was not the only issue; there was upwind versus downwind, horizontal versus vertical, two versus three blades... [But the giants] were a big deal, they showed up on the cover of *Popular Science*.

Divone believes that the chief lesson of the windpower story is that a good program should "resist market shifts, technical shifts, political shifts... You need a robust program." And, he adds, "we thought we were doing that."[6]

Robert Thresher, who began his association with the FWEP as a contractor in the mid-1970s and who today directs wind technology programs at the National Renewable Energy Laboratory, agrees that the newsworthiness of the giant machines gave a misleading

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[6]Interview with Divone.

picture of the FWEP. In fact, he argues, the program had many tasks, such as wind mapping, research on institutional barriers to windpower, and development of small, innovative and vertical-axis turbines. Nor were the giants simply "bad machines." Thresher doubts that the big turbines ever could have met the (pre-inflation) price goals of 3-4 cents/kWh; they lacked not only mass production, but also the up-front investment. But he locates a primary barrier to their continuing evolution in institutional inertia. "People are risk-averse," Thresher says, "afraid that in five years someone will say it was a bad investment." Moreover, to succeed the large turbine program required an expensive supply network of cranes, personnel and spare parts. Ultimately, however, Thresher fingers the price of oil. No-one advocating the development of renewable energy technology foresaw the glut, and with cheap oil flooding the market, no-one seemed to care about renewable energy.[7]

## PART III: Outsiders Offer Critiques

### NASA's aerospace dreams

Nevertheless, the FWEP lies open to various criticisms. One area concerns the machines themselves. While Thresher correctly dismisses the charge of "bad" hardware as simplistic, the stress-related failures that dogged the large turbines indeed indict human design practices. NASA and its subcontractors systematically underestimated the complexity of the wind environment, and their cranky, highly-engineered machines proved too fragile for their circumstances. In the words of one critic, the FWEP's giant wind turbines represented self-indulgent "aerospace dreams."

In the early 1970s, the NSF solicited NASA's help for its exploration of windpower, partly because of the aeronautic and space agency's background in meteorology and low-speed aerodynamics. These skills proved invaluable, and NASA later managed the FWEP's large-turbine element. However, NASA engineers had gained their experience by designing airfoils for jets traversing the upper atmosphere, where the airstreams flow comparatively

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[7]Interview with Thresher.

smoothly. As they learned, a wind turbine blade suffers from chaotic, interacting, cyclic stresses quite different from those acting on jet aircraft. These include opposing gravitational forces on different sides of its rotation, changing shear angles, and wake effects from nearby objects, other wind turbines, and the turbine's own tower. Even debris from dead bugs, which changes the blade's shape, begets strange forces.

Similarly, helicopter firms such as United Technologies and Kaman Aerospace worked as subcontractors under NASA's supervision. Their experience in fabricating long blades from composite materials initially seemed quite relevant to wind turbine design, and they hoped to find in wind turbines a profitable new market for their expertise. Over time, they realized that although a helicopter rotor functions in a high-stress environment as does a wind turbine, it also has the tremendous power of an engine driving it through the eddies and wakes of the wind. Much more at the mercy of the windstream, wind turbines did not represent, as one wind industry analyst characterizes the early Federal perspective, "a helicopter on its side."[8] The "messy" wind environment near the ground, the millions of rotations over a projected thirty-year lifespan, and the absence of powered rotation increased the stress on the giant turbines beyond the point anticipated by their aerospace designers.[9]

The American approach to designing wind turbines compounded this problem. Following the advice of Austrian consultant Ulrich Hutter, which validated their proclivity toward high-technology, the Federal team fashioned highly-specialized exemplars of engineering art. By progressively shaving the material required to generate each kilowatt of power, they reduced capital cost; by improving aerodynamic efficiency and pursuing innovative concepts, they boosted theoretical energy capture. But the resulting machines

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[8]Personal communication to Adam Serchuk from Robert Kahn, of Robert D. Kahn and Co. (9 June 1994).

[9]In time, it also became clear that airfoils designed for aircraft do not provide optimal energy capture for wind turbines. The FWEP progressed appreciably in designing its own airfoils, which may boost energy capture by 30% over aircraft-type blades. Thresher, "Wind Energy Development: Technology Status and Commercialization" in *Conference on Renewable Energy*, p. 48.

proved too frail to survive the transition from the drawing board to the windfarm. Rivets popped, skins cracked, bolts sheared off, and shafts fractured.

Today, Divone attributes some of the minor hitches and major fiascos in the MOD program to the normal process of technological development. He muses that the FWEP "had significant problems with the large machines, but in pushing into new and risky sizes and technologies, we expected them."[10] But while these problems may indicate normal growing pains, as Divone implies, they also mark the engineers' narrow concentration on the machine itself to the exclusion of its operating environment. A preference for elegant but risky designs exacerbated the problem. By the 1980s, heavy, rigid Danish turbines, less efficient on paper but able to keep turning dependably, provided a reminder of an alternative design path not taken.[11]

It seems unlikely that the FWEP managers could have followed a different design credo. The FWEP's "aerospace dreams" represent in microcosm the dominant technological culture of a nation. Most members of the Federal windpower team drew inspiration from William Heronemus, who had envisioned an "appropriate big technology" capable of applying massive engineering resources to resolve the "energy crisis." Thus, they *shared* the assumptions and values of the electric, defense and aerospace industries. Their innovation consisted not of a championing a new technological style or ideology, but of proposing a new energy supply resource. Given this context, the FWEP managers' decisions appear reasonable, and their determination admirable. Unfortunately, neither good decisions nor good intentions can always overcome institutional inertia, nor do they guarantee the best possible technology.

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[10]Personal communication from Divone to Adam Serchuk (29 October 1993). In contrast, Divone notes that he did not anticipate such problems with the smaller machines. He characterizes the bugs in the small-turbine program as "rarely technological," and attributes them to "an immature industry."

[11]The rejuvenated FWEP retains this outlook. Ron Loose, head of the FWEP since 1992, derides Danish caution, which advocates heavier, conservative designs, as "if you're not sure, beef it up," and hopes that the light, flexible U.S. machines will win in the end. Quoted in Ros Davidson, "In Search of Wisdom," *Windpower Monthly* (July 1993), p. 29.

