The Medicine Bow Wind Energy Project

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Wind Power from Medicine Bow

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Introduction

On September 4, 1982, in the small, south-central Wyoming town of Medicine Bow, nearly 500 residents watched as federal and state officials dedicated Wyoming's first wind power turbines, billed as two of the largest in the world. Proclaimed "Wind Turbine Day" by Medicine Bow Mayor Gerald Cook, the festivities occurred one century to the day after the nation's first central electric generating system, Edison Illuminating Company's Pearl Street Station in New York City, began supplying electricity to residents and businesses. One turbine, a $6 million WTS-4 designed and built by Connecticut's Hamilton Standard, a division of United Technologies, was the world's largest in physical size and power output. At 391 feet tall with its two blades fully extended, it was capable of generating 4 megawatts (mW). The other turbine, a smaller, $4 million MOD-2 built by Washington's Boeing Engineering and Construction Company, stood 350 feet tall with its two blades extended, and was capable of generating 2.5mW. The estimated combined power output of both units could meet the needs of 3,000 homes, or 9,000 people.[1]

Among those in attendance were Wyoming Senator Malcom Wallop, Governor Ed Herschler, and Bureau of Reclamation (Reclamation) Commissioner Robert Broadbent, who predicted that by the year 2000 wind would provide a "significant source" of power in the Rocky Mountain region. This venture into harnessing Wyoming's winds into electric power was a first for Commissioner Broadbent's Department of Interior agency, one better known for constructing dams, hydroelectric plants, and canals throughout the American West since its 1902 inception. Known as the "Medicine Bow Wind Energy Project," it was a joint demonstration effort between

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[1] "Wind Turbines Start Operation; New Era Hailed," *The Denver Post*, September 5, 1982; "Bow Dedicates First Giant Wyoming Wind Turbines," *The Medicine Bow Post*, September 9, 1982.

Reclamation, the National Aeronautics and Space Administration's Lewis Research Center, and the Department of Energy in their attempt to assess the feasibility of capturing wind to not only generate electric power, but to tie this power into Reclamation's existing hydroelectric plants along the Green and Colorado rivers, specifically Flaming Gorge and Glen Canyon dams. (See Appendix 1) If successful, plans called for a huge wind farm with as many as 852 wind turbines in the area.[2]

Success, however, eluded this joint federal demonstration project in alternative power generation. Although Medicine Bow generated electricity, it was sporadic due to reliability issues with both units, especially Boeing's MOD-2, which operated off and on for eighteen months before a failed main bearing brought it to a permanent halt. Presented with a $1.5 million repair bill by Boeing, along with diminished funding by Congress, in 1987 Reclamation sacked the project and sold the MOD-2 for $30,000 to a scrap metal dealer, who dynamited it and hauled it away. The more dependable Hamilton Standard WTS-4 generated electricity until 1986, when a bolt worked loose inside and ground up the generator. A local engineer purchased it from Reclamation for $20,000, then repaired and operated it as the "Medicine Bow Energy Company" until a heavy windstorm in 1994 ripped the machine apart. And so ended this joint federal research and development (R&D) effort into large-scale wind energy generation, which historian Robert Righter claimed "underscored a major drawback into the economy of scale…. Engineers simply experienced the difficulties of building reliable large turbines."[3]

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[2] "Bow Wind Energy History Reviewed," *The Medicine Bow Post* Special Edition, September 2, 1982.
[3] Robert W. Righter, *Wind Energy in America: A History* (Norman: University of Oklahoma Press, 1996), 176, 178-79.

Wind Energy: A Historic Context

While the Medicine Bow Wind Energy Project failed to harness wind for large-scale power generating purposes, this is nothing unusual—the early history of large-scale (defined here as having a peak output of 1mW or more) wind energy generators is littered with failure, mostly due to reliability issues. Smaller systems, however, have fared better. Throughout history, two kinetic elements, water and wind, have been manipulated by humans for simple tasks. While the technology of harnessing water for large-scale use has steadily progressed since the Industrial Revolution, harnessing wind for large-scale use has proven more problematic. In his handbook on Wind Energy Conversion Systems (WECS), a generic term for machines like those installed at Medicine Bow, engineer V. Daniel Hunt explains that wind, as opposed to much denser water, presents unique problems:

> One is immediately confronted by three problems in any program to make use of wind power on any significant scale: 1) its low energy density necessitates a large capture unit; 2) the energy must be captured from moment to moment and its availability varies; and 3) energy storage involves considerable additional costs. These factors have limited the historical use of wind power almost exclusively to small-scale systems.[4]

Early examples of small-scale wind machines can be traced to the use of crude windmills in Persia as early as the seventh century, used mostly to grind grain. Largely unchanged until the twelfth century, the horizontal axis (also known the Dutch-type) windmill made its appearance in France and England; in the mid-1700s Dutch settlers brought them to America to grind grain and pump water—again, to serve useful purposes on a small scale. By 1890 the Danes had designed and produced the first modern electricity-generating windmills, and by 1908 several hundred 5-25 kilowatt (kW) wind power stations had sprouted up across Denmark's landscape. And since the 1850s, more than one million small-scale (less than 1mW) windmills had been used in the

[4] V. Daniel Hunt, *Windpower: A Handbook on Wind Energy Systems* (New York: Van Nostrand Reinhold Company, 1981), 9.

United States to pump water and generate electricity. They grew so popular that by 1919 windmill industry sales approached $10 million.[5]

Nonetheless, wind energy system research foundered until after World War I. The airplane's continued development, however, coupled with a deeper understanding of advancing aeronautic technology like airfoils and propellers launched the WECS industry in new directions during the interwar years. Mechanical engineers discovered that blades shaped liked aircraft propellers, as opposed to flat, traditional windmill blades, not only helped increase overall torque and efficiency, but eliminated traditional complicated gearing systems in that the rotor could be attached directly to the armature shaft.[6]

Interwar technological advances led to the construction of what was then the world's largest WECS by engineer Palmer C. Putnam. In his quest to reduce electric costs at his Cape Cod home, Putnam in 1939 presented a preliminary plan to the S. Morgan Smith Company of York, Pennsylvania, a builder of hydraulic turbines. They liked Putnam's large-scale wind energy project idea, and thus the Smith-Putnam wind turbine energy experiment, a forerunner to modern, large-scale WECS experiments like Medicine Bow's, came into being. Located atop "Grandpa's Knob" near Rutland, Vermont, and connected to the Central Vermont Public Service Corporation, the $1 million 1.25kW Smith-Putnam turbine began operations in October 1941 as the largest wind turbine ever built and tested. Standing 110 feet high, the rotor was 175 feet in diameter, with each stainless-steel blade weighing eight tons. Most importantly, each blade's pitch was adjustable, so a constant rotor speed of 28.7 rpm could be maintained—even at wind speeds approaching 75mph.[7]

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[5] Ibid., 9-10.
[6] Righter, *Wind Energy in America*, 73-74.
[7] Hunt, *Windpower*, 13.

In its first sixteen months of operation, the Smith-Putnam produced 298,240 kilowatt hours (kWh) in 695 hours of on-line (meaning synchronized to a power grid) production. On February 23, 1943, however, a bearing failed at the downwind end of the main shaft. Because of World War II's wartime manufacturing priorities and restrictions, it took until February 1945 to secure and install another bearing. Once fixed, the turbine operated for one month, when in 20 mph winds an overstressed blade snapped off the rotor and plunged down the mountainside. Putnam considered repairing the unit, but faced formidable obstacles in obtaining parts, and once parts were available, their costs proved prohibitive. Although Smith-Putnam scrapped the project, mostly due to its economic infeasibility, it proved wind could be harnessed for power generation purposes.[8]

Enter the Curious Feds

The Smith-Putnam experiment in large-scale wind power generation did not go unnoticed, specifically at the federal level. Percy H. Thomas, a high-ranking engineer with the Federal Power Commission (FPC) in Washington, D.C., closely observed the events that took place at Grandpa's Knob. A pioneer, Thomas not only believed in harnessing wind for power, but also in the concept of renewable energy sources. Since the FPC was tasked with investigating alternative methods of energy generation, Thomas, with the blessings of his boss, Assistant Secretary of the Interior (and former Assistant Reclamation Commissioner) William Warne, embarked on an extensive wind energy research program that lasted from 1943 to 1951.[9]

During this time Thomas compiled and analyzed data from the Smith-Putnam experiment. In addition to concluding that faulty machinery was the main reason for the machine's failure, he determined that in order to be economically feasible, a 5,000-10,000kW

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[8] Ibid., 13-14; Righter, *Wind Energy in America*, 133-34.
[9] Righter, *Wind Energy in America*, 136-38.

wind turbine was needed, and designed two large wind machines: one would generate 6,500kW and the other 7,500kW. Thomas's proposed dual-rotor 6,500kW WECS turbine was enormous in scale: the tower would reach 475 feet high, with two three-blade rotors 200 feet in diameter attached side-by-side. The rotors would drive DC generators and produce 6500kW at wind speeds greater than 28 mph, while a DC-to-AC synchronous converter would supply the electrical network. All of this machinery would be housed at the top of the machine. Thomas estimated capital costs for this machine at $75 per kW. In 1951 the FPC and the Department of the Interior attempted to entice Congress to fund the prototype; however, because of the Korean War, Congress rejected funding and cancelled the project.[10] Robert Righter explains that "there was a hidden agenda: the international climate and nuclear power. These nullified serious interest in wind energy."[11]

It is worth noting that, despite Thomas's setback, this was the first instance in which the federal government expressed interest in developing a wind power research and development program. Former Reclamation Assistant Commissioner William Warne must be credited with the idea that power generated by wind could be integrated into larger hydropower projects for supplemental and reserve purposes. When Thomas and Warne presented their WECS proposal to Congress, they admitted that while no formal site had been chosen, Sherman Hill southeast of Laramie, Wyoming, was a logical location due to its consistent wind speed and close proximity to transmission lines that tied into Reclamation hydropower systems.[12] But there was new form of energy on postwar America's horizon, the atom, and it was gaining momentum.

[10] Hunt, *Windpower*, 14.
[11] Righter, *Wind Energy in America*, 143.
[12] Ibid., 142.

