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**ALTERNATIVE OR TRADITIONAL?
A HISTORY OF SOLAR AND WIND ENERGY**

by

Nathan S. McConnell

B.A. University of New Mexico, 1993

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presented in partial fulfillment of the requirements

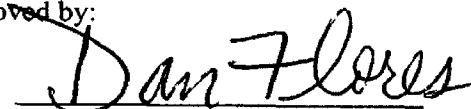
for the degree of

Master of Arts

The University of Montana

May 2004

Approved by:



Dr. Dan Flores, Chair



Dean, Graduate School

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Abstract

McConnell, Nathan S. M.A., May 2004 History

Alternative or Traditional? A History of Solar and Wind Energy

Advisor/Director: Dan Flores (DF)

As the title suggests, "Alternative or Traditional?" investigates two energy resources regarded by contemporary society as belonging to the future. During the energy crises of the 1970s, many energy experts and policymakers expressed interest in solar and wind technologies, some in the United States even promised that the nation would inevitably turn to these resources. We still may. My interest in what we now refer to as alternative energy began with a successful revenue bond initiative that occurred in November 2001. The VoteSolar Initiative helped formulate Proposition B and put the measure on the ballot in San Francisco. Designed to raise one hundred million dollars to fund solar, wind, and energy conservation improvements on city-owned buildings, the initiative passed easily. From a modern perspective, it seemed as though the promise of renewable energy technologies had finally met with success. As I groped around for a thesis topic that would hold my interest, I decided to investigate the two resources that most appealed to voters, solar and wind energy. I was surprised by the findings. Solar and wind energy have a long and inadequately publicized history with humanity. This thesis attempts to alleviate this dearth of knowledge by encapsulating passive solar, active solar, and wind energy within the context of major social energy transitions. In the first chapter, I set out the energy transition stories of ancient China, early modern Britain, and the industrial United States. The next three chapters trace the long history of passive solar, active solar, and wind energy technologies, and the final chapter analyzes recent trends in the US. Two major arguments hold the work together. Solar and wind energy have long held the interest of human societies, and the world will someday run out of fossil fuels. As the US has the ability to alter its energy policy, solar and wind energy remain plausible choices for the future.

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Introduction



(H)istorians must turn away from John Muir and Aldo Leopold and look more closely at E. F. Schumacher, Amory Lovins, Murray Bookchin, Stewart Brand, and the generation of environmentalists who struggled to craft an environmental philosophy that recognized humans “were gods, and might as well get good at it.”¹

This thesis began has its genesis in challenge. Groping around for a suitable line of inquiry early in my second semester of graduate work, I had still not found a topic. Several areas piqued my interest, yet I could not find a subject that promised to hold my attention enough to produce an acceptable work, especially my first as a historian. I needed a challenge, and, thankfully, I had an advisor who implicitly understood the nature of graduate school, which is to find areas of interest that can hold a person’s attention well after graduate work is finished. Better still, my advisor assigned an article that struck me as particularly interesting. Andrew Kirk’s “Appropriating Technology” argues that modern environmentalism has its roots in a philosophy less familiar with the American naturalist ethos espoused by John Muir and Aldo Leopold and more in common with appropriate technology advocates like Amory Lovins and E. F. Schumacher.²

Kirk implicitly challenges environmental historians to bridge the gap between the overwrought antimodernist hero worship and the silence that plagues modern countercultural techies. I accept Kirk’s call, if in my own way. This

¹ Kirk, “Appropriating Technology,” 376.

thesis explores global energy transitions, solar and wind technological development, and the modern union of technology and policy in the United States. While other historians have analyzed resource consumption and environmental change generally, none has explained the longue duree view of energy transitions and alternative energy technologies within the context of modern environmental politics. This thesis explores the changing nature of solar and wind energy technology from their beginnings to applications in the early twenty-first century. While the resources themselves have not changed in the two millennia covered here, the ways that humans have harnessed the energy sources has adapted considerably, and this metamorphosis came largely due to shifting governmental policies.