NASA's subcontractors

Other observers criticize the role played in the FWEP by the diversified corporations, as well as the nature of government contracting procedures. The manufacturers of the FWEP's large turbines worked on a "cost-plus-fixed-fee" basis, in which the government reimbursed all R&D costs plus a specified margin of profit. Boeing's wind turbine effort, for example, took place in Boeing Engineering and Construction, a "cost-plus center" within the commercial company. Wind developer Lotker, who tried to initiate a windfarm project using Boeing MOD-2s, sardonically refers to the cost-plus system as an "interesting" way to do business. He suggests that Boeing relied on the "games" of the government contracting business, such as over-runs, in which a company wins a government contract by bidding low, spends more money than promised, and then charges the government for the extra amount. Such habits, he criticizes, prevented Boeing from making decisions that could have led in the long-tern to a commercial product. "By funding classic government contractors," he says, "the DOE institutionally assured that these guys would never go into the commercial windpower business. Everything's obvious in retrospect, but it couldn't have worked."[12]

Other critics locate the problem in NASA's attempt to attack the "energy crisis" by the same frontal approach that had won the "space race" fifteen years earlier, when a consensual goal had justified any expense. Subcontractors from the defense and aerospace industries, accustomed to protecting human life at any cost and then recouping their expenses, designed their wind machines with an equally carefree hand. For these reasons, the argument goes, NASA and its manufacturers had difficulties in designing high-volume production-line machines.

Joseph Iannucci, who dealt with Boeing after his utility, PG&E, purchased a MOD-2, recalls that the FWEP

> had the big, high-tech guys, big thinkers that were used to putting people on the moon. But the real-life stuff had little problems, like that stupid low-speed shaft,

[12]Interview with Lotker.

> where they drilled a hole for a sensor and it kept breaking. It was a million-dollar part... but they were not thinking about cost performance.[13]

Iannucci believes that the organizations in the large-turbine program, accustomed to a guaranteed market in the Federal government, lacked the experience and the will to design for the conservative, cost-oriented utility industry. They entered the wind business, he accuses, only to perform free R&D. Iannucci especially berates Boeing for plugging along on the MOD-5B project even after announcing their withdrawal from the wind business.

Robert Lynette, currently a wind consultant and a designer of mid-sized machines, began his long association with the wind industry as a supervisor on Boeing's MOD-2 project. Lynette attributes the MOD-2's failure to economic factors. Although he characterizes the MOD-2 as "one hell of an engineering feat" given the loads involved in its operation, Lynette contends that Boeing "absolutely missed the boat on size." But added to the absence of a market and a service infrastructure capable of absorbing the enormous MOD-2, Boeing's exorbitant labor and overhead costs prevented the company from commercializing a wind machine of any size. Lynette stresses that Boeing intended to market the MOD-2. "It was not just a matter of taking R&D money from the government," he protests. Rather, the combination of a bloated company and an over-sized product doomed the MOD-2 effort from the start.[14]

By contrast, the FWEP's Dan Ancona praises Boeing's wind subsidiary, Boeing Engineering and Construction, for its awareness of the difference between building unique, high-technology gadgets, and commercial, mass-produced tools. He concedes that after the parent company re-absorbed BEC in 1982, Boeing finished the MOD-5B only because it was cost-plus funding. "But," he affirms "I sincerely believe that their heart was in the right place." Ancona points as evidence to Boeing's aborted effort to commercialize an improved MOD-2 turbine. "That was on their own tab," he notes. Ancona explains Boeing's retreat

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[13]Interview with Iannucci.

[14]Telephone interview with Lynette.

from this venture as a rational business decision, made only after oil prices started to fall and the Federal tax credits for purchasers of wind equipment expired. "They saw a commercial market, and that market changed. And a commercial entity will respond to changes." Today, Ancona adamantly praises Boeing as "one of the best companies I ever worked with."[15]

Ancona, Iannucci and Lynette disagree in appraising Boeing's performance, but none of them professes surprise at the firm's abandonment of windpower. In so doing, they tacitly acknowledge the chief danger in government-driven commercial development. The Federal government had identified windpower as desirable for social and geopolitical reasons. But private firms often scorn policies that would benefit society in the long term, perhaps because they lack liquid resources, because they have short decision horizons, or because too few of the "social" benefits would translate to a profit for the firms themselves. While a demand from the FWEP that subcontractors contribute their own resources to the windpower development effort might have screened out some frivolous participants, the dubious nature of the endeavor might also have scared off all potential manufacturers.

In any case, FWEP manager Ancona vehemently denies that the program could have required cost-sharing arrangements with manufacturers in its early years. "There was no industry," he exclaims, "so there was no money to share!"[16] In the cases of both small and large turbines, the FWEP had little choice but to foot the bill. Tinkerers might conceivably fabricate small wind turbines in a garage workshop, but these innovators remained desperately under-capitalized in the 1970s. Without a revenue stream from a commercial product, they lacked the means to bear, or even to share, the cost of their work. At the same time, development of a turbine large enough to capture the economies of scale that FWEP managers foresaw around 2.5 MW required a substantial industrial base. In the absence of a large-turbine industry, the FWEP had to turn to skeptical diversified aerospace

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[15]Telephone interview with Ancona.

[16]*Ibid.*

corporations. The lesson may be that when promoting a technology for social reasons in the absence of an existing market niche, the government should demand that manufacturers share the cost as soon as possible. In the early stages, however, Federal subsidization seems unavoidable.

The role of the utilities

Beginning in the late 1980s, a private consortium composed of EPRI, PG&E, Niagara-Mohawk Power and Kenetech Windpower developed an advanced turbine projected to generate power on a par with utilities' current avoided costs. Kenetech claims to have incorporated the advice of its utility partners during the design process, and the firm hopes to benefit from their credibility with other utilities. The project represents breakthrough cooperation between a renewable energy firm and the utility industry.

The notion of including potential customers in the R&D process has gained support in Federal circles as well. For example, grants made under the FWEP's Innovative Subsystems Project now require that manufacturers contribute at least 30% of project costs.[17] Likewise, Kenetech's variable-speed machine finds a potential competitor in R. Lynette & Associate's AWT-26, a 275-kW turbine. Lynette developed the stall-controlled machine as part of the NREL's Wind Turbine Development Program, which underwrote only part of the project's $5.5 million cost. The FloWind Corp. recently won a bid to construct a 25-MW windfarm in Washington state using AWT-26s, showing, the DOE claims, "how utilities, the wind industry, and the federal government can work together to commercialize new energy technologies."[18]

Some Kenetech employees hint that the government's new tack copies their consortium; they note that NREL personnel participated as observers in technological

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[17]*Wind Energy Program Overview: Fiscal Year 1993*, p. 13.

