Renewable Wind Energy

A Case Study of

Technology Commercialization, Business Economics and Public Policy

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Originally prepared for Baldwin Wallace College
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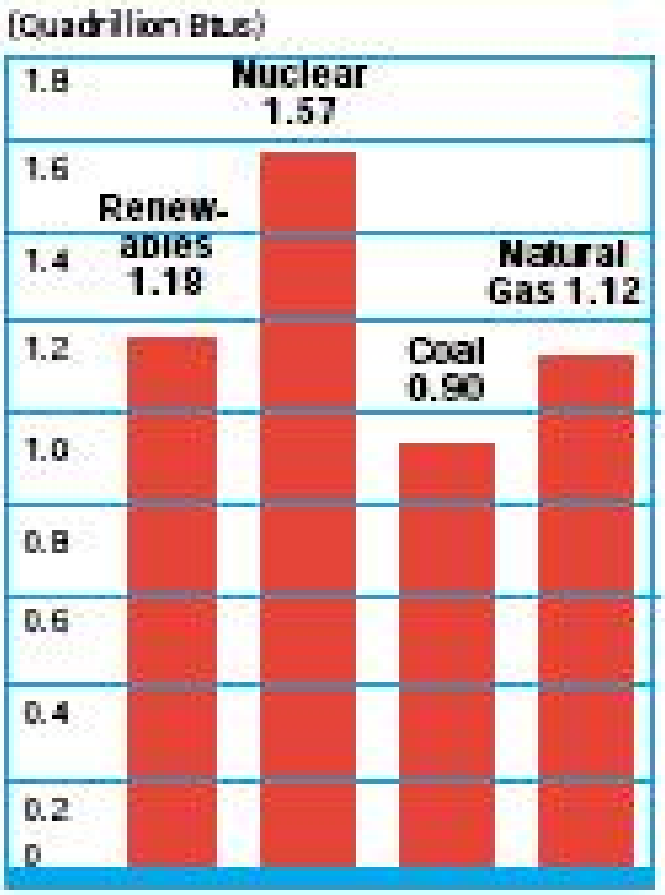
Renewable Energy

Energy resource that is replaced by a natural process at a rate equal to or faster that it is consumed (e.g. solar, wind, geothermal, tidal, biomass, etc.)

Important because:

- Reduces our dependence on foreign sources
- Cost competitive with rising oil prices - opportunity
- No increase in green house gases (global warming)

Increase in U.S. Energy Production: 1990-1999



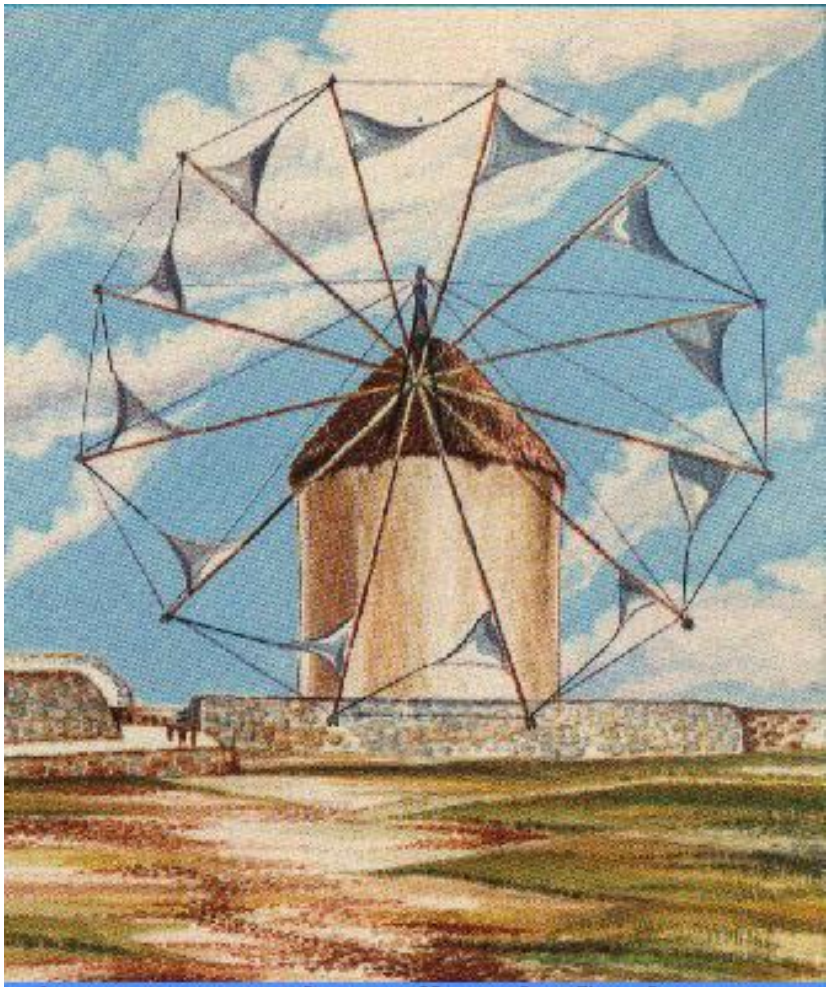
During the last decade, renewable energy sources contributed substantially to the growth in energy production, outpacing all fuel sources except nuclear