The Rise and Fall of Nuclear

Ultimately, it was America's emerging fascination with the development of nuclear energy for peaceful purposes that killed the Thomas/Warne proposal. "Congress was convinced by scientific experts that peaceful use of atomic power would transform society, and nuclear power plants would usher in that society," Righter noted. "Thus, Congress appropriated billions of dollars for research and development of nuclear energy, and not a cent for alternative forms of power production."[13] Statistics point out this lavish largesse: from 1951, when Thomas and Warne failed to impress Congress with their innovative proposal to use wind power to supplement hydroelectric power, to 1970, the year of the first Earth Day, the Atomic Energy Commission (AEC) *alone* received $16.35 billion to create America's nuclear power infrastructure.[14]

As a result, while countries such as England, France, Germany, and Denmark continued small-scale wind power research and development (R&D) during the Cold War era, the United States went into a nearly three-decade-long era of almost total inactivity. Coupled with increased economic prosperity and a near-quixotic vision of unlimited safe and clean power, nuclear energy captured the attention of lawmakers, scientists, and an electricity-hungry American population. As the domestic GNP expanded at an average rate of 3.9 percent between 1960 and 1972, energy consumption grew at an average annual rate of 4 percent during that same time.[15] "Energy seemed limitless and Americans who, during the war had conserved, afterwards consumed," Righter noted. The American infatuation with nuclear power reached its apex in the

[13] Ibid., 143-44.
[14] AEC funding statistics from U.S. Department of Commerce, Bureau of the Census, *Historical Statistics of the United States, Bicentennial Edition, Colonial Times to 1970, Part 2* (Washington, D.C., Government Printing Office), 966. The Atomic Energy Commission was created in 1946.
[15] Hunt, *Windpower*, 17.

early 1970s when utility companies ordered the construction of 234 nuclear plants by 1975. While not a direct factor, the Arab Oil Embargo of 1973 helped support this demand.[16]

But America's love affair with the atom would soon run its course. A rising level of grassroots environmental awareness—the first Earth Day in April 1970 being a milestone event—coupled with widespread antinuclear protests, and uncertainty regarding safe disposal of toxic, spent nuclear waste, dovetailed to bring the nuclear power industry to a screeching halt. After 1974 only fifteen nuclear plants were ordered, none after 1975, and no plants have been built since 1978. Another blow, the Three Mile Island incident of 1979, in which many safety precautions failed and resulted in radiation leakage and a near meltdown, crushed the public's confidence. Additionally, the $2.25 billion default and bankruptcy of the Washington Public Power Supply System and its five nuclear plants in 1983 dealt the industry a major financial death blow. "At no time in U.S. history has science and technology … promised so much and produced so little. It represented a major defeat for U.S. technology, and one that cost not only ratepayers, but taxpayers billions of dollars," Righter remarked.[17]

Energy Crisis: Alternative Sources Revisited

Other factors that helped push wind (and other alternative) energy research out of its dormancy and into the forefront was America's reliance upon fossil fuels and foreign oil to help meet increasing demands. As demand skyrocketed, utility companies became increasingly reliant on coal-fired power plants to fill production gaps nuclear could not meet. But this also created a backlash, one driven by larger public health awareness and environmental concerns with air pollution, specifically carbon dioxide, smoke, and the particulates coal-fired power plants emitted. The Clean Air Act of 1970 was a major step forward in attempting to address these

[16] Righter, *Wind Energy in America*, 149.
[17] Ibid., 150-51.

problems. America’s consumption of cheap foreign oil to drive their heavy, inefficient automobiles continued unabated until October 19, 1973, when the Organization of Petroleum Exporting Countries (OPEC) cut off supplies of cheap foreign oil to America. As a result of this embargo, the price of oil quadrupled over the next six months, and sticker-shocked consumers dealt with long lines to purchase available gasoline. “The gluttonous American appetite for oil found the cupboard bare,” noted Righter.[18]

As a result, the OPEC oil embargo pushed America into reevaluating its needs and priorities. Righter sees this not only as a landmark in American thought towards energy consumption, but one that helped spark a reassessment of alternative energy generation, specifically wind:

> Within that short period, significant changes occurred. Energy conservation became part of the American lexicon. The Detroit automobile industry commenced designing more fuel-efficient vehicles. Americans realized the vulnerability of the nation to foreign influence. The government looked for new sources of oil—and new sources of energy.
>
> Scientists and engineers now returned to some old concepts: they resurrected wind energy, that relic of the past. Engineers would clothe this ancient, natural energy source in the garb of computers, high-tech materials, and the language of the space age. It would, however, still represent a basic, ancient idea: harness the wind for the service of man.[19]

Within this context, a new voice emerged from the shadows of uncertainty. Retired Navy officer and Massachusetts Institute of Technology (MIT) engineering professor William E. Heronemus rose to the forefront as a vocal advocate of wind power. While he admired the work of Palmer Putnam and Percy Thomas, he initially had zero interest in alternative power sources like wind. But pollution issues with the Connecticut River, as well as the threat of an unwanted nuclear plant near his home, shifted his philosophy. Heronemus became an outspoken environmentalist

[18] Ibid., 153-54. Otherwise known as the Arab Oil Embargo, due to the fact that most OPEC exporting nations were in the Middle East, lasted from October 19, 1973, to March 14, 1974.
[19] Righter, *Wind Energy in America*, 155.

who trumpeted the new concept of clean, sustainable energy sources. Although he considered wind energy to be "unsophisticated," this did not deter him; Heronemus supported research that could result in the construction of huge wind farms spread across America. "Need we bother very much with … fission and fusion if there were alternatives?" he challenged in a 1972 address to the American Society of Mechanical Engineers and the Institute of Electrical and Electronic Engineers. "There is a strong case for revived interest in in Wind Power … And it is such a gentle alternative to high temperature combustion, fission, and fusion schemes!"[20]

More support for alternative energy research came from a high level. While pledging further federal support for coal and nuclear sources in face of the dire energy crisis, in 1974 President Richard M. Nixon committed funding for solar energy research to the tune of $12 million annually. Not long after, he signed into law the *Solar Energy Research Act of 1974*, which established the Solar Energy Research Institute (SERI), a division of the Federal Energy Research and Development Administration (ERDA). As authorized by Congress, SERI drew upon the vast engineering and technical expertise within other agencies like Los Alamos National Laboratory, the National Science Foundation, and the National Aeronautic and Space Administration's Lewis Research Center (NASA-LeRC) in Cleveland, Ohio.[21]

Armed with lavish funding—nearly $600 million over a five-year period from SERI's 1977 start of operations—and with assistance from the Department of Energy's (DOE) Wind Technology Division and the supportive administration of President Jimmy Carter, the federal wind power program moved ahead. Its stated goals were: undergo research and development to build durable and economical wind systems; perform field tests and applications to demonstrate

[20] William E. Heronemus quotes from Righter, *Wind Energy in America*, 155-56.
[21] Ibid., 157-58. In 1991, SERI was formally designated a National Laboratory of the U.S. Department of Energy, and its name was changed to the National Renewal Energy Laboratory (NREL), headquartered in Golden, Colorado.

wind power can work on a widespread basis; and develop the technological capability of private industry to ensure successful commercialization.[22]

From SERI and NASA-LeRC, money flowed to private contractors to help design and build experimental/prototype wind turbines. Companies like Alcoa, Boeing, McDonnell-Douglas, Hamilton Standard, Grumman Aerospace, General Electric, and Westinghouse received most of this money, because they had the extensive in-house technical expertise to design and build WECS prototypes. These companies and NASA-LeRC engineers focused most of their efforts into the "Modification" (MOD) program, designed to build and test WECS systems. The first prototype unit, a 100kW MOD-0 turbine designed by NASA-LeRC, was erected at NASA's Plum Brook site near Sandusky, Ohio. Although it became operational in late 1975, it failed as quickly as it was built. Westinghouse constructed four of the second group of prototype MOD units, a 200kW MOD-0A, and erected them in New Mexico, Puerto Rico, Rhode Island, and Hawaii. It was closely followed by General Electric's MOD-1, a 2mW machine erected atop a windy hill near Boone, North Carolina.[23]

These turbines are considered "first generation" wind machines built primarily for research, to gain further knowledge of operational loads, variable windspeed environments, and possible integration into larger utility networks. Whether these prototypes worked would determine the direction of the wind power program. But units' rotors seemed to always be idle, creating an image problem with the public, which did not understand that idle wind machines still provided important data, and raised the perceptions that wind power programs were an expensive taxpayer-funded folly that would not work.[24]

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[22] Hunt, *Windpower*, 315.
[23] Righter, *Wind Energy in America*, 158-59.
[24] Ibid., 159.

In 1976 the Boeing Engineering Company of Seattle, Washington, entered the field with the first "second generation" WECS, the 2.5mW MOD-2. Unlike the others, the MOD-2 featured an upwind, two-bladed, teetered rotor with a hinged connection of its pitch-adjustable blades to the hub. "This teetered hinge," Righter explained, "allowed five degrees of teter [*sic*] relative to the normal plane of rotation. When working properly, this reduced blade loads and the vibration inherent in two-bladed rotors." Soon after, another second generation WECS appeared on the scene, Hamilton Standard's huge 4mW WTS-4 two-blade wind turbine, a design that featured a railroad boxcar-sized nacelle perched atop a 80-meter-tall hollow steel column.[25] Both units would prove significant as Reclamation would team with DOE and NASA-LeRC to research not only windpower's viability, but to see if wind-generated electricity at Medicine Bow could be tied into the Reclamation's existing hydropower infrastructure, as envisioned by its former Assistant Commissioner William Warne.

Reclamation's Early Investigations

The first instance of Reclamation examining the merits and possibilities of getting into wind power appeared in a 1957 report on future resource development in the North Platte River basin of Colorado, Wyoming, and Nebraska. The report drew extensively upon the Smith-Putnam experiment at Grandpa's Knob, and pointed to locations—specifically Wyoming—with the same average wind speeds of 25mph as that at Grandpa's Knob. Reclamation acknowledged the "value of power from the wind is not so great by itself as it is in conjunction with a hydro and steam plant," and that the greatest value of wind power would occur in the winter, when it was

[25] Ibid., 158-59. The final DOE-NASA WECS was the 3.2 mW Boeing MOD-5B, erected at Kahuku, Hawaii, in 1987; Ibid., 159-60).

needed most, as reservoirs were at their lowest and this power could be tied into hydroelectric systems.[26]

This report also mentioned the technicalities of careful site selection (also known as "siting") for wind power development. Reclamation relied on U.S. Weather Bureau (now National Weather Service) records to determine maximum wind velocities in the design and placement of wind turbines. Physical geography was also crucial, as the windiest sites were those located in notches or ridge saddles with prevailing winds blowing perpendicular to the notch or ridge. Height was also important, because wind velocities increase with height; those velocities were 1.5 times more powerful at 500 feet above the ground than at 40. The report also brought up the importance of maintaining constant turbine speeds in the face of variable wind speeds, by using the same feathered blade technology as the Smith-Putnam unit. "In this design the efficiency aspect … is not considered important, since the supply of wind energy is theoretically unlimited."[27]

Similar to the unsuccessful recommendations Percy Thomas and William Warne presented to Congress six years earlier, the 1957 report recommended Sherman Hill between Cheyenne and Laramie as a prime location to erect an experimental wind machine. The primary justifications for this location included fairly constant wind speeds, close proximity to a major highway, and being within thirty miles of a major electric load center at Cheyenne, so any power generated could be tied into an existing 115 kilovolt (kV) line. Finally, the report recommended that investigations into the relationships between elevation, tower height, and wind energy