[18]*Ibid.*, p. 3, 10-11; Gantenbein, "Something in the Wind," pp. 40, 42; interview with Lynette.

reviews of the 33M-VS.[19] Regardless of the idea's genesis, one wonders whether, if utilities had participated in the FWEP's large-turbine program as more than hosts of government machines, they might have influenced the design of the FWEP's wares, or at least shown more enthusiasm for the concept.

Utilities played a marginal role in the early FWEP, but not because the government excluded them. Indeed, FWEP managers would delightedly have welcomed utility participation. Most utilities resisted renewable energy technologies on their own account, because wary managers perceived innovations such as wind turbines as an addition to the stresses besieging their system, rather than a relief from them. Regulatory practices, described in more detail below, reinforced utility managers' conservative tendencies.

Given that global politics and domestic economics provided the driving motivation for the program, rather than a groundswell of user enthusiasm, the Wind Energy Systems Act of 1980 represented as good a solution to the commercialization problem as might be hoped for. This law provided for the subsidization of up to half of the cost of large wind machines to private purchasers, offered low-interest loans, and funded Federal procurement and resource mapping. In time, its cost-sharing provisions might have aroused sufficient interest in windpower among utilities to carry the industry without Federal crutches, and also given homeowners the means to purchase small machines.

Before Congress could implement the Act, however, the political climate changed drastically. The new Reagan Administration immediately cut government-run marketing programs. The evaporation of Federal funding for demonstration and commercialization left the FWEP holding the bag with large turbines that were too big, too fragile and too expensive to make the transition from the laboratory to the market on their own. Utilities, never enthusiastic, quickly dismissed windpower, seemingly forever.

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[19] Interview with Holley.

The small wind program

As we have seen, many of the FWEP's critics characterize it as a large-turbine program. That description misrepresents the FWEP, which involved itself in various branches of research, as well as supporting activities such as wind mapping. With regard to budgets, Divone estimates that the FWEP's active small-turbine element received one-quarter of the program's funding.[20] Still, although a large share of the funds and most of the publicity indeed went to NASA's large machines, a more important distinction exists; the FWEP lacked a coherent vision of the role that small machines might play in the nation's energy future.

The DOE visualized that future as an "energy economy," in which policy-makers evaluated new supply technologies according to their cost of energy. This method hurt small wind turbines, which trailed their larger cousins in terms of economic performance and potential "quad" contribution. Their chief advantage, according to supporters in the AWEA and elsewhere, consisted of their potential to erode the utility-dominated national electric system, thereby encouraging environmental sustainability, community responsibility for energy production, and resistance to the country's technological elite. Since the FWEP never espoused these goals, the small-turbine element often seemed a sop tacked onto the edge of the FWEP to placate a vociferous minority of small-turbine manufacturers and counter-culture spokespeople. The hearts of most FWEP managers lay in a coherent vision of thousands of multi-megawatt machines manufactured by large aerospace companies and owned and operated by utilities.

Interestingly, even today many analysts postulate a "sweet spot" in the multi-megawatt range for horizontal turbines in terms of cost of energy. Randall Swisher, Executive Director of AWEA, admonishes that:

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[20]Interview with Divone. It bears repeating that the FWEP changed budget format frequently, making it difficult to pinpoint funding levels according to scale. On the basis of unofficial calculations of technology allocations from FY 1973 to FY 1985 made by the FWEP's Ancona, intermediate and large turbines received 52%, small turbines 15%, Darrieus machines 6% and generic research 27%. Ancona, "Wind Energy Budget."

> It's easy to criticize in hindsight... It should have been clear that gearing up to that size would produce strain on materials, but there was a theoretical basis for big machines that was somewhat defensible... It's too easy to be critical.[21]

Thomas Gray, former Executive Director of AWEA, agrees and defends the FWEP's design studies and mission analyses:

> This debate is not over yet. I don't challenge the science of those [early] studies. New studies point to an optimum size of 500 kW, but I would not be surprised to see it go larger.[22]

Corroborating Gray's speculation, Jay Carter, Jr., is reportedly scaling up Carter Wind Turbines' 300-kW unit to produce a 1.5-MW machine.[23] The Commission of the European Communities also sponsors a number of efforts to construct machines between 1 and 2 MW in capacity.[24]

Research versus commercial machines

A final criticism of the FWEP concerns an unresolved tension between research and commercial machines. The very concept of generational development raises questions. FWEP insiders phrased each generation as only a research step, but, because of the need to secure funding for the following year and to build up public and legislative support, they exaggerated the commercial readiness of each generation. Program managers admitted to following an unrealistic development schedule in the early years; why were the MOD-0As built at all, they asked, if plans for the MOD-1 were set in concrete too early to take advantage of lessons learned from their operation? While the FWEP tried to resolve this problem around 1980, the complaints of some PG&E executives that they had bought the MOD-2 believing it to be a commercial product raises suspicions that the problem remained. The furor in Congress after the cancellation of the MOD-3 and the MOD-4 offer grim proof

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[21]Interview with Randall Swisher, Executive Director of AWEA, in Savannah, GA (3 October 1993).

[22]Interview with Gray.

[23]"Jay Carter, Turbine Firm Work to Develop 1.5-MW Machine," *Wind Energy Weekly* (electronic version) 13 (24 January 1994).

[24]E. Hau, J. Langenbrinck and W. Palz, *WEGA: Large Wind Turbines* (Berlin: Springer-Verlag, 1993).

of the "use-it-or-lose-it" nature of Federal funding, perhaps indicating that the FWEP's problems indict the Federal R&D practices as a whole.

## PART IV: Windfarms

As we have seen, the emergence in California of entrepreneurial windpower depended on the decentralized activities of numerous actors, some of which had nothing to do with windpower. Therefore, one cannot always point to decisions, and, as in the case of the FWEP, assess them. The question becomes rather, given a group of techniques, which can future policy-makers try to reproduce, and how might such decision-makers augment promising but partially-successful strategies from the past?