Source: 2006 President Energy Policy

A Brief History of Wind Energy

First windmills, Persia - 600 AD

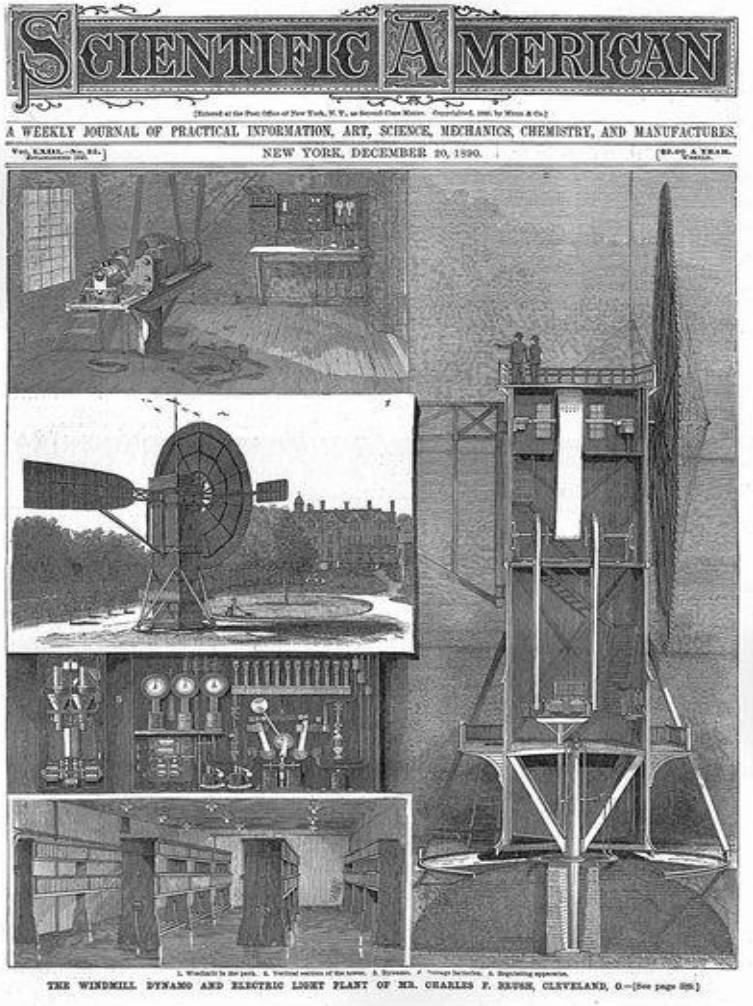
Water Pumping and Grinding Grain



An ancient grinding mill on the Greek island of Mykonos.

Charles Brush Wind Turbine, 1888

Cleveland spawned the world's first electric generating wind turbine



SCIENTIFIC AMERICAN

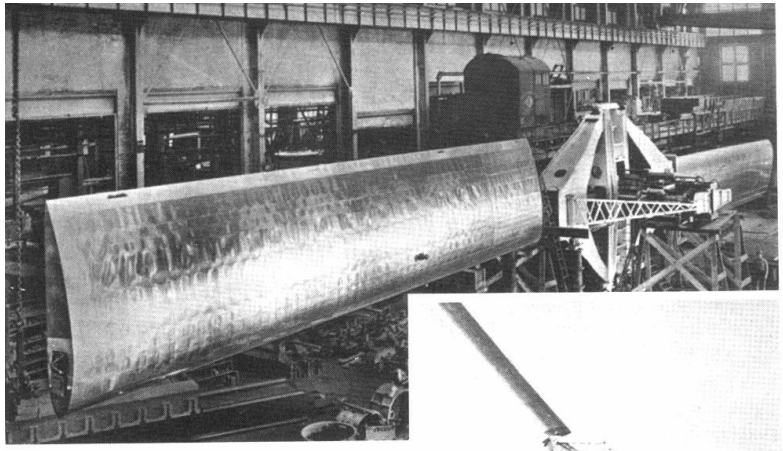
A WEEKLY JOURNAL OF PRACTICAL INFORMATION, ART, SCIENCE, MECHANICS, CHEMISTRY, AND MANUFACTURES.

NEW YORK, DECEMBER 20, 1890.

THE WINDMILL DYNAMO AND ELECTRIC LIGHT PLANT OF MR. CHARLES F. BRUSH, CLEVELAND, O.

Smith-Putnam Wind Turbine, 1941

Cleveland manufactured the world's first Megawatt-size large wind turbine that was installed at Grandpa's Knob, Vermont



(a) *(Courtesy of Carl J. Wilcox)*

175 ft. diameter rotor assembly at Wellman Engineering Co. in Cleveland

(b)

(Reprinted by permission of Van Nostrand Reinhold Company)