If any society ever adopts solar and wind energy as primary sources, it must first experience an energy transition. Abandoning familiar resources can be a difficult task, yet countless societies have adapted their energy consumption patterns. This thesis begins with an overview of three energy transition experiences that implicitly suggests the enduring character of solar and wind energy. Ancient China, early modern Great Britain, and the industrial United States all made dramatic shifts in their energy resources. The changes all include three common characteristics. First each society had an economic system in place that allowed a change to occur without upsetting government's role as provider and protector. Next all three nations had the ability to adapt their technological expertise to the demands of new energy resources. Finally, each country had

² Kirk, "Appropriating Technology," 376.

political institutions in place that could balance the need for new energy sources with the demands of social stability.

The following three chapters explore specific alternative energy technologies. Passive solar technology refers to the ways that humanity uses the sun's energy for domestic heating and cooling. Beginning with architectural designs, humanity has devised a plethora of ways to harness sunlight. Within a modern context, passive solar technology's chief benefit is energy conservation. Next I explain how humanity struck upon the idea of converting sunshine into electricity. Photovoltaics represent a pinnacle for solar energy development and an alluring technology in the modern era. Finally, I analyze wind energy. Societies across the globe have long held wind in high regard due to its constant nature, but wind technology has changed dramatically since its earliest applications. Today, wind energy has the ability to contribute significantly to modern energy production.

I conclude this thesis by analyzing the union between solar and wind technology and modern environmental politics. After a brief overview of American energy policy since the 1970s, I examine the causes of the 2000-2001 California electricity crisis. One important effect of the shortages came in San Francisco during the November 2001 election, when the nonprofit group, VoteSolar, crafted a revenue bond for public scrutiny. By portraying solar and wind energy as antidotes to the constant problems that faced Bay Area residents, VoteSolar and other advocacy groups convinced nearly three-quarters of San Francisco voters to approve a \$100 million project that would retrofit city-owned

buildings with passive solar energy saving measures, purchase electricity generated by wind turbines, and, most significantly, install photovoltaic solar panels on city-owned rooftops.

VoteSolar's efforts have had a positive impact on national energy policy. Several states have adopted rigorous renewable energy portfolio standards (RPS) and other localities have promised to install solar- and wind-friendly measures. I conclude my thesis by considering whether the promises made by the United States government after the 1973 OPEC oil embargo finally have merit. During the seventies, particularly during the Carter Administration, the federal government undertook major efforts to demonstrate solar and wind energy technologies to citizens across the nation, yet by the end of Reagan's first term in office, it was clear to most alternative energy advocates that pro-solar policies had no friends in the White House. The solar and wind industries managed to adapt, much as the technologies changed throughout their histories, so that by the early twenty-first century, people could realistically depend on the sun and wind for power.

Chapter 1



From Ox Mountain to OPEC: Energy Transitions in World History

Energy Policy Redux

It took nature over 500 million years to store in the ground these stockpiles of 'fossil fuels' which civilization is now consuming in a flash of geologic time.

President's Materials Policy Commission, 1952

For Americans living through it, the 1973 oil embargo was a monumental occasion. The Arabian contingent of the Oil Producing and Exporting Countries (OPEC) made good on its promise to cut petroleum production, an act with serious consequences for the United States. Long lines at gas stations, exorbitant home heating costs, and an uneasy dependence on foreign resources all forced Americans to consider the sources of their energy. The consequences of unchecked energy consumption had already caused the US to pass a number of environmentally protective regulations.¹ The 1970s also saw citizen movements like E.F. Schumacher's "appropriate technology" and Amory Lovins' "soft energy path" that alerted people to the possibilities of alternatives.² In the 1970s, the United States seemed on the verge of changing how it got its energy.