### PURPA and the future of entrepreneurs in the energy business

The Public Utility Regulatory Policies Act of 1978 opened the door to independent energy generation. This law unexpectedly but effectively deregulated the American electricity generation sector, permitting the emergence of windfarms, cogeneration plants, and a variety of other alternative energy suppliers. Assessment of PURPA surpasses the scope of this treatment. However, one aspect of the legislation deserves comment.

PURPA disqualified from its protections facilities in which utilities owned a controlling interest. Congress's Joint Committee of Conference remained silent on why it framed the legislation in this way,[25] but lawmakers presumably feared utility discrimination against true independents in favor of their own subsidiaries. Critics of this provision objected that alternative energy would not only benefit society at large, but could also help relieve the financial distress of the nation's electric utilities, if only they realized it. Congress, such critics argued, should have used financial incentives to wheedle the sluggish utilities toward socially-useful change. But PURPA, rather than encouraging utilities to accept alternative energy, seemed to force them, as one analyst put it, "to cooperate with

[25]U.S. Congress, Conference Report to Accompany H.R. 4018, *Public Utility Regulatory Policies Act*, p. 89.

their competitors at little gain" to themselves,[26] giving rise to the antipathy that hamstrung the early wind industry.

In response to such objections, and perhaps because Congress believed that alternative energy had outgrown some of PURPA's protections, the Energy Policy Act of 1992 created a new class of electricity-producing facilities, called Exempt Wholesale Generators (EWGs). The 1992 law removes EWGs from utility-style regulation, but permits utility ownership.[27] This development complements a growing interest in windpower among utilities. As some utilities consider buying power generated by windfarms, others, such as Northern States Power and the Iowa-Illinois Gas & Electric Company, contemplate building their own wind facilities.[28]

Edgar DeMeo, chief of EPRI's solar and wind programs, explained utility interest in constructing windfarms as a result of the technology's maturation:

> It's not as risky as it was ten years ago, before the industry settled on a preferred turbine size range and before we had the millions of hours of operating experience that have since offered critical feedback on turbine reliability.[29]

Indeed, other members of the wind community have characterized California's windfarms as a massive R&D experiment, in which innovators had the luxury of testing their machines in the field.[30] Given that interpretation, it might seem that entrepreneurs have carried out the R&D, frequently in the face of implacable opposition from utilities, and deserve protection from utilities who now want a piece of the action themselves.

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[26]Gentry, "Public Utility Participation," pp. 297-299, 321.

[27]"Bush signs energy law; wants smooth transition," *Electric Light and Power* 70 (December 1992), pp. 1-2.

[28]See, for example, "Major windpower program is planned in the Midwest," *ENR* 227 (18 November 1991), p. 25, and; Wald, "A New Era," pp. D1, D12.

[29]DeMeo quoted in Lamarre, "A Growth Market," pp. 6, 9.

[30]See, for example, Carl Weinberg's comments in Moore, "Excellent Forecast for Wind," p. 16.

In fairness to the utilities, the traditional regulatory compact rewarded the provision of cheap, reliable service, and discouraged risky behavior, including (according to industry thinking) investment in untried technologies. Stockholders, too, looked askance at decisions that might threaten the dependable returns that they had come to expect. However, while DeMeo depicts current utility interest in wind as a rational appreciation of an improved technology, one may also discern an attempt to reassert utility control over the electric system. Carl Weinberg, former director of PG&E's R&D division, argued strongly in 1990 that "the electric utility is the logical institution for managing solar [and wind] electricity."[31] Elsewhere, Weinberg has justified this position by noting utilities' access to capital cheaper than that available to entrepreneurs; he argues that utility management of solar and windpower would lower electricity bills.[32]

Weinberg does not simply favor preserving the *status quo*; he proposes utility absorption of renewable energy as one element of a momentous shift away from centralized power production and interconnection toward a "distributed utility." Nevertheless, this prescription for change constitutes a conservative attempt to reformulate the utility, as opposed to its elimination in favor of entrepreneurial electricity generation. With regard to windpower, the chief question concerns the future of entrepreneurial capital in the business.

Events such as the creation of exempt wholesale generators and Weinberg's call to reconceptualize the utility acknowledge the progress made by alternative energy, and they represent a challenge to the new entities that have emerged. The effect of PURPA on the wind industry, while huge, does not appear set in stone; the persistence of venture capital in the energy business seems more in doubt in the mid-1990s than it did a short time before. Sixteen years after PURPA, no-one believes that deregulation will disappear, but the system remains in a state of flux.

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[31]Carl J. Weinberg and Robert H. Williams, "Energy from the Sun," *Scientific American* 263 (September 1990), p. 155.

[32]Interview with Weinberg.

Tax credits

The investment tax credits that enticed venture capital to the wind industry in the 1980s provoked harsh reactions. Even defenders of the wind industry concede that the credits, which paid according to the cost of the technology, facilitated fraud by "tax farmers" who had no commitment to producing electricity or to perfecting an energy technology. By contrast, a credit which paid according to the energy produced (such as the 1.5 cent/kWh incentive passed as part of the Energy Policy Act of 1992) might have limited abuse. While some observers argue that the government ought to have imposed a production credit from the start, others doubt that skeptical investors would have risked an investment dependent for its returns on the smooth operation of a new technology. Defenders of windpower often argue that the industry's progress justifies the unfortunate abuse of the investment credits.

EPRI's DeMeo surmises that the energy costs of wind technology, even in the early 1980s, approached utilities' avoided costs closely enough that a production credit would have worked. Iannucci, formerly of PG&E, asserts that "if they had paid on a cent-per-kilowatt-hour basis, bingo! You would have had people trying to pump out kilowatt-hours instead of kilowatts, which was the main problem." Weinberg, also a former PG&E executive, remembers warning Congressional staffers that investment credits would generate projects, but not energy.[33] Yet Iannucci and Weinberg profess uncertainty that production credits could have attracted enough cash to enable technological progress.

Others insist that the incentives served their purpose. "If not for the investment credits," argues AWEA's Gray, "we'd just be getting the first machines in the ground today." Gray approves of the recent institution of production credits, but characterizes them as more appropriate for a mature technology. Donald Bain, now with the Oregon Department of Energy, shakes his head over the up-and-down political battles over the tax credits, but doubts that a more "rational" policy process could have produced a better result. Had one instituted production credits too early, Bain asserts, "the industry would have failed.