Mod-0 Experimental Wind Turbine, 1975

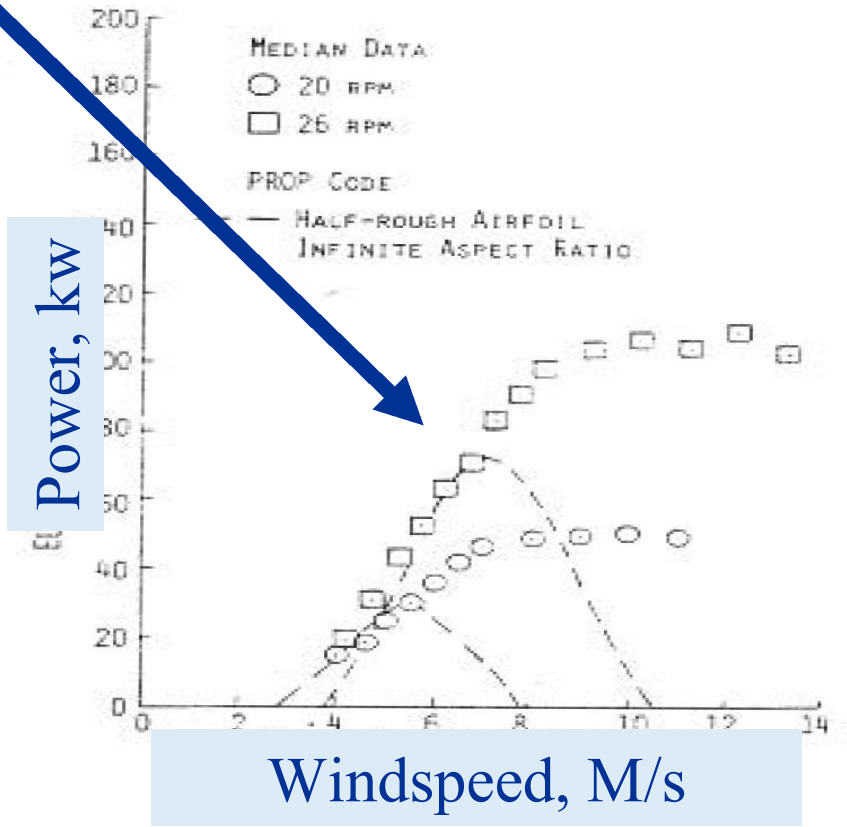
Cleveland's NASA Glenn led the nation's program for large wind turbine development (1974-1987). Mod-0 installed in Sandusky.

Technology Transfer Example

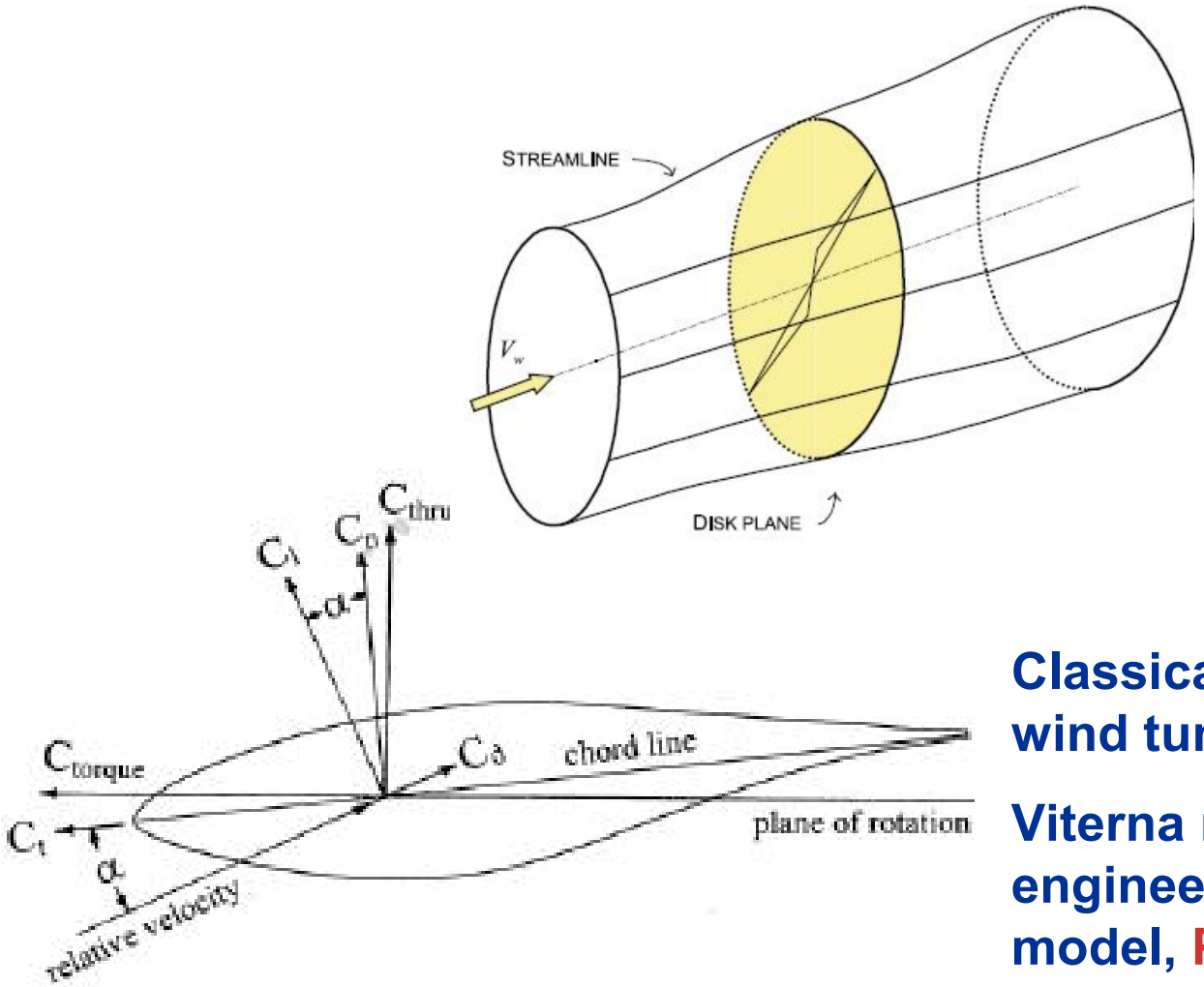
Engineering / Commercial Challenge

Comparison of measured and calculated performance using classical theory for the NASA Mod-O

In 1980, Existing engineering design methods were found to miscalculate power output and forces on wind turbines by over 100 percent in high winds