As with other movements in the United States, the pressure to shift energy policy had historical precedent. Policy scholars had concerns about energy supply since the immediate post-World War II era, when tight resources threatened economic growth,

¹ Three prominent ones, the National Environmental Policy Act of 1969 (NEPA), 42 USC 4321 et seq., the Clean Air Act of 1970 (CAA), 42 USC 7401 et seq., and the Clean Water Act of 1972 (CWA), 33 USC 1251 et seq., all became law well before the OPEC embargo of 1973.

² See Andrew Kirk, "Appropriating Technology: The *Whole Earth Catalog* and Counterculture Environmental Politics," *Environmental History* (6:3, July 2001), 374-94.

itself closely linked to expanding energy use. In late 1951, with the pressures of the Korean conflict stressing domestic energy supplies, President Harry S. Truman commissioned an executive study to propose a comprehensive overhaul of national energy policy. The President's Materials Policy Commission, better known as the Paley Commission after chairman William S. Paley, considered the hodge-podge, pragmatic policies of the past, analyzed policy options, and suggested alternatives. Foreshadowing the problems that would arise some twenty years later, the report portended that "the time will come...and perhaps well beyond 1975, when civilization's energy needs will outrun nature's declining store of fossil fuels available for economic use." Rather than wait for depletion, the report recommended that the government find ways "to harness economically such unconventional resources as solar and atomic energy."³

Flash forward twenty years to the Nixon administration. The United States had grown woefully dependent on foreign, particularly Middle Eastern, sources of oil for use in everything from gas-guzzling "muscle" cars to electricity-producing power plants. Even before the devastating OPEC oil embargo in autumn of 1973, President Nixon addressed some problems of depending on the global market. In late June of that year, Nixon announced "Project Independence," which called on the United States to "meet America's own energy needs from America's own energy resources" by the end of the decade.⁴ Perhaps unwittingly, Nixon echoed the sentiments of the Paley Commission, which warned that "the Free World...cannot be allowed to become over dependent (sic)

³ President's Materials Policy Commission, volume 1, *Resources for Freedom: Foundations for Growth and Security* (Washington DC: Government Printing Office, 1952), 104, 106, quoted in Craufurd D. Goodwin, ed., *Energy Policy in Perspective: Today's Problems, Yesterday's Solutions* (Washington, DC: The Brookings Institution, 1981), 53-4.

⁴ *Executive Energy Documents*, printed at the request of Henry M. Jackson, Chair, Committee on Energy and Natural Resources (Washington, DC: US Government Printing Office, July 1978), 86.

on Middle East oil....”⁵ In other words, insightful policy wonks foresaw trouble ahead, yet American leaders failed to take action.

Like the US in the 1970s, many societies have had difficulty adjusting to resource scarcity. In terms of human energy use, a pattern emerges in which a society finds a valuable resource, uses it until it is gone, then struggles to find suitable replacements. This chapter analyzes two such situations, in ancient China and in early modern Great Britain. In certain rare occasions, societies have changed their energy resources before having depleted previously valuable ones. I cover one such occasion here, the industrial United States. Rather than run out of resources, as happened in China and Britain, the industrial United States embraced the paradigm shift because of the nation’s abundance. These three historical instances reveal the factors that influence major societies’ energy resource transitions. While other historians have studied particular resource consumption and change generally, none has considered the historical role of energy transitions within the context of solar and wind energy resources.

Ancient China, early modern Great Britain, and industrial America all exhibited three indispensable characteristics. First, all the nations had an economic system that could adapt to a new energy resource. Next, each society demonstrated technological adroitness; and finally, all of them had the political institutions in place that made change possible. For nations that have undergone energy transitions, or major changes in the resource(s) upon which a society primarily depends, those societies must possess some combination of economic openness, technological expertise, and political responsiveness.

The emergence of the Paley Commission in the 1950s, and later Project Independence in the early 1970s, indicate that policymakers can anticipate the need to

⁵ Goodwin, quoting *Resources for Freedom*, in *Energy Policy*, 55.

change energy resources. Each also indicates that the US will continue to change its pattern of energy production and consumption. America's dependence on fossil fuels, particularly petroleum, has placed the nation in a precarious situation, particularly in the context of historical energy transitions. The 1970s represent a time in which the United States confronted energy shortages nationwide for the first time. I include the period during and after the 1973 OPEC oil embargo to illustrate a premise central to my thesis: in the early twenty-first century, the United States appears on the brink of changing the energy resources it uses.