[26] U.S. Department of the Interior, Bureau of Reclamation, *Report on the North Platte River Basin, Colorado-Wyoming-Nebraska: An Inventory of Physical Potentialities for Resource Development* (Denver: Bureau of Reclamation, Region 7, June 1957), 264-65.
[27] Ibid., 267-68.

content begin as soon as possible: "many consecutive years of observations … are desirable. Therefore, an early start is urgently needed."[28]

That early start, however, took two decades to materialize. Similar to the non-attention wind power received during the peak of nuclear energy madness in the 1950s and 1960s, it took until the first half of the 1970s for Reclamation to further detail possibilities of wind power as a supplemental energy source. They did, however, in a February 1976 congressional testimony, mention meteorological data Reclamation had collected as part of Project Skywater, an ambitious cloud-seeding program, and how that data could be tied into wind power research:

> Windflow models, measuring systems, specialized data, and forecasting techniques developed for the Bureau of Reclamation's cloud seeding program (Project Skywater) offer a readily available means of developing the wind resource…. Bureau expertise is also available in electrical power generation and control research and in interconnected and distribution system operation and marketing for possible integration of this resource into Reclamation's extensive power distribution systems.[29]

That same month, Reclamation announced the formal launch of their fifteen-month-long Western Energy Expansion Study. Armed with $290,000 in ERDA funding, the study would not only examine ways to expand water-related energy production in the western United States, it would also consider possible integration of wind and solar energy into the Reclamation's hydropower infrastructure. "Once all the potentials are identified," Commissioner Gilbert Stamm remarked, "we can analyze and assign priorities to those which merit more detailed investigation and possible development."[30] It is interesting to note that Stamm included coal, oil shale, geothermal

[28] Ibid., 269-70.
[29] "The Bureau of Reclamation Role in Solar Energy Development," Congressional testimony dated February 23, 1976, 3, located in the Records of the Bureau of Reclamation, Record Group (RG) 115, Accession Number (Acc#) 115-11-049, Box (B)9, Folder (F)1156076, National Archives and Records Administration, Rocky Mountain Branch, Broomfield, Colorado (hereafter NARA-CO).
[30] Department of Interior News Release, February 3, 1976, located in Ibid., NARA-CO.

and solar in addition to wind in his statement. Like the rest of post-nuclear-energy and Arab oil embargo America, Reclamation leadership was thinking big, when it came to alternative energy.

Planning Studies and Project Approval

With research money secured, Reclamation engineers went to work coming up with a conceptual plan to integrate wind power into hydroelectric systems, based on Warne's theories and successful applications in Sweden. Most of this effort centered around two employees, Stanley J. Hightower of Reclamation's Engineering and Research Center in Denver, and Abner W. Watts, of Reclamation's Lower Missouri Region. Their findings stand as the first inclusive assessment on the feasibility of a wind power program, based on six studies: wind assessment, wind turbine performance, cost estimates, marketing aspects, implementation plans, and environmental considerations. Acknowledging that a wind power system required careful evaluation of site characteristics, Hightower and Watts drew upon National Climatic Center wind data, complied and analyzed by Sandia Laboratories, for 758 weather stations throughout the western United States. Of the 758, three sites stood out as having the highest available wind power: Guadalupe Pass, Texas, Livingston, Montana, and Medicine Bow, Wyoming. Of those three, Medicine Bow was the scientists' top choice, due to its close proximity to Reclamation's existing hydropower grid. "Therefore, Medicine Bow has tentatively been selected as the best site for initial integration of wind power within the Bureau's hydroelectric network," they theorized.[31]

Hightower and Watts also mentioned a University of Wyoming (UW) study that plotted available wind power throughout the state of Wyoming. Their research concluded that while

[31] Stanley J. Hightower, and Abner W. Watts, "A Proposed Conceptual Plan For Integration of Wind Turbine Generators With A Hydroelectric System," Unpublished paper presented at the Annual Meeting of the Missouri Basin Systems Group, Sioux Falls, South Dakota, March 9, 1977, 6, in RG115, Acc#NRG-11-049, B9, F1157555, NARA-CO.

Medicine Bow had a slightly lower average wind speed than the Sandia study indicated, Medicine Bow's winds were still the highest available in the state. The UW study also pointed out a crucial factor: average wind speeds were higher in the winter months than any other time of the year—one primary requirement for hydropower integration. "This is an ideal characteristic for integration with hydropower," Hightower and Watts remarked, "because spring runoff provides more water for hydropower in the summer when the wind power is lowest, while the windpower is higher in the winter when there is less water available." They also mentioned another ideal characteristic: wind speeds at Medicine Bow were highest during the day, which also corresponded to daily peak power demands.[32]

Thus, Hightower and Watts outlined an implementation plan, one that would integrate wind-turbine generation with hydropower systems:

> Generating capacity must be available that can be dedicated to firm up the wind turbine energy during the hours and days provided in the marketing plan; reservoir storage capacity must be available to store the wind turbine energy not delivered to the load for a 12-month period and carry over storage for a period of several years to maintain average annual yield for the wind turbine energy; operation flexibility must be available to release water stored in the reservoirs for generating the peaking capacity and energy…, and sufficient regulating capacity must be available in the load control center to provide the additional automatic generator control for the wind turbines.

This plan would integrate the wind turbine power directly into two existing Colorado River Storage Project (CSRP) powerplants, specifically Arizona's Glen Canyon Dam and Wyoming's Flaming Gorge Dam—facilities that met all criteria listed in their proposed implementation program. They also stressed this would require forty-nine WECS turbines rated at 2mW each located at Medicine Bow, to provide energy equivalent to 799,000 barrels of oil annually. Hightower and Watts also stressed Reclamation would, as per recent federal laws, adhere to all environmental considerations dictated by the National Environmental Policy Act of 1970

[32] Ibid., 9, 12.

(NEPA), and for cultural resource requirements of the National Historic Preservation Act of 1966 (NHPA).[33]

A few months after the Hightower and Watts report came out Reclamation received $200,000 in special funding under the Congressional Authorization of August 7, 1977 (Public Law 95-96) to formally initiate wind studies. In December Reclamation identified five suitable sites on Bureau of Land Management (BLM) lands near Medicine Bow and nearby Rock River (see map 1 in Appendix 1), and contracted with UW to install twelve-foot-tall anemometer towers at each of the five sites—designated A through E—in order to collect more precise wind data such as speed, direction and frequency. Reclamation also announced that contracts had been issued for the environmental analysis of the sites, including possible impacts on the endangered black footed ferret, antelope, and raptor species. Two reports submitted later in 1978, one on cultural (historical and archeological) resources, and one on paleontological resources within the five sites, showed no impacts to cultural resources or paleontological remains at any of the sites.[34]

Completed one year later, detailed environmental studies concluded that the construction of wind turbines would have no significant impact on wildlife, provided that Reclamation stayed within the boundaries of the five sites chosen for preliminary studies. As a result of the data collected by the small anemometer towers, Reclamation chose Site A, located about five miles south-southwest of Medicine Bow, as the best location for wind test machine construction. Excellent and consistent wind conditions, minimal environmental impacts, proximity to services provided in Medicine Bow, and a location next to railroads and highways, were the primary reasons for Site A's selection. Also, in 1978, Congress appropriated $2.5 million to continue the

[33] Ibid., 32, 35-37.
[34] Bureau of Reclamation Press Release, "Wind-Hydroelectric Integration Study" #1, June 1978, n.p, NARA-CO.

study, including the construction of a 198-foot-tall meteorological tower on Site A to provide detailed wind information at three different elevations. Installed by Western Scientific Services of Fort Collins, Colorado, the tower became operational in October 1978. In addition, the fiscal year (FY) 1979 budget included $2.5 million for the construction of a system verification unit (SVU), with DOE considering the Medicine Bow site for the purpose of a multiple unit demonstration project.[35]

On November 24, 1978, Reclamation formally approached NASA-LeRC in Cleveland, Ohio, to participate in their windpower integration study, which NASA-LeRC accepted two months later. In late April and early May 1978, Reclamation and NASA-LeRC penned interagency agreement 9-07-7-x0123, which stipulated that NASA-LeRC participate in a project to build a single-megawatt wind turbine at Medicine Bow. It would be designated as a SVU and be integrated with existing Reclamation hydropower facilities. The agreement specified two objectives: verify the technical and economic feasibilities of operating large wind turbines in conjunction with hydroelectric facilities, and transfer wind turbine technology to Reclamation by training its personnel in all aspects of design, operation, and maintenance. Reclamation was responsible for overall program management and funding, while NASA-LeRC oversaw project management in the design, installation, checkout, and initial operation of the SVU turbine for two years after acceptance.[36]

Over the next few months, press reports speculated on what exactly might be built at Medicine Bow. Reports revolved around the latest in high-tech wind power generation

[35] Bureau of Reclamation Press Release, “Wind-Hydroelectric Integration Study” #2, November 1978, n.p., NARA-CO. This was the first instance where the Boeing MOD-2 was being considered by Reclamation and DOE as one of the test SVUs; an artist’s rendition of the MOD-2 was inserted in this press release.

[36] “Project Plan: System Verification Unit (SVU) Wind Turbine Project for Department of the Interior, Bureau of Reclamation by the Lewis Research Center, National Aeronautics and Space Administration,” July 1979, 1-3, in RG115, Acc# 115-99-152, B92, F9901313, NARA-CO.

technology, the 2.5mW Boeing MOD-2 SVU. Reclamation, as well as the supportive local population, eagerly anticipated the delivery of the Boeing unit to the site. Data collected from the wind verification tower, installed the previous year, indicated that top wind speeds clocked in at 68 to 71mph. This data supported the substantial size of the Boeing unit: standing on a 200-foot-tall tower, the steel rotor blade would measure in at 300 feet from tip to tip, wider than the wingspan of Boeing's 747 jumbo jet. Tipping the scales at 169,000 pounds, the blades were 11.3 feet wide at the widest point, and 4.7 feet wide at the narrowest. Concerns over noise generated by one or multiple machines did not concern locals, who viewed a wind farm as a tourist attraction.[37]

On October 17, 1979, Reclamation Commissioner R. Keith Higginson testified to the House Subcommittee on Energy Development and Applications regarding H.R. 3558, the *Wind Energy Systems Research, Development, and Demonstration Act of 1979*. In his testimony, Higginson outlined, in simple terms borrowed from William Warne's concept, precisely how electricity generated for the wind would supplement the agency's hydropower infrastructure:

> The integration of wind energy with hydroenergy systems would work as follows: when the wind blows and energy is generated, the water that would otherwise be released through hydroelectric units to meet system energy demands is stored in the existing reservoirs. The reservoirs would then be used as storage batteries for the energy laden, but, intermittent winds. When winds are light, or there are peak energy demands to be met, this stored water is then released through the hydro-powerplants. Ideally, the regulation of water releases can be correlated with the wind generation to provide the greatest utilization of both of these renewable resources.