Classical Blade Element - Momentum Theory

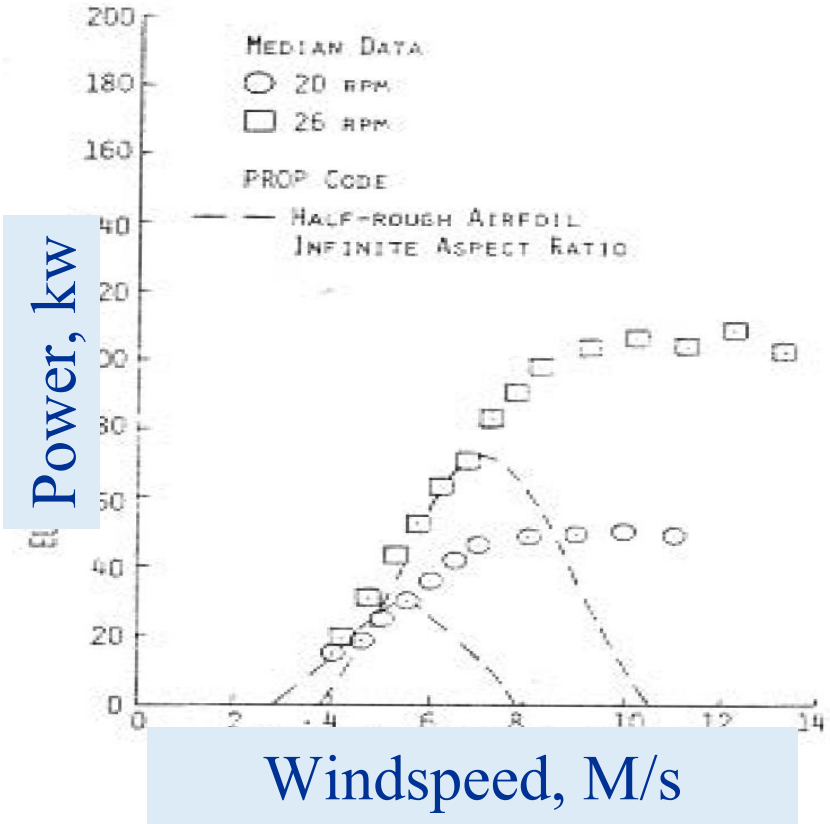


Classical Theory used 2-D wind tunnel airfoil data.

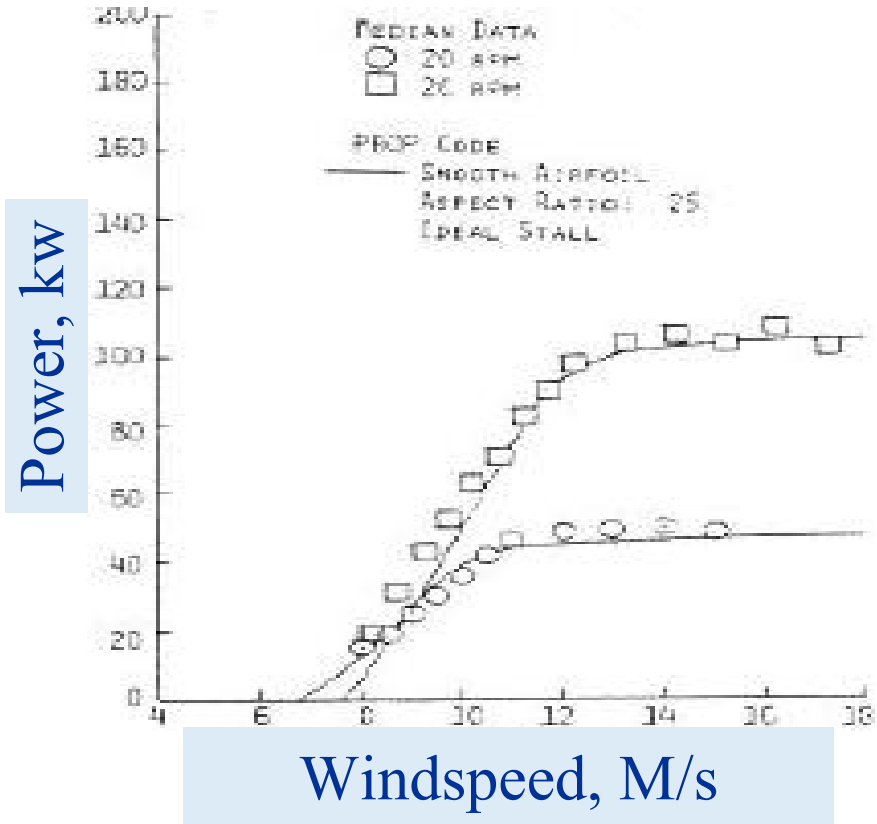
Viterna reverse engineered a 3-D airfoil model, Presented in 1981 – tepid response

"Viterna Method" Improved Design Accuracy

Original Classical Theory inaccurate prediction of power (and design forces)



Engineering design accuracy greatly improved after Viterna method applied



Assessment of "Viterna Method" 10 Years Later

Annual Reviews
www.annualreviews.org/aronline

As mentioned in previous sections, designers have not been able to predict high wind speed performance accurately on stall-controlled turbines. Viterna (Viterna & Corrigan 1981) was the first to suggest that airfoil stall characteristics were causing the errors. Rotor performance codes used wind tunnel data to describe the post-stall airfoil lift and drag properties. Viterna speculated that these properties were modified by spanwise flow and pressure gradients. He developed an empirical correction, based on blade aspect ratio, which improved the predictions of peak power. This correction remains the most widely used stall performance model in the US, even though it has little foundation in the basic physical mechanisms of stall. More recently a number of researchers have conducted tests that show how rotating blade airfoil performance differs from wind tunnel measurements on a nonrotating blade (Butterfield 1989b, Butterfield et al 1990, Hales 1991, Madsen 1990, Ronsten et al 1989, Wood 1991). All these tests have confirmed Viterna's speculation of rotating blade stall characteristics.