The American reaction to the 1970s energy crisis indicates what direction the country might take when (and if) the need to choose a new energy path arises. Although I discuss the technological and resource possibilities in greater detail in subsequent chapters, the US response to the crisis years of the seventies provides necessary background for discussion of more recent developments, which indicate that American economics, technology, and policy can support a major shift in the nation's energy resources. Whichever direction the US ultimately chooses, the examples from ancient China, early modern Britain, and the industrializing United States all make clear that American society will change dramatically from its experience with energy transition.⁶

Ancient China

There was a time when the trees were luxuriant on Ox Mountain. As it is on the outskirts of a great metropolis, the trees are constantly lopped by axes. Is it any wonder that they are no longer fine?... A man's letting go of his true heart is like the case of the trees and the axes. When the trees are lopped day after day, is it any wonder that they are no longer fine?

⁶ I recognize the possibility that technology may allow us to continue burning fossil fuels at current levels, but I set this potential reality aside for the moment.

Mencius, fourth century BC

China's energy situation did not much improve between the time Mencius opined at the diminishing forests of Ox Mountain and the nation's first political unification a century later. Timber played an important role in the development of Chinese civilization, and the depletion of the resource forced the nation to adapt. Nature offered several potential options, but the two with the most to offer were coal and water. Weighing the merits of each resource, Chinese leadership opted to encourage what historian Karl Wittfogel described as a "hydraulic society," one based on irrigation and farming.⁷

At the time of China's first political unification, in 221 BCE, policymakers ruled over the most technologically advanced nation on the planet. Most societies depended on timber for fuel in the years before the common era, yet Chinese engineers developed iron and steel tools centuries before others did. Such expertise gave Chinese farmers an advantage over their contemporaries in other parts of the world, and after political leadership became a relative constant in the early common era, a pattern emerged in China that others would repeat later: tools forged with the high temperatures of charcoal, a wood product, helped farmers clear fields of trees; the act also produced fuel for metalworkers to ply their trade. In tandem, the process created an unsustainable pattern that would eventually force Chinese leaders to adapt to new energy sources.

The struggle to turn forests into farmland shows but one side of the multi-dimensional relationship between China's people and natural resources. Resource depletion proved a constant problem in East Asia, and throughout its early development,

China coped with shortages by applying technological solutions. By turning to an abundant natural resource, coal, China's northern region helped stem the tide of deforestation, while laying the groundwork for future technological developments. Ultimately, Chinese policies dealt with an agricultural economy that steered the nation away from industrial innovation.

Political stability gave China an essential advantage in the nation's ability to develop technology and to adapt to resource scarcity. China's political story begins with the nation's first unification in the third century, BC. In 221 BC, Qin Shi Huangdi managed to consolidate the vast lands of eastern Asia into a single political entity. China's founding marks the beginning of a successful and enduring national tradition, and the advent of a relatively stable political structure allowed technological advances that influenced much of the world. Although Chinese metalworkers preferred to use charcoal to power their furnaces, coal became an important fuel, particularly in the timber-starved northern provinces. Coal's higher temperatures allowed smelting techniques that could produce sturdier farming implements and stronger weaponry. Qin's achievement created a centralized bureaucracy that attempted to merge the needs of a growing population with China's already legendary technological reputation, and despite numerous political crises, the Chinese government continued to encourage innovation into the fourteenth century AD.