Higginson also testified that California's Central Valley was the location of yet another study by Reclamation, the "Wind-Hydro Opportunities Study," whose goal was to investigate the

[37] Zeke Scher, "Putting Wyoming Wind to Work," *Denver Post Empire Magazine*, July 15, 1979.

possibility of integrating wind energy with hydroelectric pump-back storage.[38] One year later, on September 8, 1980, Congress enacted H.R 5892, the *Wind Energy Systems Act of 1980* to provide for the accelerated program for wind energy development, as Public Law 96-345.

The Project Gets Underway

In January 1980 Reclamation, now known as the "Water and Power Resources Service,"[39] (WPRS) awarded a fixed-price contract in excess of $6 million to Connecticut's Hamilton Standard to install a second SVU at Medicine Bow Site A. The significance here is that it marked the first time a wind turbine was acquired by a federal agency other than the DOE. Much larger than the Boeing 2.5mW MOD-2 SVU under construction at the site, Hamilton Standard's 4mW WTS-4, the world's largest wind turbine in size and generating capacity, was a downwind, two-bladed, horizontal axis, free-yaw synchronous generator wind turbine with a 257-foot rotor diameter (see Table 1, p.20). Mounted on a 262-foot-high tubular steel tower, it would stretch to 390.5 feet high with its blades locked in full vertical position. One aspect of the WTS-4 that appealed to WPRS officials was that, unlike the MOD-2, the WTS-4 drew upon Swedish-tested and proven wind turbine designs. Hamilton Standard also argued that if the Medicine Bow wind project proved successful and expanded to include more SVU units, the WTS-4 would be more cost effective, because forty-one WTS-4s could do the work of fifty-nine

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[38] Statement of R. Keith Higginson, Commissioner, Bureau of Reclamation, before the Subcommittee on Energy Development and Applications on H.R. 3558, the Wind Energy Systems Research, Development, and Demonstration Act of 1979, a bill to provide for an accelerated program of wind energy research, development, and demonstration, October 17, 1979, 2-3, in RG115, Acc#115-11-149, B1, F1156076, NARA-CO.

[39] In 1979, Commissioner Higginson changed the name of the Bureau of Reclamation to the *Water and Power Resources Service,* a name that would last only until May 1981, when President Ronald Reagan's Interior Secretary James Watt reversed Higginson's act and the name reverted back to Bureau of Reclamation. See Andrew H. Gahan and William D. Rowley, *The Bureau of Reclamation: From Developing to Managing Water, 1945-2000,* Vol. 2, (Denver: Bureau of Reclamation, 2012), 839, 849.

MOD-2s.[40] The fact that the WTS-4 drew upon extensive European R&D efforts may be a factor in its greater dependability over the Boeing unit.

By 1981 the first monthly reports on the SVUs started filtering out of the Medicine Bow site. Most of these early WPRS-Lower Missouri Region status reports centered on the SVU they procured, and were in the process of planning, the WTS-4 (the MOD-2 was still not completed in early 1981). WPRS looked at defining maintenance requirements, determining staffing levels, completing the public involvement program, and holding assorted management meetings with Hamilton Standard officials both at the site and in Connecticut. Preparation work on the WTS-4 site commenced on May 18.[41]

Table 1: Comparison of Medicine Bow SVU Wind Turbines

	Hamilton Standard WTS-4	**Boeing MOD-2**
Acquired through	Reclamation/WPRS	Dept. of Energy/NASA-LeRC
Rotor Type	Filament-wound fiberglass	Steel
Rotor Diameter	257 feet	300 feet
Blade Rotation	30 rpm	17.5 rpm
Tower Height	262 feet	200 feet
Tower Type	Hollow steel	Hollow steel
Height with Blades in Vertical Position	391 feet	350 feet
Generator Capacity	4mW	2.5mW
Generator Type	Synchronous a.c. 60Hz	Synchronous a.c. 60Hz
Total Weight	791,000 lbs	580,000 lbs
Blade Direction Faced	Downwind	Upwind

Source: U.S. Department of the Interior, Bureau of Reclamation, *1980 Annual Report* (reprint from Summary, Bureau of Reclamation, Hydro and Windpower Too.) 43.

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[40] "Contract Awarded for World's Largest Capacity Wind Generator," Bureau of Reclamation, Engineering and Research Center Staff Information Letter, February 29, 1980; "Hamilton Standard Wins Medicine Bow SVU Award," *Wind Energy Report*, January 1980, 1, 4.

[41] Bureau of Reclamation, Monthly Project Report, System Verification Units, January and February 1981, in Federal Records Center (FRC) Group 115, Acc#115-13-100, B2, F1233246, Federal Records Center, Broomfield, CO; hereafter FRC-CO, hereafter SVU Monthly Project Reports. FRC holdings are still considered agency records, and are closed to the public except for Freedom of Information Act (FOIA) inquires.

By August construction of the two SVUs was underway. Photos in the Lower Missouri Region "Employee Newsletter" showed the MOD-2 tower being welded and installed into place. A couple months later, Reclamation reported to NASA-LeRC that the MOD-2's construction was progressing well, to the point that the agency expected first rotation from that unit in December. Reclamation also reported that of all foundation work for the WTS-4 had been completed, and that the tower, tower access ladder, and walkway had been welded into place. In addition, Hamilton Standard and NASA-LeRC personnel conducted specialized training sessions at Reclamation's Denver Federal Center offices, mostly covering WTS-4 system/design performance and electrical control systems.[42]

Yet, despite the MOD-2's successful first rotation in December 1981, alternative energy budget cuts by the Reagan administration and Mother Nature brought testing to a halt. After its first rotation, Reclamation secured the MOD-2 in "standby" configuration until NASA-LeRC and DOE could resolve the funding problems, in order to sign off and accept the machine for operation. Even in standby mode, in January 1982 the MOD-2 encountered minor wind damage, when the support structure for the nacelle anemometers was damaged in winds exceeding 86 mph. NASA-LeRC requested that Boeing inspect the damage, and secure any loose parts; in addition, NASA-LeRC requested a design change to correct the problem, not only at Medicine Bow, but to MOD-2 machines installed at their Goodnoe Hills, Washington, research and development site. Work also continued on the WTS-4, mostly off-site preparation of the nacelle in Sweden, and the fiberglass-wound blades in Connecticut. Officials were optimistic that this

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[42] Bureau of Reclamation, Lower Missouri Region, *Employee Newsletter No. 37*, August 1981; Bureau of Reclamation and NASA-LeRC, "Management Report, System Verification Unit Wind Turbines" October 1981, in FRC Group 115, Acc#115-30-100, B2, F1233243, FRC-CO.

unit, not subjected to the funding constraints dogging the MOD-2, could achieve its first rotation by May.[43]

Reclamation clarified the MOD-2's funding issues in a March 1982 newsletter. In December 1981 Congress had cut DOE/NASA-LeRC funding for the finished unit, with about $1 million still needed to test, maintain, and operate the unit for one year. In addition to Reclamation seeking more funds, Wyoming Governor Ed Herschler mentioned he would explore the possibilities of alternative funding, such as from state or local sources, to get MOD-2 into operational status, if federal funding could not be secured. And, while the WTS-4's tower was secured in place, several delays that revolved around the nacelle's construction and technical problems, were being resolved. Reclamation expected the nacelle, as well as both blades, to be delivered to the site by May—with the nacelle alone taking two months to arrive from its manufacturer, Karlskronauaruet (KKRV) in Sweden—via Germany, then ocean liner to Houston, then rail to Medicine Bow. Reclamation also mentioned economic concerns as to wind turbine costs that would remain high until machines could be deemed feasible, and mass production could commence. "Operation, maintenance, and replacement costs of wind turbine units remain one of the major uncertainties," the newsletter noted.[44]

In June 1982, as construction progressed on the Medicine Bow wind facility, one of the engineers responsible for initial research into the wind power program, Stanley Hightower, delivered a paper to the Rural Electric Wind Energy Workshop held in Boulder, Colorado. In addition to praising the work that had happened to date on both machines, Hightower stressed that when completed and operational, both units would function unattended, remotely operated

[43] Bureau of Reclamation and NASA-LeRC, "Management Report, System Verification Unit Wind Turbines," January 1982, in RG115, Acc#115-11-049., B6 F1156345, NARA-CO.
[44] Bureau of Reclamation Press Release, "Wind-Hydroelectric Integration Study" #5, March 1982, n.p. A May 1982 Monthly Progress Report noted that $440,000 had been restored to complete and adjust the MOD-2 unit, see SVU Monthly Progress Report, May 1982," in FRC Group 115, Acc#115-13-100, B2 F1233246, FRC-CO.

by Reclamation's Casper Control Center, located about ninety miles to the north. Hightower also explained the reasoning behind having two machines of differing size, materials, mechanical design, power output, and placement. "Reclamation engineers can evaluate the advantages and disadvantages of each under exactly the same wind conditions, at the same time," he stressed. "The results will help determine the best design and size of units for the rest of Medicine Bow Project."[45]

Hightower also noted that the two machines would allow engineers to study the amount of space needed between turbines (otherwise known as "interference wake"), should the project expand to include more units. "Ideally," he suggested, "units should be placed close enough together to keep electrical connection costs at a minimum, but far enough apart to eliminate excessive wind interference between machines." He also mentioned that in addition to Medicine Bow, the agency had "several" other wind projects underway. One he used as an example for his paper was a small 25kW Jay Carter turbine installed at the Weber Basin Job Corps center north of Salt Lake City, Utah. "By monitoring the performance of this unit," he wrote, "Bureau engineers plan to assess the cost effectiveness of kilowatt-size machines for irrigation pumping and other applications where small scale power generation is required by the Bureau." He also hoped Medicine Bow-generated windpower would help "write a new page" in Reclamation's history.[46]

By July 1982 Reclamation reported that despite minor mechanical issues with the WTS-4 which Hamilton Standard had helped to resolve, the unit was essentially completed. They expressed confidence it would achieve its first rotation in August and be checked off as fully operational. On the MOD-2, Boeing checked off all operational tests as complete. Reclamation

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[45] Stanley Hightower, "The Bureau of Reclamation's Wind Program," paper delivered at the Rural Electric Wind Energy Workshop, Boulder, Colorado, June 1, 1982, in RG115, Acc#115-11-049, B9 F1157555, NARA-CO, 3-4.
[46] Ibid., 4, 5.

officials expressed pleasure not only with Boeing's "excellent support" for the project; but also that the unit was installed on-schedule, with only minor operational tests needed. In this glow of enthusiasm, Reclamation agreed to a two-year operations and maintenance contract for Boeing starting October 1.[47]

In August Reclamation released the final feasibility report on the project. The report complied with and met all NEPA and NHPA requirements including environmental, social, economic, and cultural resource issues. It declared no significant impacts and publicized the project as one that, when connected to the agency's hydroelectric system, would help "meet the nation's long-range energy requirements, and lessen the depletion of our fossil fuels and dependency on foreign oil."[48] Project Manager Walt Fite remarked that once Reclamation-NASA-LeRC determined which machine performed better, had the least number of mechanical problems, and had the least impact on the environment, its manufacturer would most likely get the contract to expand the project.[49]

Project Dedication—and Project Problems

Less than a month later, on September 4, a series of formal dedication ceremonies heralded Reclamation's nascent venture into alternative energy. A crowd of local and national dignitaries and politicians mingled with ecstatic Medicine Bow residents to express their enthusiasm over the two wind machines, and what they might hold for the state, and nation, if successful. Fred Maxwell, president of Boeing Engineering and Construction Company, remarked that he hoped "the machines will lead to many more in Wyoming," and that "the wind won't run out and we don't need to import it." Vernon Meyers, institutional manager of NASA, said he believed that

[47] Bureau of Reclamation and NASA-LeRC, "Management Report, System Verification Unit Wind Turbines," July 1982, in RG115, Acc#115-11-049., B6, F1156345, NARA-CO.
[48] Bureau of Reclamation, "Wind-Hydroelectric Energy Project, Wyoming, Executive Summary, Feasibility Report, Environmental Assessment," August 1982, 1, in RG115, Acc#115-11-049, B3, F1156092, NARA-CO.
[49] "Bow Wind Energy History Reviewed," *The Medicine Bow Post*, September 2, 1982, 4.