25 yrs later (2005) – Part of international commercialization standard

Public Policy

Energy Crises of 1973 and 1979

1973-74 "Energy Crisis" began when OPEC, the Organization of Petroleum Exporting Countries, instituted an oil embargo that reduced the amount of oil provided to the United States. This embargo resulted in long lines at gas stations and higher prices for gasoline.

1979 A second energy crisis occurred with the overthrow of the Shah of Iran, a U.S. ally.

An attendant pumps gas at a busy station in 1974, with waiting cars lined up along the street

Public Policy – U.S. Congress 1980

Wind Energy Systems Act

CONFERENCE REPORT

[To accompany H.R. 5892]

The committee of conference on the disagreeing votes of the two Houses on the amendments of the Senate to the bill (H.R. 5892) to provide for an accelerated program of wind energy research, development, and demonstration, to be carried out by the Department of Energy with the support of the National Aeronautics and Space Administration and other Federal agencies, and for other purposes, having met, after full and free conference, have agreed to recommend and do recommend to their respective Houses as follows:

That the House recede from its disagreement to the amendment of the Senate to the text of the bill and agree to the same with an amendment as follows:

In lieu of the matter proposed to be inserted by the Senate amendment insert the following:

That this Act may be cited as the "Wind Energy Systems Act of 1980".

FINDINGS AND PURPOSE

SEC. 2. (a) The Congress finds that—

(1) the United States is faced with a finite and diminishing resource base of native fossil fuels and, as a consequence, must develop as quickly as possible a diversified, pluralistic national energy capability and posture;

(2) the current imbalance between supply and demand for fuels and energy in the United States is likely to grow for many years;

(3) it is in the Nation's interest to provide opportunities for the increased production of electricity from renewable energy sources;

(4) the early wide-spread utilization of wind energy for the generation of electricity and for mechanical power could lead to relief on the demand for existing non-renewable fuel and energy supplies;

(5) the use of large wind energy systems for certain limited applications is already economically feasible;

(6) the use of small wind energy systems for certain applications is already economically feasible, and therefore, the Federal Government should not undertake any financial incentive or financial initiative which may detrimentally affect commercial markets for small wind energy systems;

(7) an aggressive research, development and demonstration program to accelerate widespread utilization of wind energy should solve existing technical problems of converting wind energy into electricity and mechanical energy and, supported by an assured and growing market for wind energy systems during the next decade, should maximize the future contribution of wind energy to the Nation's future energy production;

(8) it is the proper and appropriate role of the Federal Government to undertake research and development, to participate in demonstration programs for wind energy systems and to assist private industry, other entities, and the general public in hastening the widespread utilization of such systems;

(9) the widespread use of wind energy systems to supplement and replace conventional methods for the generation of electricity and mechanical power would have a beneficial effect upon the environment;

(10) the evaluation of the performance and reliability of wind energy technologies can be expedited by the testing of prototypes under carefully controlled conditions;

(11) innovation and creativity in the development of components and systems for converting wind energy into electricity and mechanical energy can be fostered through encouraging direct contact between the manufacturers of such components and systems and utilities and other persons interested in utilizing such components and systems; and

Technology Commercialization

NASA / Industry Wind Commercialization 1974-1987

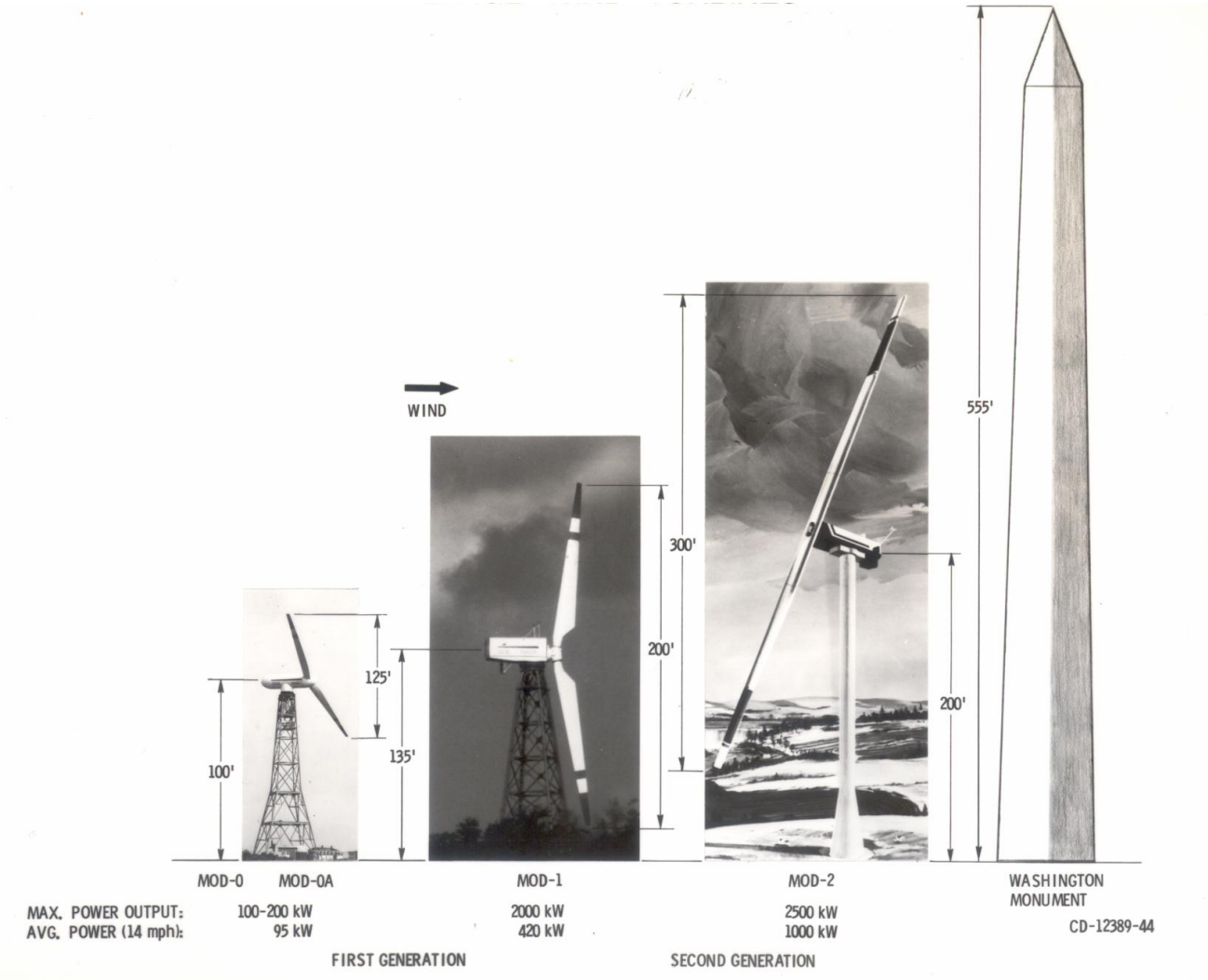
Total of 13 Utility Size Turbines Designed and Installed