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[33]Interviews with DeMeo, Iannucci and Weinberg.

The technology wasn't there, the firms weren't there, the knowledge about the resource base wasn't there." Jan Hamrin, founder of the Independent Energy Producers Association, adds her praise of the result, but insists that the transition should have been smoother.[34]

In most aspects of the case of the tax credits, the participants themselves provide a solid analysis. The succession of investment and production credits do seem to have functioned well. Two points need further analysis, however. First, as Hamrin suggests, seven long years intervened between the abrupt elimination of the investment credits and the introduction of production incentives, with a devastating effect on the wind industry. Only six out of forty windpower developers survived the "shake-out" of the mid-1980s. Similar attrition afflicted manufacturers.

"Shakeout," a phrase used by economists to describe a selection process that quickly decreases the number of players in a market, often implies a shaking only of "unfit" firms. In fact, we have no guarantee that the best survive. In the alternative energy field, some evidence suggests otherwise. Consider the case of LUZ International. Investors in this innovative solar thermal facility backed off in 1991 as Congress and the California legislature dithered over whether to renew solar tax credits and other incentives. As a result, widely-praised LUZ, which had lowered solar energy costs from about 25 to 6.5 cents/kWh, declared bankruptcy. Ironically, the credits survived.[35] The story of LUZ implies that society might benefit from a more conscious and less jerky energy policy process.

Second, those members of the wind industry who suggest that the sequence of investment and production credits functioned appropriately often shrug off the "taxfarm" abuses of the early 1980s as a real, but small and inevitable, price to pay for a useful

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[34]Interviews with Gray, Bain and Hamrin.

[35]See Michael Lotker, *Barriers to Commercialization of Large-Scale Solar Electricity: Lessons Learned from the LUZ Experience*, Sandia National Laboratories Report SAND91-7014 (1991); Christopher Anderson, "The future is now (again)," *Nature* 354 (5 December 1991), pp. 344-345. But note that some observers attribute LUZ's failure to an unsound financial structure.

technology. It is tempting to write off a few "broken eggs" in any journey toward a marketable product. However, a measure of government regulation might have helped eliminate the fraud that eventually aroused effective opposition to windpower.

The FWEP maintained a small-turbine testing center at Rocky Flats. Between 1976 and 1982, this facility tested fifty-four machines at the request of their manufacturers. With minor effort, the FWEP could have expanded this program to grant a "Seal of Approval" to successful turbines, or merely to require and then to publicize the results of standardized performance tests, in the same way that the DOE today requires manufacturers to provide energy consumption data to consumers of major appliances. Standardized testing need not have cost very much, since the infrastructure already existed. Nor would it necessarily have represented unwarranted market interference. Even some critics of "big government" conceded that the government might obtain standardized energy information more efficiently than private firms, and they agreed that the provision of such data might enhance the efficiency of the energy market.[36]

Had the FWEP instituted a mandatory testing program or a "Seal of Approval," some fraudulent developments and shoddy machines might never have troubled the public. In addition, American manufacturers might have preserved a greater share of their own domestic market. Instead, they quickly lost market share to imports, chiefly from Denmark, largely because American developers perceived Danish units as more dependable. In fact, Danish turbine manufacturers had to earn government certification from the Risø National Laboratory Station for Wind Turbines to qualify for Denmark's own tax credits and export loan guarantees. Risø personnel set conservative standards, perhaps stifling some creativity and variety, but the popularity of Danish machines seemed to justify their approach.[37]

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[36]See, for example, Ronald J. Sutherland, "Market Barriers to Energy Efficient Investment," *The Energy Journal* 12, no. 3, pp. 15-34.

[37]See Lynette and Gipe, "Commercial Wind Turbine Systems" in Spera (ed.), *Wind Turbine Technology*, p. 186.

The drive for such regulation might have originated in the wind industry itself, rather than with the DOE. We commonly assume that governments impose regulation on powerful industries to protect the public. In fact, some scholars argue that industries often solicit regulation to legitimize themselves in the public eye, or to erect legal barriers to market entry by new players.[38] For example, while many businessmen vigorously resisted establishment of state regulatory commissions in the 1910s, Samuel Insull, the pioneer of the electric utility industry, actively sought oversight, which he found an acceptable alternative to the mushrooming municipal-ownership movement and a way to win public trust.[39] In the same way, the American wind industry might have avoided some of the political backlash against renewable energy in the 1980s through self-policing. Unfortunately, the AWEA did not move toward self-regulation until shortly before the expiration of the tax credits. By that time, the industry's peccadillos had earned it a host of enemies.[40]

## ISO4

Dissatisfaction with ISO4 commonly centers on charges of "overpayment" and "overcapacity." As we have seen, both charges have some basis. The CPUC apparently endorses such criticism, and it has crafted its Final Standard Offer around an "auction" which allows interested independent energy producers to bid to supply limited amounts of capacity at a fixed price.

However, charges by utilities of overpayment for unnecessary alternative energy capacity due to ISO4 may misrepresent the situation. Facilities holding ISO4 contracts

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[38]For this thesis see George J. Stigler, "The theory of economic regulation," *The Bell Journal of Economics and Management Science* 2 (Spring 1971), pp. 3-21. For responses to Stigler, see Sam Peltzman, "Toward a More General Theory of Regulation," *Journal of Law and Economics* 19, (August 1976), pp. 211-240, and; Thomas K. McCraw, "Regulation, Chicago Style," *Reviews of American History* 4 (June 1976), pp. 297-303. See also material on James Landis and the Securities Exchange Commission in McCraw, *Prophets of Regulation*, pp. 153-209. For regulation in California, see Mansel G. Blackford, "Businessmen and the Regulation of Railroads and Public Utilities in California During the Progressive Era," *Business History Review* 44 (Autumn 1970), pp. 307-319.

[39]McDonald, *Insull*, pp. 117-123.