"we'll see large machines, similar to the ones here, across the nation." While most expected President Ronald Reagan to neither show up nor acknowledge the project's dedication, a letter from his Interior Secretary (and Wyoming native) James G. Watt proclaimed that "Medicine Bow—like the West itself—has always been identified with the frontier spirit…. Today, the people of Medicine Bow find themselves at another frontier, an energy frontier. The dedication … of two giant wind turbine generators marks the beginning of a new era in this nation's drive for energy self-sufficiency."[50]

Despite the heady optimism and praiseworthy rhetoric, almost immediately mechanical and electrical problems started to dog the project. In mid-October, the WTS-4 had to shut down after a nine-minute run that generated 1 megawatt-hour (mWh) of electricity, due to a faulty vibration generator located inside a gearbox on the generator's high speed main shaft. In addition, software issues caused shutdowns at the turbine's peak generating rate of 4mW. Since the dedication, the WTS-4 had only been on line for twelve hours, generating 15mWh of electricity. Still, Reclamation praised the unit, claiming all problems were intermittent in nature and easily fixed, and on December 2 it managed to successfully run the WTS-4 for one hour at full rated power for *Life* magazine representatives, noting "the fact that this short run was accomplished without a single glitch or problem, again demonstrates how intermittent these problems have become."[51]

Not long after, Reclamation devised a new term to describe these issues: "nuisance shutdowns." A December 1982 management report noted the MOD-2 was temporarily shut down, as a result of a low speed shaft failure at the DOE/Bonneville Power Administration's (BPA) MOD-2 turbine at Goodnoe Hills, Washington. Reclamation acknowledged that while

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[50] "Wind Turbine Ceremony Marks New Era for State," The *Medicine Bow Post*, September 9, 1982, 1-2.
[51] Bureau of Reclamation, SVU Weekly Project Reports, October 18-24 and November 29-December 5 1982, in FRC Group 115, Acc#115-13-100, B2, F1233246, FRC-CO.

they sent the site's Boeing representative home until that problem was resolved, they would occasionally run the MOD-2 briefly to keep the hydraulic oil circulated. They also reported more control system issues, ones that caused the unit to go from remote disable to startup mode for no apparent reason. And the WTS-4 continued to have problems, including failed relays, erroneous signals, low speed shaft vibrations exceeding tolerance limits, and reverse power shutdowns during synchronization and low power outputs. "Although the mechanical problems have been corrected, the nuisance shutdowns continue to occur," the project manager explained. The WTS-4 could not operate for more than two hours at a time, so Hamilton Standard planned to burn new programmable read-only memory (PROM) cards for the control system to raise acceptable ranges for the parameters causing the shutdowns.[52]

These problems, however, continued into 1983. The MOD-2 remained idle and the WTS-4, while operating a "few hours," continued to be plagued by nuisance shutdowns, including one where high winds were blamed for low speed shaft vibrations. Hamilton Standard completed software changes that allowed the WTS-4 to operate efficiently, but damaged cable trays in the tower's upper reaches resulted in yet another shutdown until the problem was corrected. However, Reclamation reported that their small Jay Carter turbine in Utah was performing very well, generating 16,800 kilowatt hours (kWh) of electricity in 1,320 on-line hours.[53] By month's end enough problems had been corrected to where the WTS-4 had generated 71mWh of energy in twenty-seven hours online, but still had assorted nuisance

[52] Bureau of Reclamation and NASA-LeRC, "Management Report, System Verification Unit Wind Turbines," December 1982, in FRC Group 115, Acc#115-13-100, B2, F1233243, FRC-CO.
[53] SVU Weekly Project Reports, January 7 and 14, 1983, in FRC Group 115, Acc#115-13-100, B3, F1233251, FRC-CO.

shutdowns and "other minor problems" that prevented it from running consistently—one requirement for project sustainability.[54]

By April it appeared Medicine Bow's MOD-2 turbine would never go back on line, as it remained idle—save for occasional startups to keep the hydraulic oil circulated—until DOE and NASA-LeRC resolved the low speed shaft failure with the Goodnoe Hills MOD-2 unit. Meanwhile, Hamilton Standard had fixed the WTS-4 to allow it to run and generate power, but only when wind speeds and the lack of nuisance problems allowed it to do so. To date, the MOD-2 had generated (mostly before the precautionary shutdown) 468mWh of energy on 392 hours of on-line (grid sync) time, while the WTS-4 had generated 490mWh of energy on 207 hours of grid sync time. Clearly, both Medicine Bow units were underachieving due to nuisance and other issues, including precautionary measures, as well as low winter wind speeds.[55]

Reassessing The Situation

As a result of all the problems with both units, in May Reclamation began reassessing program roles and objectives barely nine months after dedicating the project—and investing nearly $16 million for both units. "We are seeking a decision on an action plan which would lead to the continuing operation or disposal of the wind turbines at the site," wrote Lower Missouri Regional Director Bill Martin. He discussed options with the MOD-2: undertake a total repair with an additional investment of $1.7 million, undertake an on-site repair costing $121,000, with frequent inspections during down time, or restart operations and run it until a low speed shaft crack "or other unsafe condition" develops. He proposed this one, because the other two would not allow the MOD-2 to be operated during the high-wind winter months. With the WTS-4, Martin noted that this unit would be available for retention, disposal, or transfer at the end of

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[54] SVU Weekly Project Report, January 28, 1983, in Ibid.
[55] SVU Weekly Project Report, March 28, 1983, in Ibid.

FY1984. Unlike the MOD-2, there was no congressional committee mandate to dispose of the turbine by March 1984. Martin, however, mentioned that the WTS-4's fate lay in the success, or failure, of the program in general, and they were already exploring options for sale to private investors, a transfer to another agency program, or disposal of the unit through the GSA process. He also said that if Reclamation wished to continue to support the SVU program, it should be transferred from the region to their Engineering and Research Center; if not, the MOD-2 should be transferred to DOE, and the WTS-4 sold at the end of FY1984.[56]

The response to Martin's letter indicates that agency leadership was running low on patience with the program. Lower Missouri Basin Region Operations and Maintenance Chief James Cook recommended that Reclamation not put any more funds into the Boeing unit "as I have problems rationalizing the cost effectiveness of such an investment when there are other units that could provide testing data and the energy produced is not price competitive." Cook also suggested not operating the WTS-4 beyond the minimum needed to gather test data, due to low resale value for units that are even in good condition, and that it could "sell for significantly less if continued operation should result in damage to the unit." Cook offered a suggestion that can be considered as the first nail driven into the coffin of Reclamation's wind energy project:

> Given the current state of world oil-based energy markets, production of wind energy is much like shale oil and coal gassification [*sic*]—not cost effective and possible to sustain if heavily subsidized. Prudent investors have moved funding out of both of these efforts. I believe that we should likewise prudently withdraw any further from wind energy after the completion of our current effort with the minimum possible investment of staff and financial resources.[57]

The cautionary assessments of leadership, and the well-documented problems with both units, were downplayed by Stanley Hightower in a paper he presented at the Sixth Biennial Wind

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[56] Bill Martin to (unnamed) Assistant Commissioner, May 12, 1983, in RG115, Acc#115-11-049, B9, F1157554, NARA-CO.
[57] James Cook to William Martin, May 13, 1983, in FRC Group 115, Acc#115-00-007, no box #, F47630, FRC-CO.

Energy Conference and Workshop in Minneapolis in June 1983. In his presentation, he praised both units as operating "very well." While he pointed to the same output statistics as reported in the SVU weekly project reports, he mentioned that "test results of loads and performance appear to match design values better than anticipated. Like all prototype systems, there have been operational problems which could only have been corrected by operating the machines over an extended period of time and … performing the needed design modifications as required."[58] Thus, his paper, and the SVU weekly project reports, paint two different pictures: one of all is going well and moving along as planned, and the other of constant operational glitches, design flaws, delayed repairs, and other "nuisance issues" that resulted in documented down time, especially with Boeing's unit and its long precautionary shutdown period.

Numerous problems continued to affect both units throughout the remainder of 1983. In addition to various mechanical issues—including replacing defective truss members on the WTS-4's spinner assemblies, a manufacturing flaw originally detected on a WTS-3 in Sweden—a lightning strike during a late August electrical storm fried the turbine's control system boards. All required a crew from Hamilton Standard to remain on-site to sort out and fix the problems. Reclamation noted that getting these control system electronics back on line was a "slow and tedious process," with defective replacement boards adding to their misery. Problems with one equaled problems with the other; Boeing engineers remained on-site to try and solve more than twenty-four control system problems that prevented the MOD-2 from planned periodic operations.[59] While SVU project reports through the end of 1983 indicated that some problems were ironed out on both units, but as soon as they were solved, more appeared. Despite setbacks,

[58] Stanley J. Hightower, "Status of the Bureau of Reclamation's Two SVU Wind Turbines at Medicine Bow, Wyoming," a paper presented to the Sixth Biennial Wind Energy Conference and Workshop, Minneapolis, Minnesota, June 1-3, 1983, 5, in RG115, Acc# 115011-049, B9, F1157555, NARA-CO.
[59] SVU Weekly Project Reports, September 12 and 19, 1983, in FRC Group 115, Acc#115-13-100, B3, F1233251, FRC-CO.

the WTS-4 continued to operate more than the MOD-2, and by year's end it had generated (to date) 1461mWh of energy on 716 hours of grid sync time, as opposed to the MOD-2's 520mWh on 449 hours of grid sync time.[60]