Mod-0A 200kW wind turbine in Puerto Rico. Three others were installed in Rhode Island, New Mexico, and Hawaii. Assembled by Westinghouse

Mod-1 2000kW wind turbine in North Carolina. It identified and solved noise emission and other integration issues with installations near cities. Built by General Electric

Mod-2 cluster of multiple 2.5 MW wind turbines in the state of Washington. Other Mod-2s were installed in California. Built by Boeing Aerospace.

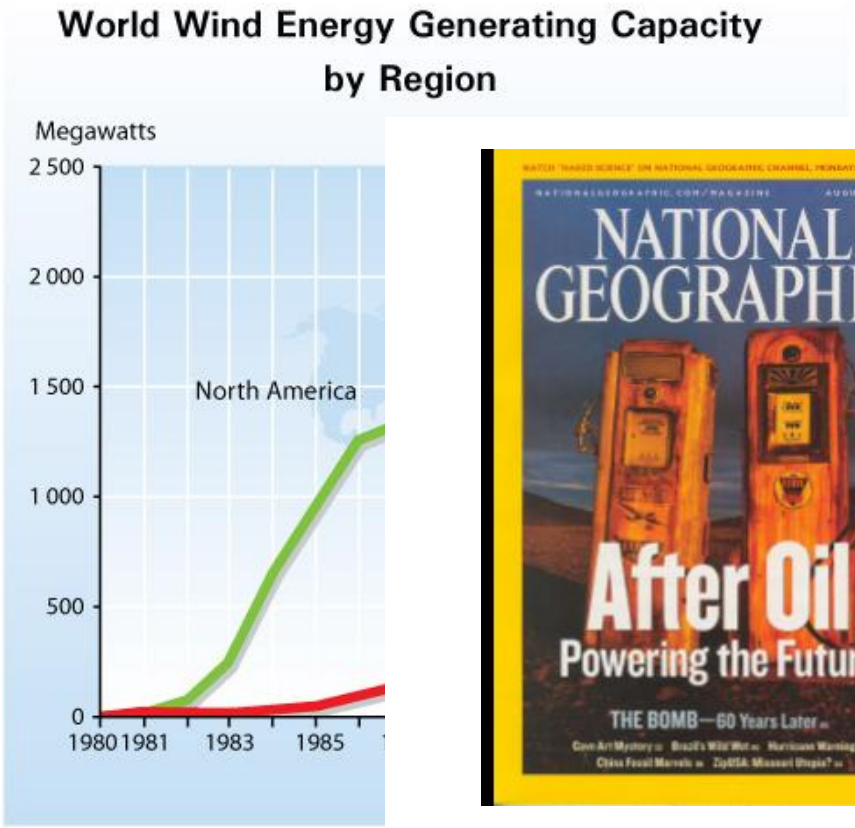
NASA Large Wind Turbines



NASA / DOE Mod-2 Wind Turbines

NASA / DOE Mod-2 Wind Turbines

A Renewable Energy Success Story



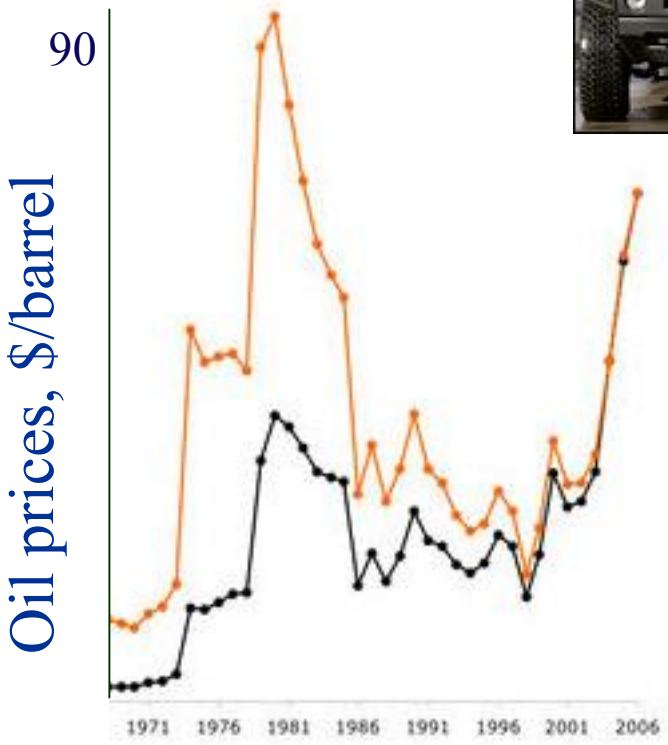
WIND IS CURRENTLY THE BIGGEST SUCCESS STORY IN RENEWABLE ENERGY. EUROPE'S TURBINES CAN GENERATE THE POWER OF 35 COAL-FIRED PLANTS.