[40]See, for example, Solomon, "Windmillers Clean Up Act," pp. 1, 3.

indeed earned favorable tariffs, but the rates embodied a "fair bet" on energy prices accepted by all parties; had energy prices soared higher than anticipated, the alternative energy generators might have declared bankruptcy to escape the (in that case) unfavorable contracts. In any event, utilities passed the energy prices directly to their customers through fuel adjustment clauses, and their ire at "overpayment" may therefore constitute rabble-rousing against an emerging threat to their control of the electric system. With regard to the capacity issue, the CPUC and other participants in the ISO4 procedure indeed rejected a capacity cap. This action reflected an underestimation of the number of potential takers, but also the belief, *propagated by California's utilities themselves*, that the state stood on the brink of a capacity shortage and needed every possible capacity addition.

An interesting side issue concerns the extent to which Californian ratepayers funded the development of wind power for the rest of the world. David Morse of the CPUC muses that "it's not clear what benefit the state gets, other than being able to claim that we have more renewable energy than anyone else," and he asserts with chagrin that even given the environmental and economic value of windpower, "we've paid more than we've got."[41] On the other hand, his colleague Scott Cauchois opines that "in California, on the whole, it's been a good investment." Cauchois points to the emergence of a large international turbine manufacturing and project development industry for his state, and notes that cogeneration, not renewables, accounted for the bulk of ISO4's imputed overpayments.[42]

ISO4 undeniably helped raise California's electric rates above the national average. Yet other factors outweighed ISO4's impact on rates. Most important, California depended heavily on imported oil, while high commercial and residential use produced an unbalanced load pattern. Morse correctly asserts that Brown-era policy makers, through early encouragement of alternative energy, effectively subsidized many important technologies for the rest of the country, but their decisions to do so reflected California's energy dilemma of

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[41]Telephone interview with Morse.

[42]Interview with Cauchois

the mid-1970s, the severity of which dwarfed that of their neighbors. This dilemma pre-dated the appearance in California of renewable energy; it had its roots largely in the state utilities' ambitious and risky commitments to large fossil and nuclear plants,[43] made without first assessing public opinion and environmental impact. The Reagan-era CPUC, as we have seen, cooperated with these plans. It bears emphasizing that while complaints about high prices and unnecessary capacity additions that aided the development of windpower are somewhat justified, they also represent a smokescreen, hiding larger and more expensive decisions in which California's utilities and regulators bear equal complicity.

## PART IV: Larger Historical Movements

So far, we have discussed specific aspects of the FWEP's internal structure and the emergence of the windfarm industry. Our appraisals have balanced the perspectives of historical actors with that of an outside analyst and pondered the options open to the actors at any given moment in the story. Yet, many of the actors point to larger elements, outside their control, as the factors that determined the fortunes of windpower in the 1970s and 1980s.

### Economies and diseconomies of scale

As we have seen, America's electric utility system buckled in the early 1970s from three notable stresses. First, generating technology reached a plateau of "stasis," an apparent end to increasing economies of scale. Management culture and business practice had long aimed at selling increasing amounts of energy, under the assumption that each new piece of equipment produced by the supply industry would attain greater economic and thermal efficiencies. The late 1960s and early 1970s found the utilities still pursuing the same growth-oriented strategies, but stymied by the failure of the latest equipment to perform as expected. Economies of scale, some observers suspected, had ceased.

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[43]For instance, PG&E's Diablo Canyon nuclear plant cost $5.8 billion, eighteen times initial projections. The utility's customers currently pay over 11 cents/kWh for the plant's electricity, more than double the cost of energy claimed by Kenetech for its new wind turbines. Lewis, "PG&E," p. 686.

Yet large wind turbines proved unable to capitalize on the "diseconomies of scale" then apparent in conventional generating equipment. Of course, with capacities of a few megawatts, even the football-field-sized FWEP giants remained runty machines compared to the gigawatt-scale nuclear and fossil plants fancied by the utility industry. However, they substantially exceeded the abilities of the manufacturers to produce them or of the potential market to manage them. While few people argued with the calculations showing economies of scale available for turbines whose rotors measured 400 feet and which generated up to seven megawatts, problems involving the commercialization of these machines proved intractable. They cost too much, they took too long to build, they unexpectedly required technological breakthroughs, and the manufacturing industry resisted making the huge investment necessary to achieve economies of mass production.

Although some developers such as Windfarms Ltd. tried to assemble projects of giant turbines, most pursued machines in the hundred-kilowatt range. These units did not necessarily represent better hardware; indeed, they suffered frequent breakdowns and disappointing performance. But as NREL's Thresher describes, mid-sized machines entailed a smaller investment up front. "They were not specialized machines," he says. While all wind turbines used custom rotors, the smaller ones could make use of standard towers. Rather than a true generator, many small turbines featured a standard induction motor used as a generator. Developers erected the smaller machines with boom trucks instead of cranes. "You can buy into a mass production line at beginning," Thresher sums up, because "all the infrastructure is there." Moreover, because it took less time to manufacture small turbines, developers could exploit the utilities' increasing dissatisfaction with interminable construction delays for conventional plants.

In sum, large wind turbines ironically suffered from many of the same weaknesses that had debilitated the electric utility industry and originally impelled policy-makers to consider alternative energy. These weaknesses included over-ambitious technology, high capital cost, a requirement for a huge investment into production facilities, and long lead times that slowed incorporation of operating knowledge into successive generations. Giant wind turbines, like giant nuclear and fossil plants, represented *diseconomies of scale*. Pursuit of both large renewable and conventional energy technologies seems attributable to an infatuation with size for its own sake, and to a blinkered concentration on theoretical economies to the exclusion of considering the technology's fit with the existing infrastructure and economic environment.

The oil crisis and insulation

The second broad factor constraining the history of windpower concerns shifts in energy prices and politics. The long-standing "consensus" concerning the proper operation of the electric system broke apart in the 1970s as oil-producing nations, previously powerless in the global energy community, brashly asserted their economic power. The electric utility industry, more dependent on imported oil than many Americans realized, soon felt the effects of this previously-ignored player's entry. Even outside of oil-dependent New England, Hawaii and California, other energy (and non-energy) prices soon followed the upward trend of oil. In addition to these immediate effects of the embargo of 1973, the "energy crisis" occasioned vociferous calls for decisive government action, two effects of which were the diversification of Federal R&D research into fringe technologies such as windpower, and the consolidation of energy policy into the ERDA and subsequently the DOE.

The collapse of the oil market in the mid-1980s removed much of the perceived incentive for continuing research into alternative energy, reflecting America's perennial apathy toward long-term energy planning. As oil prices plummeted toward $10/bbl, Congress, the public and the manufacturing firms lost interest in windpower. Only the comparatively smaller, one-product firms maintained their commitment to the nascent technology.