As 1984 dawned it appeared the project was in serious jeopardy. Although Reclamation Commissioner Robert Broadbent directed the Medicine Bow site to continue SVU operations for at least two more years to gather data from the machines as available, both suffered from continued mechanical issues and manufacturing defects, compounded by severe Wyoming weather. January blizzards driven by very high winds prevented Reclamation and contract personnel from accessing the site; only when crews used snowcats were they able to work on both turbines. Among the problems with the WTS-4 were trying to figure out how to protect circuit boards from lightning strikes, and the replacement of forty-five fatigued bolts attached to the hub extension cylinder. The MOD-2 did not operate due to low hydraulic oil levels on the pitch system, which was traced to leaking actuator seals on both blade tips.[61] By mid-February, however, the WTS-4's mechanical and electrical issues had been worked out to the point it began to operate successfully.[62]

Successful operations, however, were short lived. The number one problem with the WTS-4 turbine was the spinner assembly, a problem that prevented the unit from operating on a consistent basis. By March Reclamation expressed frustration to Hamilton Standard that previous repair and modification attempts, such as adding doublers, new brackets, bolts, moving attachment points, and other measures, were not working. To add to the list, a loud banging noise emanated from within the tower at all operational speeds. A preliminary assessment

[60] SVU Weekly Project Report, December 19, 1983, in Ibid.
[61] Bureau of Reclamation and NASA-LeRC, "Management Report, System Verification Unit Wind Turbines," January 1984, in FRC Group 115, Acc#115-13-100, B2, F1233243, FRC-CO.
[62] SVU Weekly Project Report, February 21, 1984, in FRC Group 115, Acc#115-13-100, B3, F1233250, FRC-CO.

indicated that, according to Reclamation, the "bond between the tower and foundation for a short portion of the imbedded tower length has broken down permitting the tower to stretch/compress laterally." And, as usual, the MOD-2 remained idle due to hydraulic oil leaks and operational problems with the control system.[63]

Temporary Good Fortunes

By summer, however, it seemed that Reclamation, Boeing, and Hamilton Standard officials had solved problems with the MOD-2 and WTS-4. A report on the week of June 16, one of the only weekly reports that noted successful operation of both units, indicated that after replacing a faulty voltage regulator, Reclamation was able to successfully fire up the MOD-2 and synchronize it to the Western Area Power Administration (WAPA) grid for two hours. This was despite the fact that the low speed shaft, the part that caused the precautionary shutdown over the previous several months, had not been replaced. During the same week, the WTS-4 operated successfully for fifteen hours. Project Manager William Johnson noted that while it was operating well, they planned to shut it down to perform planned strain gage work on the blades. On July 2, Reclamation announced that Boeing would replace the MOD-2's low speed shaft at no cost to the agency, sometime in late summer or early fall.[64]

On July 6, NASA-LeRC wind energy project manager Darrell Baldwin announced that since all appeared to be going well with both Medicine Bow machines, and NASA-LeRC believed that it filled its commitments, it planned to conclude the interagency agreement with DOI/Reclamation on September 30, citing increased activity with its space shuttle and aeronautic programs. Baldwin noted, however, that NASA-LeRC planned to extend its support to the DOE Wind Energy Program through FY1985 and "perhaps" FY1986, and that any involvement at

[63] SVU Weekly Project Report, March 5, 1984, in Ibid.
[64] SVU Weekly Project Reports, June 25 and July 2, 1984, in Ibid.

Medicine Bow "would be mutually established by DOE and NASA based on funding to be provided by DOE."[65]

On August 1, acting Reclamation Commissioner Robert Olsen announced that the agency would continue with the wind-hydropower project through September 30, 1986. While Reclamation asked Congress for $350,000 in funding to continue the project through FY1985, it appeared that if this was the only funding, the project could not continue. However, possible additional financing by the DOE's Wind Energy Branch and WAPA would allow operation and testing to continue. "This testing and data collection effort is vital to the overall Federal wind program," Olson noted. In addition, Boeing assured Reclamation they would repair the faulty low speed shaft and install a new lubrication system in the MOD-2 at no cost to the government, in an attempt to get the unit operating at the earliest possible time.[66] By September all major repairs to both units had been completed and, despite minor operation problems, both operated successfully. The WTS-4 and MOD-2 respectively logged 110 and 51 hours of grid sync time during the first three weeks of the month.[67]

In November elated Reclamation officials noted WTS-4 synced successfully to the grid for 82 hours the week of October 27, with the MOD-2 clocking in at a whopping 122 hours of grid sync time, including a continuous 30-hour run—a feat never achieved in the nearly three years since its first rotation. Despite other nuisance problems that resulted in occasional shutdowns, both machines operated consistently through the end of the calendar year.[68] As 1985 approached, Reclamation seemed optimistic that not only were the machines generating energy

[65] Darrell H. Baldwin to William Martin, July 6, 1984, in FRC Group 115, Acc#115-99-927, B2, F113550, FRC-CO.
[66] "Medicine Bow Wind Machines to Continue Operating," Bureau of Reclamation News Release, August 1, 1984, in FRC Group 115, Acc#115-99-9927, B2, F113550, FRC-CO.
[67] SVU Weekly Project Reports, September 10, 17, and 24, 1984, in FRC Group 115, Acc#115-13-100, B3, F1233250, FRC-CO.
[68] SVU Weekly Project Reports, November 5 and 26, and December 3, 10, and 17, 1984, in Ibid.

and recording data, Reclamation, Hamilton Standard, and Boeing were able to deal with small problems to the point that downtimes were minimal. As of January 1985 the WTS-4 had generated 3317mWh of energy in 1,613 hours of grid sync time, while the MOD-2 had generated 1788mWh of energy in 1,302 hours of grid sync time; DOE/BPA reported similar numbers with the three MOD-2 units at their Goodnoe Hills site in Washington.[69]

A Huge Repair Bill

The project's good fortunes, however, proved temporary. Never a model of reliability throughout its short operational life on Wyoming's windy landscape, in January 1985 the MOD-2 came to a permanent halt. Immediately, Reclamation placed it in "lockout" mode (blades locked vertically in place) and took the unit out of service, because Boeing workers discovered cracks not only in the problematic low speed shaft, but also its associated bearing assembly. Lower Missouri Regional Director William Martin commented that repairs would involve the complete teardown of the rotor and nacelle assembly, which could cost upwards of $1 million and all of 1985 to accomplish.[70]

After a February meeting in Denver between Reclamation, Boeing, and NASA officials, Boeing formally presented Reclamation with a $1.5 million repair bill. Boeing offered to contribute approximately half, about $700,000, to repair the disabled MOD-2. These repairs would stretch well into calendar year 1986. Reclamation balked. They reasoned that, if repaired on-time, that would leave only two months for the unit to operate in the wind season. So while Reclamation and other federal participants stood committed to supporting the wind energy program through the end of FY1985, Martin stated "we have concluded that further Federal

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[69] NASA-LeRC, "Operation Summary for Wind Energy Systems, Week Ending January 4, 1985," in FRC Group 115, Acc#115-13-100, B2, F1233240, FRC-CO.
[70] William Martin to Peter Gunderson, President, IRM Inc., January 30, 1985, in FRC Group 115, Acc#115-99-927, B2, F113550, FRC-CO. Gunderson had previously inquired about possibly acquiring the MOD-2 if and when Reclamation decided to dispose of the unit.

investment in this technology is not advisable. We are exploring various options for disposal of this machine."[71] Project Manager William Johnson mentioned that the final decision would occur only after Wyoming's congressional delegation evaluated all options.[72]

Reclamation did not have to wait for this decision. Four days later, the SVU project manager informed the agency that Wyoming's congressional delegation, headed by Senator Alan Simpson, would not support the MOD-2's repairs. As such, Reclamation began drawing up options for disposition of the crippled unit, including one option for the DOE to use it as a spare parts source for their Goodnoe Hills facility. In May Reclamation announced that it had offered the MOD-2 "as is" to the DOE's Wind Energy Technology Division through an administrative transfer. In early June, DOE formally declined acceptance of the crippled turbine as a whole, but remained interested in individual spare parts.[73]

As the MOD-2 stood quiet, the WTS-4 continued to operate, but only intermittently. Like its locked-down sibling, it too suffered from assorted mechanical problems. The difference, however, was that Hamilton Standard helped Reclamation engineers solve these issues, at no cost to the government, as opposed to Boeing presenting a huge repair bill, then offering to pick up less than half of the tab. Nevertheless, the tall WTS-4 seemed to attract occasional lightning strikes, creating damage to operating control electronics, and problems with yaw slip rings, gearbox drains, teeter lock damage, and other nuisance issues—all while the previous-generation Hamilton Standard turbine, a WTS-3 installed in Sweden, continued to perform well with only

[71]William Martin to Senator Malcom Wallop, April 16, 1985, in FRC Group 115, Acc#115-99-927, B2, F113550, FRC-CO.
[72] William Johnson to Robert Gyllenborg, Bureau of Reclamation, April 18, 1985, in FRC Group 115, Acc#115-13-100, B2, F1233244, FRC-CO.
[73] William Martin to Daniel Ancona, DOE, May 7, 1985, in FRC Group 115, Acc#115-99-927, B2, F113559, FRC-CO; William Johnson to Robert Gyllenberg, Bureau of Reclamation, in FRC Group 115, Acc#115-13-100, B2, F1233244, FRC-CO.

minimal downtimes.[74] By December the SVU project manager reported that management of the Medicine Bow project had been formally transferred to Upper Missouri Regional Supervisor of Power Charles Legerski, and that Reclamation was awaiting a decision from the General Services Administration's (GSA) office in Auburn, Washington, regarding the MOD-2's disposal.[75]

The End Draws Near

As 1986 dawned, it was clear that Reclamation's only foray into wind energy generation was nearing its final days. In addition to SERI assuming on-site operational management, the WTS-4 remained out of service due to teeter lock problems and yet another lightning strike frying its electronic components.[76] Even SERI officials acknowledged they could not keep up with repairs to the unit, and deemed inadequate lightning protection and improper grounding posed a serious safety hazard, one that could cause electrocution or serious injury.[77] As Regional Director Martin wrote to DOE Wind/Ocean Technology Director Lynn Rogers, they planned to spend the $350,000 in budgeted FY1986 monies on various task orders to try and bring the WTS-4 back on line. But the tone of Martin's letter indicated the end was imminent. "We are approaching the final phase of the Medicine Bow Wind Turbine Program," Martin wrote.[78]

Despite the fact that some WTS-4 problems had been ironed out, and the machine operated sporadically in spring 1986, the end began to gain momentum in June 1986 when real property appraiser George Page prepared an appraisal report regarding the unit's salvage value

[74] William Johnson to Robert Gyllenberg, Bureau of Reclamation, in FRC Group 115, Acc#115-13-100, B2, F1233244, FRC-CO.
[75] William Johnson to Charles Legerski, Bureau of Reclamation, in Ibid.
[76] "Medicine Bow, Wyoming, Wind Turbine Test Programs and Operation Monthly Report," in FRC Group 115, Acc#115-13-100, B2, F1233241, FRC-CO.
[77] Susan Hock, Wind Energy Research Center, Solar Energy Research Institute, to Charles Legerski, in FRC Group 115, Acc#115-99-927, B2, F113541, FRC-CO.
[78] William Martin to Lynn Rogers, in Ibid.