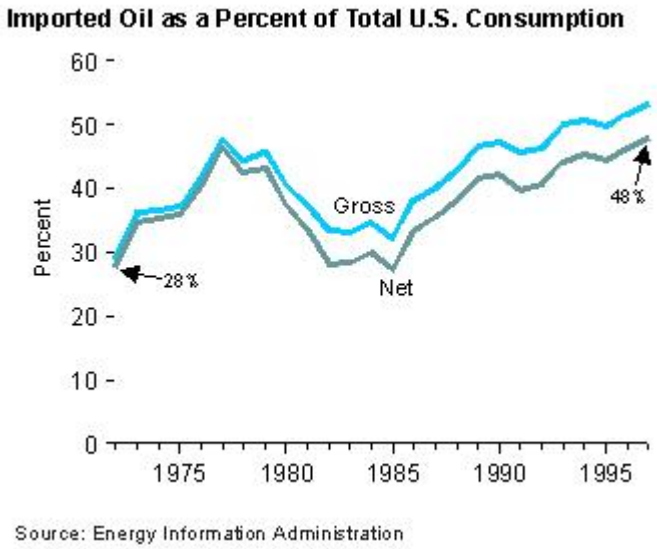
Examples of NASA Pioneering Technology

Multi-megawatt / 100 meter diameter class

- Tube towers
- Variable speed synchronous generators
- Various blade materials: steel, wood, fiberglass, concrete
- High efficiency airfoils
- Tip power control
- Acoustic emission modeling
- Aeroelastic structural modeling
- Two blade teetered hub
- . . .

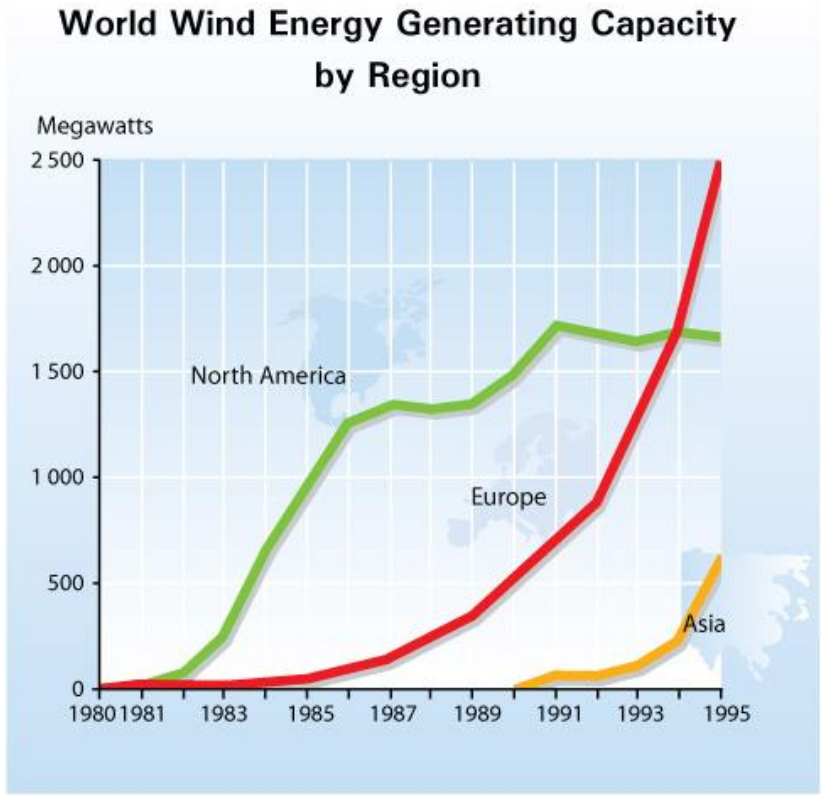
The Rest of the U. S. Story





Source: Energy Information Administration

The Rest of the World's Story



Denmark now dominates a $15B and growing world wind turbine market

A Change in Business Investment and Public Policy 1985-87

HEI wind turbine funding OK'd

By Nina Berglund
Advertiser Business Writer

An idle, 360-foot-high wind turbine tower on Oahu's North Shore finally will receive blades and motors, thanks to a renewal of federal funding for its construction.

President Reagan, bowing to pressure from Hawaii's congressional delegation and others, signed a measure late Tuesday that clears the way for completion of the huge turbine here, said to be the world's largest.

The turbine is supposed to be the centerpiece of an ambitious wind energy research project, and construction began on it late last year.

But in January, after millions of dollars in federal and private funds already had been spent on the turbine's development, construction was halted when the Reagan administration "deferred" $10.2 million in funding for the project this year.

C. Dudley Pratt Jr., president of Hawaiian Electric Industries, which intends to buy the turbine after its completion, decried the funding deferral as "not only shortsighted, but also a tragic waste of taxpayer monies."