Lack of political support for energy research crippled the FWEP. It might easily have done the same to the adolescent California windfarms. However, the wind entrepreneurs survived the glut because of protection by ISO4 contracts, promulgated by the

California Public Utilities Commission. These contracts guaranteed renewable energy entrepreneurs ten years of steadily rising prices based on energy prices projected in 1983. When, against expectation, oil prices dropped in the mid-1980s, happy signatories found themselves with a source of revenue well above the utilities' own avoided cost of producing electricity. Those companies who used that protected time and financial space to plan for the expiration of ISO4's guaranteed prices in the mid-1990s (notably U.S. Windpower/Kenetech Windpower) claim now to be ready to compete for energy contracts without the benefit of subsidies or favorable prices.

Environmentalism

Finally, windpower drew support from the emergence of a new litigious environmentalism which linked opposition to air, water and landscape pollution by utility generating facilities with consumer outrage over rising bills. This alliance of idealism and worldly anger provided a final source of stress on the utility system. However, even the environmental fervor of the early 1970s failed to sustain the FWEP. By the time President Ronald Reagan took office, many Americans had grown suspicious of the use of environmental rhetoric by selfish or fatuous individuals, who protected their own comforts at the expense of the community. Other citizens simply assumed that the Federal government had matters in hand and lost interest, while paying lip-service to the environmental ideals of the previous decade. This retreat, combined with the "stagflation" of the late 1970s, made many Americans receptive to Reagan's charge that environmentalism had stifled economic well-being. The antipathy of the Reagan Republicans toward the FWEP had a basis in their fiscal philosophy, but owed its virulence to their basic contempt for what they perceived as "anti-growth" environmentalism.

The California windfarms also provoked opposition that characterized itself as "environmental." In some cases, this may have represented the well-known "not-in-my-backyard" syndrome of homeowners who objected to the sight, sound, safety considerations and possible effect on property values of wind turbines. In others, it hid sincere attempts to rectify the advantages of renewable energy with their impact on beautiful landscapes. This dilemma resembled that facing earlier energy consumers who objected to the building of power plants in scenic locations. The replacement of Jerry Brown by George Deukmejian in California's state house occasioned a further loss of support in that state for environmentalism and for windpower in particular.

The loss of Federal support for the environmental goals that had led to the passage of PURPA's section 210 and the implementation of the renewable energy tax credits might have debilitated the windfarms, just as it helped devitalize the FWEP. However, nourished by ISO4 and championed by Brown-era commissioners and staff on the CPUC and CEC, the windfarms survived.

Conclusion: larger trends

Ultimately, the FWEP rode to prominence on the wave of larger historical trends, namely technological stasis, the energy crisis and the environmental movement. Throughout the 1970s and 1980s, the program pursued a design strategy--for what seemed like good reasons--that failed to take advantage of the larger trend toward technological stasis in the mainstream electric utility system. Nor did the FWEP prove ultimately successful in exploiting the energy crisis and the environmental movement. In the mid-1980s, the tide of these trends simply shifted, stranding the FWEP, directly and almost exclusively dependent on the continuance of Federal enthusiasm, on high ground. As Russell found in the case of British cogeneration and combined-heat-and-power plants, the macro-level movements of history swamped out the intense, micro-level negotiations over the shape of a new energy technology. The success of the windfarms depended on their ability to exploit these movements, while insulating themselves propitiously against unexpected downturns.

## PART VI: To Challenge the System or Preserve It?

The preceding analysis discussed the FWEP and the windfarms with respect to their ability to resist larger historical movements. Yet their different histories indicate, in addition to unequal abilities to resist, differing abilities to adapt and resonate to established institutions. That companies such as Kenetech Windpower seem to have adapted to the prevailing business environment suggests that windpower may represent a less drastic challenge to the established system than is often presumed.

Consider the distinction drawn by historian Thomas Hughes between conservative and radical innovation. The former, he believes, preserve technological systems, and frequently originate with scientists or engineers who occupy a place within the established system. Radical innovation, on the other hand, frequently comes from independent sources, and may form the cornerstone of a competing system.[44]

Hughes posits a fairly clear boundary between radical and conservative innovation. As we have seen, the windpower story draws part of its historiographical significance from undermining that distinction. While Hughes implies that negotiations concerning the acceptance of innovations such as windpower depend on whether the technology is *essentially* conservative or radical, the story of windpower shows that these characteristics *result* from negotiations.

Some early wind visionaries proposed a truly radical role for decentralized, renewable energy technologies. Adoption of these innovations would effectively erode the existing system, and replace it with a new one. This use of windpower never materialized. Instead, the Federal government pursued giant turbines, a typically conservative innovation. They embodied the management values and economic assumptions of not only the electric utility system, but American industry in general. Yet the giant turbines failed to catch on. It seems that their conservative nature, ironically, opened them to the same troubles plaguing the system that they attempted to preserve.

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[44]Hughes, "The Evolution of Large Technological Systems," in Bijker, Hughes and Pinch (eds.), *The Social Construction of Technological Systems*, pp. 57-59. See also Hughes, *American Genesis: A Century of Invention and Technological Enthusiasm 1870-1970* (New York: Penguin Books, 1989), pp. 49-50. Some of the following analysis draws on Richard F. Hirsh and Adam Serchuk, "Momentum Shifts in the American Electric Utility Industry: Catastrophic Change or No Change at All?" presented at 1993 Annual Meeting of the Society for the History of Technology in Washington, DC (16 October 1993).

As we have seen, different management decisions might have avoided some of the FWEP's problems. If Federal engineers had tempered their enthusiasm for machines featuring high rotor speed, low weight, aerodynamic efficiency and innovative concepts, and had identified sturdier, simpler designs, the FWEP's machines might have had fewer public disasters. But after examining the dilemma facing Divone and his staff, it seems difficult to find an easy solution. Hindsight offers no obvious way for the FWEP to have enjoined greater utility participation, or to have broken NASA of the management habits that had sustained it in its space endeavors. Furthermore, given favorable conditions, some of the FWEP's problems appear surmountable; for instance, if oil prices had stayed high, and if the Reagan Administration had been less antagonistic toward renewable energy, the Wind Act might have solved the commercialization problem.