after FY 1986. Page concluded that if the WTS-4 was dismantled for salvage, the government could expect to pay $1 million to dispose of the unit and its support facilities. "In my view," Page stated, "the likelihood of finding a potential bidder through the GSA procedure is remote." Since Reclamation assumed responsibility of disposing of WTS-4 after the testing period was over, he presented six options for consideration by agency management: 1) disassembly and salvage, by far the most expensive option, 2) outright sale without relocation from site, 3) outright sale with relocation from site, 4) ownership transfer, 5) inactive ownership, or mothball, and 6) continue operations or do nothing.[79]

While all this was going on, retired Reclamation electrical engineer George Young won out on his $50,000 bid to GSA—the only one submitted—to acquire the crippled MOD-2. Young, who worked on the project before his retirement, seemed confident that he could get the problem machine up and running—but only if he could obtain more financing to the tune of $1 million to facilitate repairs. Much of the expense needed in repairing the MOD-2 depended on renting a special crane to hoist heavy components atop its 200-foot-tall tower. "It's no get-rich scheme," he told a *Rocky Mountain News* reporter in March. "I didn't want to see it scrapped, mainly." In September, however, a frustrated Young returned the MOD-2 to the government, citing difficulties in raising funds needed to fix the machine. "I didn't start out on this thing in order to fail on it," Young remarked.[80]

The unit's fate was quick and decisive. In 1987, the Richardson Oil Company of Denver purchased the $4 million MOD-2 from Reclamation for $30,000, and in September, dynamited it

[79] George Page to Arthur Mischke, Chief, Reclamation Lands Branch, in FRC Group 115, Acc#115-13-100, B2, F1233251, FRC-CO.
[80] "Engineer Enjoys Joust With Windmill," *Rocky Mountain News*, March 16, 1986, 62; "Engineer Defeated in Tilt With Windmill," *Rocky Mountain News*, September 22, 1986, 16.

and hauled it away.[81] Speaking on behalf of the people of Medicine Bow, Mayor Gerald Cook remarked that it was "a very sad day … almost like losing a child."[82] While any astute observer over the previous few years could safely insert "problem" in front of "child," one-half of the Medicine Bow Wind Energy Project was officially history. This was not unusual, since the other Boeing MOD-2 turbines, including the DOE/BPA units at Goodnoe Hills, Washington, permanently ceased operations due to mechanical problems and manufacturing defects—cracked low speed shafts were the most widely publicized. "We can be grateful that the company builds better airplanes than wind turbines," Righter quipped.[83]

As far as the other half of the project goes, at 6:14 pm on August 12,1986, after a total to date of 4095 grid-sync hours that generated a total of 8025mWh of power, Hamilton Standard reported a phase-to-ground failure of the WTS-4's generator. An investigation noted that a single, half-inch stud broke loose inside the generator motor, causing mechanical damage to the generator and the WTS-4 to nearly seize up.[84] Due to the reasonable repair estimate by Hamilton Standard, $160,000 exclusive of labor costs, Wyoming Senators Alan Simpson and Malcom Wallop wrote the commissioner of Reclamation to ask the agency to defer the unit's GSA disposal process until January 1987. Both senators believed WTS-4 provided much valuable

[81] Promissory Note, Richardson Oil Company to Bureau of Reclamation re the sale of Boeing MOD-2 turbine, in FRC Group 115, Acc#115-99-927, B2, F113575, FRC-CO; Robert Righter, *Windfall: Wind Energy in America Today* (Norman: University of Oklahoma Press, 2011), 21. Some accounts, including Righter's, and those in local and state newspapers, claim Reclamation sold the MOD-2 for $13,000. The promissory note cited clearly says $30,000, so a possible mispronunciation may have contributed to this mistake, especially if a reporter gathered information over the phone; after all, 13,000 and 30,000 do sound alike.
[82] Medicine Bow Mayor Gerald Cook to U.S. Representative Dick Cheney, in FRC Group 115, Acc#115-99-927, B2, F113553, FRC-CO.
[83] Righter, *Windfall*, 21.
[84] Hamilton Standard to Bureau of Reclamation, September 24, 1986, in FRC Group 115, Acc#115-13-100, B2, F1233241, FRC-CO.

recorded wind energy test data over the course of its more consistent operation, and that it "offers unique research opportunities that should not go unexploited."[85]

In a letter dated November 18, Reclamation's assistant commissioner for Engineering and Research expressed his support for the Simpson/Wallop proposal as "one that would be useful in providing energy under conditions of price escalations or shortages in fossil fuels, as faced in the early 1970s when the … wind energy-hydro generation project at Medicine Bow was conceived." While he supported the unit's repair, he mentioned that, if such an arrangement cannot be finalized "within a reasonable period," Reclamation should complete the unit's disposal through the GSA process.[86]

Ultimately, Reclamation decided to temporarily forgo disposition because the WTS-4's repair bill was reasonable, and that the Wyoming Senate delegation made a convincing case to continue further research—at least for the short term. In July 1987 Reclamation signed a research and development (R&D) agreement with Hamilton Standard to continue using the WTS-4 for testing and data collection. Retroactive to March 1, Reclamation agreed to defer the GSA disposition until October 1, the R&D agreement's expiration date. Reclamation estimated the total costs at $43,364.[87]

What happened in that period is not well documented; the available archival record suffers from a gap in materials. However, a March 18, 1988, request for approval of disposal of the WTS-4 from Reclamation Commissioner C. Dale Duvall to James Ziglar, assistant secretary of Water Science in the Department of the Interior, claimed the unit could not run due to more

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[85] Senators Alan Simpson and Malcom Wallop to Reclamation Commissioner C. Dale Duvall, October 15, 1986, in FRC Group 115, Acc#115-99-927, B2, F113541, FRC-CO.
[86] Reclamation Assistant Commissioner of Engineering and Research (signature illegible) to Reclamation Commissioner C. Dale Duvall, November 18, 1986, in Ibid.
[87] "Cooperative Research and Development Proposal Between the Bureau of Reclamation and United Technologies Corporation Hamilton Standard Division for Continued Research Testing of the WTS-4 Wind Turbine at Medicine Bow, Wyoming", in RG115, Acc#115-11-049, B9, F1157554, NARA-CO.

"extraordinary" repair costs to the tune of $250,000.[88] Additionally, Medicine Bow Mayor Gerald Cook wrote to Wyoming representative Dick Cheney to discuss the unit's disposal. Acknowledging that federal funding for wind energy research had "dried up," Cook pleaded with Cheney to save the WTS-4 from the scrap heap, arguing that it could still be used to provide valuable information, generate power, and attract tourists. He offered alternatives: Reclamation could give it to the town, donate it to UW for research purposes, or someone could purchase, repair, and keep it running. He submitted a signed resolution on behalf of the Town of Medicine Bow, Carbon County, and the state of Wyoming, asking in emotional terms, that the government not "let our memories and pictures of this magnificent giant setting [*sic*] on the wind swept prairies of Wyoming be all that we have left."[89]

New Life for an Old Turbine

It worked. One month later, on April 13, the *Casper Star-Tribune* announced the turbine would stay on-site for five more years. A successful petition drive that garnered 560 signatures from Medicine Bow residents, and town resolutions from Rock River, Saratoga, and Laramie, helped save the turbine from the scrap heap of alternative energy R&D history. The world's largest wind turbine had attained iconic status to local, county, and state residents, and they wanted it to stick around. Reclamation indicated that while they preferred to sell it to another federal agency, this seemed doubtful, and they would consider all purchase offers.[90]

Re-enter the retired, yet determined former Reclamation electrical engineer Bill Young, who wanted to nurse the crippled MOD-2 back to life. After the GSA indicated that no other federal agency cared to acquire the WTS-4, Young purchased the $10 million turbine from

[88] C. Dale Duvall to James Ziglar, March 18, 1988, in FRC Group 115, Acc#115-99-927, B3, F113575, FRC-CO. In this letter, Ziglar approved the unit for disposal.
[89] Medicine Bow Mayor Gerald Cook to U.S. Representative Dick Cheney, in FRC Group 115, Acc#115-99-927, B2, F113553, FRC-CO.
[90] "Petition Drive Saves BuRec Wind Turbine," *Casper Star-Tribune*, April 13, 1988.

Reclamation for $20,000 on January 27, 1989. He then proceeded to pull the five-ton rotor out of the generator, rewound it, spent a year-and-a-half chipping metal fragments from the stator with a hand file, and reassembled the windmill. It was a success; operating as the Medicine Bow Energy Company, the WTS-4 ran for a total of 3500 grid-sync hours from 1992 until January 14, 1994.[91]

Although Reclamation had abandoned all hope of continuing with the project seven years earlier, that January day marks the symbolic—and material—end of the Medicine Bow Wind Energy Project. Operating in a heavy windstorm, the big turbine literally ripped apart when the blade pitch control failed, and one blade smashed into the tower. Hearing a loud WHUMP sound, Young looked up from his desk "to see a 35-foot blade tip tear loose and fly 400 feet high and 600 feet downwind," he recalled. "The teeter lock, weighing about a ton, tore loose and smashed into an outhouse beneath the tower. Luckily, it wasn't occupied." The next day, 60mph winds tore the four-ton nacelle platform off the tower, sending it crashing to the ground, along with hundreds of gallons of hydraulic fluid.[92] It was the final death-knell. The Hamilton Standard WTS-4, one-half of Reclamation's initial and only attempts at large-scale wind energy research and development, the machine that had attained iconic status in the area, stood tall and broken in its own pile of debris and a blackened pool of expended hydraulic fluid.

Conclusion: A Technological Failure

At first glance, it would seem that Reclamation's Medicine Bow Wind Energy Project was a huge, expensive disappointment. In a way, it was. After all, Reclamation and the DOE invested tens of millions of dollars into two unproven machines plagued with numerous electrical and

[91] Eric Herrman, "Wind Energy: the End of the World's Largest Windmill," *Mother Earth News*, June/July 1996, at http://www.motherearthnews.com/renewable-energy/wind-energy-zmaz96jjzgoe.aspx. Accessed October 21, 2013.
[92] Ibid; Righter, *Windfall*, 21.

mechanical issues, only to eventually sell them off for pennies on the dollar. Yet when viewed in the context of the project's origins—as well as other research and development ventures into alternative energy of the era—it is understandable why this was done. Safety concerns that fueled widespread grassroots backlash against the postwar nuclear energy juggernaut, coupled with and further complicated by the Arab Oil Embargo, forced federal agencies to reevaluate and pursue R&D into alternative energy means.

When Reclamation conceived of and established the Medicine Bow site, they were thinking of, and functioning within, the context of this pursuit. Drawing upon the ideas of one of their former assistant commissioners—and something Swedish engineers had successfully implemented—the theory of using wind power to tie into hydroelectric facilities seemed sound. Winds were highest in the winter months, when reservoirs were at their lowest, so wind-generated electricity could supply reserve power. Therefore, Reclamation would not have to further lower depleted winter reservoir levels by releasing water through hydroelectric plants to meet power demands.