Yesterday, Pratt hailed Reagan's signing of a supplemental appropriations bill that restores the $10.2 million in funds and now ensures resumption of the project. The bill signed by Reagan also restores $1.4 million in federal funds for ocean thermal energy research.

The turbine project "is the culmination of a national, 10-year research and development program," Pratt said, noting that Hawaii's congressional delegation, state officials and others who rallied beind the turbine deserve "a very special thank you."

The $71.4 million MOD-5B turbine — which will feature a rotor blade span as wide as a football field — is being built on a windy ridge above Kahuku by Boeing Aerospace Co. under contract to the National Aeronautics and Space Administration.

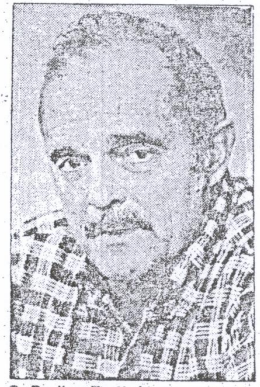
Upon completion, the turbine is expected to produce more than 15 million kilowatthours of electricity annually for sale to Hawaiian Electric Co., reducing annual oil consumption here by an estimated 25,000 barrels.

The turbine itself is designed to begin generating power when the wind is 12 mpl can operate in wind spee great as 60 mph. The uni been designed to allow rotor to turn at variable s to take full advantage o energy available in the wi

Doug Carlson of Haw Electric said it likely will at least 60 days for the fe money to be issued to Bo Construction at the turbin — which is near Haw Electric's 15-machine winc on the North Shore — wi sume as soon as funds ar cured, he said.

Pratt, in a not-so-subtle to federal officials, noted prepared statement on the bine project that "we hop the administrative proce Washington can be expe so that further delay wi minimized."

Pratt said the huge "sta the-art" turbine along wit nearby medium-size wind bines on the North Shor "a unique asset for the p of our state and for ever studying and developing energy throughout Am and the Pacific."



C. Dudley Pratt Jr.
"A very special thank you"

Hawaiians get Boeing's last wind machine

Makani Ho'olapa will bring power to 1,140 residences

By Les Gapay
P-I Reporter

Boeing's last windmill was dedicated this week by an electric utility in Hawaii.

Like the company's tilting at hydrofoil boats, subway cars and growing potatoes in the Oregon desert, wind turbines are a venture the airplane maker would probably like to forget.

"We don't plan to build any more units," said Boeing's wind program manager Dick Hacker in a telephone interview from Hawaii. "We're planning to leave the market" because low oil prices are keeping windmills for electricity generation uneconomical.

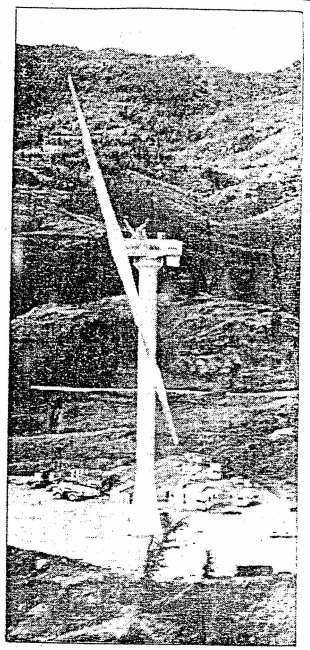
Boeing kept a low profile on the Hawaiian project and didn't make any announcement of the turbine's dedication.

But Hawaiian Electric Industries Inc. in Honolulu put out a press kit with a brochure, photos and news releases on the giant wind turbine developed and assembled in a rented building at Tukwila by Boeing and shipped to Hawaii by barge.

The wind machine — the world's largest operating wind turbine of the traditional horizontal axis type — was so big it had to be hauled in sections and accompanied by a 350-ton crane. There were no cranes in Hawaii large enough to lift its 320,000-pound rotor.

The turbine stands 360 feet tall from its base to the tip of its 159-ton blades. It weighs a total of 469 tons.

Dubbed MOD-5B by Boeing Aerospace Co



Hawaiian Electric Industries Inc.

Reagan Administration decreases funding and credits for renewable energy. Major U.S. manufacturers leave the market on declining oil prices

Acknowledgement

Special thanks to the NASA Glenn Library and History Staff, without whose conscientious and professional support over many years, much information on the development of modern wind turbine technology would not be available.

I think the health of our civilization, the depth of our awareness about the underpinnings of our culture and our concern for the future can all be tested by how well we support our libraries.

— Carl Sagan

Thought Questions

What can we learn from this?

What should NASA's Involvement be now?

The NASA Mod-5B 3.2 MW was the largest wind turbine in the world at one time. This design is available.

Backup

One Perspective

Illustrated History of Wind Power Development: Government Sponsored R&D

http://www.telosnet.com/wind/govprog.html

"Ultimately [Government-based wind power research] proved to be largely ineffective because of the interference of political factors and the withdrawal of financial support before success could be achieved."

"The fact remains that painstakingly-developed R&D programs were gutted in the early 1980's to provide funding for energy tax credits, which failed to provide sufficient impetus for broad-based private wind turbine technology development in the U.S."

One Perspective - continued

*"Danish firms … were armed with certification from the **Danish test center at Riso** and with statistics that showed their designs were more reliable (in terms of **availability for energy production**) than their U.S. counterparts. U.S. companies had balked at similar "Quality" standards when they were proposed, partly because they feared the standards would require costly and unnecessary design modifications to machines they considered "market-ready." By 1986, the **Danes had captured 50% of the U.S. wind farm market** and hundreds of inoperable, "market-ready" U.S. machines were cluttering the California landscape."*