Unfortunately for the FWEP, just as it rode the crest of much larger social and political waves in its early days, so those movements pulled the FWEP backward as the wave receded. Oil prices dropped, and the American public endorsed the economic goals of the Reagan Revolution over the environmental goals of the previous decade. The lesson of the FWEP may be, as Divone suggests, that managers must insulate a nascent R&D program from the vagaries of politics and temporary shifts in the market. The FWEP arose predominantly as a political response to a political event, Jimmy Carter's "moral equivalent of war." However, its managers and supporters proved unable to insulate it from the politics that engendered it, and it suffered greatly when the political winds shifted.

Unlike the FWEP, the entrepreneurial windfarms persisted. Nevertheless, they do not represent a radical innovation either. Those wind entrepreneurs who survived used the opportunity created by PURPA, the revenue attracted by the tax credits, and the time and space carved out by ISO4 to articulate an achievable vision of "success." By phrasing windpower as a utility supply technology, the windfarmers ensured that it represented a *conservative addition* to the electric system. To be sure, windpower constituted a radical challenge *to the utilities*, because they wrested ownership and technological control from the established sources of capital. But, stepping backward to gain a wider perspective, one sees that windfarms did not alter the *system* all that much.

In contrast to the "soft path" envisioned by Amory Lovins, the windfarms required no social change, no increased democracy, no added responsibility for energy decisions on the part of families or communities. From the customers' point of view, a giant, distant windfarm merely takes the slot in a complex, unfamiliar grid that a large nuclear or coal-burning plant might just as easily fill. In contrast to the ascetic exhortations of Jimmy Carter during the height of the "energy crisis," the windfarms demanded no changes in consumption patterns. Except for a small (and probably temporary) upward impact on rates, the windfarms remained *transparent*. One doubts that the Altamont Pass would sport a single wind turbine had their use required that PG&E's customers alter their daily routines.

As recent developments show, and as companies such as Kenetech Windpower fervently hope, the windfarms may prove so digestible as to be completely assimilated into normal utility operations. The FWEP, had it achieved its vision of utility-owned wind installations, might have given the nation an even more conservative version of renewable energy. As we have seen, the FWEP was simply too vulnerable to political and economic change, as well as being on the wrong track on some technical issues. As it happens, however, the two paths of windpower resemble each other in important ways.

## Conclusion: The Right Place at the Right Time

In 1994, America's electric utility system finds itself in the midst of great change. Its current form would have surprised pundits and policy-makers of twenty years ago. Although the nation obtains over 20% of its power from nuclear plants, no utility has ordered a new nuclear facility since 1979.[45] Energy demand has eased off of the breakneck pace of most of the century, with rather little negative effect on productivity or quality of life. Most surprising, regulators have apparently abandoned the concept of natural

[45]Nicholas S. Reynolds and Robert L. Draper, "The Future of Nuclear Power," *Natural Resources and Environment* 8 (Winter 1994), p. 9.

monopoly with regard to the generation of electricity, arguing that ratepayers can benefit from the introduction of competition in this large sector of the economy. As a result, a host of entrepreneurs exploiting alternative generation technologies and conservation have emerged to carve out a space for themselves.

Yet these changes do not represent a clear trend. In fact, in 1994 the nation's electric system writhes between two conflicting movements. The first is an effort to increase the efficiency of the marketplace by encouraging entry by new players and by demanding marginal cost pricing. Paradoxically, these initiatives may represent efforts by regulators to reduce their own roles. At the same time, however, the industry sees unprecedented intervention by regulators in utility affairs for the purpose of enforcing policies perceived as environmentally preferred. These contradictory movements have actually been on a collision course for two decades.

The future path of the industry remains in doubt. Amidst the uncertainty, the tectonic collision described above has created a fertile niche for windpower and other alternative energy technologies. Windpower burgeoned under the stimulus of *de*regulatory policies intended to remove barriers to non-utility electricity generation. At the same time, it thrived on the *hyper*regulatory tendencies that, for example, offered tax incentives to energy entrepreneurs and penalized the use of high-sulphur oil. As we have seen, the FWEP managers sought to exploit the latter trend, while failing to anticipate the former. By contrast, the wind energy entrepreneurs bet conservatively that deregulation will outlast hyperregulation, and they have shaped windpower as a conservative addition to the electric utility system, able to compete on purely economic criteria. Indeed, time will tell whether the entrepreneurs have succeeded too well; utilities trying to re-assert control over the system may absorb windpower. In any case, windpower has a good chance of surviving.

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## EDUCATION

**Ph.D.** (1995): VPI&SU, Program in Science and Technology Studies. Research on windpower as a utility supply option. Directed by Richard F. Hirsh, with Carl Weinberg as outside reader.

**M.S.** (1989): VPI&SU, Program in Science and Technology Studies. Thesis on parallel distributed processing (connectionism).

**B.A.** (1987): Vassar College, Program in Science, Technology and Society. Thesis on impact and development of expert systems.

## HONORS and AWARDS

Virginia Tech: Full or partial tuition waivers. Graduate assistantships. Sigma Xi Master's Research Award (1990).

Vassar College: General and Departmental Honors, Distinguished Thesis, Phi Beta Kappa.

## SELECTED PRESENTATION

"Momentum Shifts in the American Electric Utility Industry: Catastrophic Change or no Change at All?" (with Richard F. Hirsh), 1993 Annual Meeting of the Society for the History of Technology, Washington, DC, October 1993.

## SELECTED EMPLOYMENT

Research Assistant (Aug. 1993-present): "Renegotiating the Social Contract: The *Demand-side Revolution* and the Restructuring of the American Electric Utility Industry, 1978-1992," NSF Grant, NSF Office of Science and Technology Studies, investigator Richard F. Hirsh.

Peace Corps Recruiter (Aug. 1993-present) after serving as Peace Corps Volunteer (July 1990-Sept. 1992) in São Tomé and Príncipe. Cross-cultural trainer (summer 1991) in Cabo Verde; new recruiter trainer (summer 1994) in Washington, DC.

Research Consultant (Oct. 1992-January 1994): historical project on
Pacific Gas & Electric Company's initiative in electricity energy efficiency, Winthrop Group of Cambridge, MA.

## LANGUAGE SKILLS

Portuguese: very good. Spanish: good. French: poor.