What Reclamation (and DOE) did not fully understand, however, was the economy of scale, that large (1mW or more of output) wind turbine technology was still in its infancy, and not up to the cost-and-benefit task of dependably delivering supplemental electricity to its powerplants. Never a technology to rate millions of dollars in R&D in the decades preceding the 1970s, the large turbines of that era were unreliable machines prone to mechanical failures and electrical issues. DOE freely handed out millions of dollars to major manufacturers like Alcoa, Boeing, United Technologies, and Westinghouse to design, build, and maintain large wind machines that were not up to the economy of scale-geared task of dependable operations in relation to costs expended. When these giants were idle, it created the negative image in the public eye that wind energy research was a folly, a huge waste of taxpayer dollars. Size seemed to be a factor, however, for although not much was found about Reclamation's diminutive 25kW Jay Carter turbine at the Weber Basin Job Corps Center in Utah, available reports show that small WECS operated very well over time.

Think small was the approach European wind energy R&D took: design and build smaller, heavier-duty, more sophisticated wind machines that worked. With the Danes at the forefront, one technological advance they introduced was the three-blade rotor, which produced much less vibration—and less resulting wear on other attached components—than the two-blade designs used at Medicine Bow and other DOE wind sites. In the 1990s these second-generation turbines, all less than 1mW in output, became the norm. Danish companies like Micon, Vestas, Bonus, Nordtank, Darwin, and Wincon contributed to the plethora of small-scale wind machines erected at windy southern and central California passes like San Gorgonio near Palm Springs, Tehachapi north of Los Angeles, and Altamont near San Jose. Japanese manufacturers like Mitsubishi, and American manufacturers like GE Energy, also drew upon three-blade Danish technology to design, install, and maintain wind machines across America (Boeing and Hamilton Standard withdrew from wind machine production after the 1980s). As such, wind power technology and production evolved to where, as an electrical engineer wrote, "capital costs have plummeted, reliability has improved, and efficiency has dramatically increased, resulting in a robust commercial market product that is competitive with conventional power generation."[93]

Once this perfected technology resulted in manageable economies of scale, this created a snowball effect. By the 2000s, wind energy became widespread across America, including every western state served by Reclamation except Nevada. From 1997 to 2012, America's total

[93] Robert Thresher, Michael Robinson, and Paul Veers, "To Capture the Wind: The Status and Future of Wind Energy Technology," *IEEE Power and Energy Magazine,* 5 (November/December 2007): 46.

electrical output from wind energy increased from 1,673mW generated in 1997, to 60,707mW generated in 2012, a 3,628 percent increase in fifteen years.[94]

Predictably, perpetually-windy Wyoming benefitted from this expansion. By 2010 public non-profit utilities had erected several wind farms in the state's southern reaches, including sites near Evanston, Glenrock, Rawlins, Francis Warren Air Force Base near Cheyenne, and the first site ever chosen for wind studies in the state: Medicine Bow. Operated by the non-profit Platte River Power Authority (PRPA), the Medicine Bow Wind Project began operations in spring 1998 as the first Wyoming wind generation facility to provide service to Colorado customers, specifically Estes Park, Fort Collins, Longmont and Loveland. Currently, two 600kW and seven 660kW Vestas V-47 wind turbines generate energy on-site with a net capacity of 6mW.[95] A picture of perfected technology, these Danish 3-blade high-tech turbines provide almost the same output as the two experimental machines initially installed on-site—and do so with consistency and reliability. Furthermore, in 2008 Vestas began blade and nacelle manufacturing operations in Windsor and Brighton, Colorado, to provide closer logistic and technical support to Wyoming and other American wind farms that use their turbines.[96]

In retrospect, Reclamation's brief venture into wind power generation was not the epic failure it appears. The exhaustive wind and siting data, NEPA analyses, and public involvement studies conducted to create the first Medicine Bow Wind Energy Project—and all the data the agency gathered during the project's short duration—are prologue to the PRPA's current success. Furthermore, the nascent wind technology of the post-nuclear power craze was not up to the task, and presented Reclamation (and DOE) with a major lesson in economy of scale.

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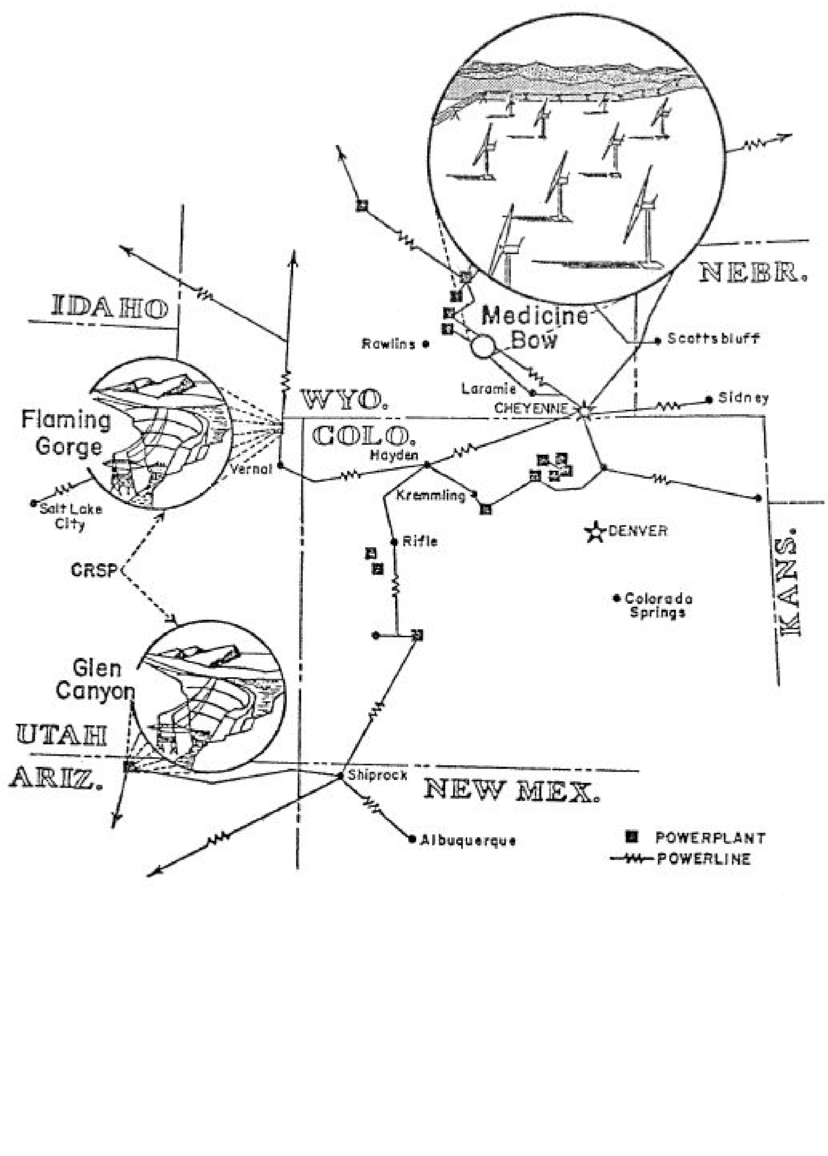
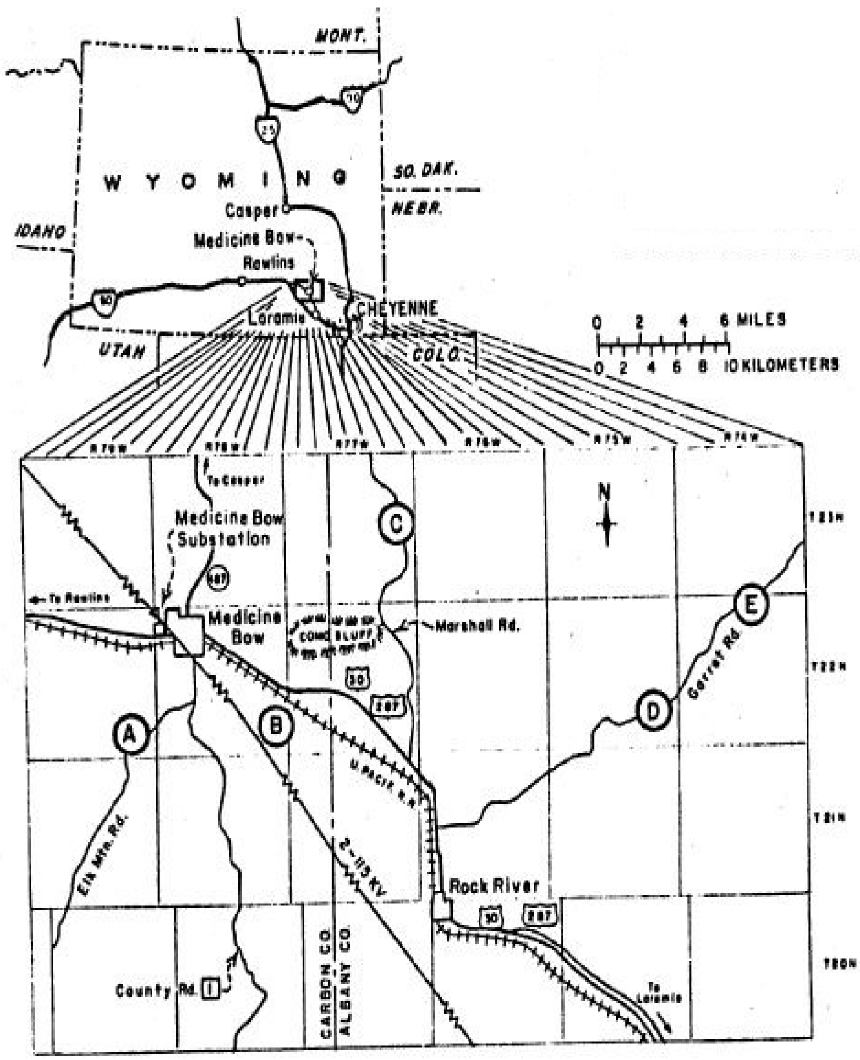
[94] Wind Energy Data, United States, located at http://www.thewindpower.net/country_en_4_usa.php. Accessed November 27, 2013.
[95] Platte River Power Authority Fact Sheet, located at http://www.prpa.org/sources/wind-energy/. Accessed December 3, 2013.
[96] Information on Vestas at http://en.wikipedia.org/wiki/Vestas. Accessed January 7, 2014.

Reclamation cannot be faulted for this. Caught up in the alternative energy frenzy, they were not prepared to deal with keeping untested machines on-line, nor were the companies that built these machines prepared to keep them consistently operational. Thus, Reclamation's Medicine Bow Wind Energy Project was not so much the agency's failure, as it was untested technology that failed the agency.

APPENDIX 1

WIND/HYDROELECTRIC ENERGY
INTEGRATION CONCEPT





Study area showing locations of the five anemometer towers designated A, B, C, D and E.

Map 1

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