Agriculture lay at the heart of Chinese unification. A massive increase in population meant that farmers endured increasing pressure to expand into forested areas. Agricultural and domestic needs formed the root causes of massive deforestation inflicted

⁷ Donald Worster, *Rivers of Empire: Water, Aridity, and the Growth of the American West* (New York: Pantheon Books, 1985), 27-8.

on the Chinese landscape. Timber proved a functional barrier to expansion because after clearing tress to develop farmland, wood provided structural support for homes, fuel to heat them, and the charcoal to smelter farming implements. Wood thus marked a barrier and a catalyst for change, and the resource helped meet the needs of an expanding population. Arthur Cotterell estimates that Chinese population reached fifty-eight million by 23 AD.⁸ Clive Ponting figures that China's population remained stable, around fifty million, by 200 AD, while European numbers stood at around thirty-five million.⁹ The rising population meant that timber became increasingly valuable, which provided the backdrop for technological innovation.

In China, the swelling population encroached on forested landscapes. While timber and its by-product, charcoal, remained highly prized for metal workers, coal provided metallurgists with the opportunity to create vastly improved products. Jean-Claude Debeir estimates that the lack of wood in the loess, or steppe, regions of northern China helped spur the early use of coal there.¹⁰ Forges produced cast iron tools by 500 BC, and Chinese metalworkers produced steel through various practices. Valclav Smils identifies two ways in which early steel makers could ply their trade: by carburizing wrought iron or decarburating cast iron.¹¹ The fusing process mastered by Chinese metallurgists bears a striking resemblance to the Siemens-Martin technique, a steel-

⁸ Arthur Cotterell, *China: A Cultural History*, (New York: Meridian, 1988), 112.

⁹ Clive Ponting, *A Green History of the World: The Environment and the Collapse of Great Civilizations* (New York: Penguin Books, 1991), 92.

¹⁰ Jean-Claude Debeir, Jean-Paul Deleage, and Daniel Hemery, *In the Servitude of Power: Energy and Civilization Through the Ages* (London: Zed Books, 1991), 55.

¹¹ Valclav Smils, *Energy in World History* (Boulder and London: Westview Press, 1994), 151-2.

Carburizing means prolonged heating of wrought iron so that carbon gradually diffuses inwardly; decarburization requires the smelter to stir molten cast iron to expel carbon. See also, Debeir, et al, *In the Servitude of Power*, 55.

making method introduced in the U.S. in 1868, although no direct link exists between them.¹²

The Chinese people developed a system for creating technologies that most found difficult to change. Metalworking innovations led to better farming implements, which helped accelerate deforestation. Chinese agriculture spread thanks to sturdier, more efficient tools fired in coal furnaces. The moldboard plow, made with coal's high heat, greatly reduced the amount of energy required from a farmer who previously tilled the soil with hand implements. Yet even with the growth of fossil-born technology, Chinese society expressed a reluctance to change. While anthracite coal allowed engineers to create cast iron, and to a far less extent steel production, Chinese metalworkers preferred to work with charcoal-powered furnaces. Jean-Claude Debeir assigns three factors to the transition from a wood-based to a coal-fueled one: fuel requirements of the burgeoning population; metalworking products for farmers and soldiers; and the massive deforestation of Chinese timberlands.¹³ The shift from trees to fossils in East Asia bears a resemblance to transitions that occur in other places where energy sources change.

China's shift from wood to coal was neither complete nor permanent. Chinese smelting continued to rely on coal, but mechanical applications never fully caught on. Although metal workers used water mills to drive hammers and bellows, an advance made in China by the first century AD, hydraulic machines having metalworking value tended to lose out to the use of water for agricultural concerns. Continued population growth meant that political leaders had to make a decision regarding the direction of Chinese innovation. Agricultural production remained at the heart of policy, and the

¹² Martin V. Melosi, *Coping with Abundance: Energy and Environment in Industrial America*, (New York: Alfred A. Knopf, 1985), 31.

mechanical developments centering on waterwheels lost out to irrigation concerns. Just as centralized bureaucracy aided in the specialization of coal in the northern provinces, made most apparent by the Grand Canal's construction, the national government called for concentrated efforts toward rice cultivation. The water-powered mills that cropped up throughout Europe in the early Middle Ages stemmed from the need to grind wheat for bread, but East Asians relied on rice, whose processing doesn't require milling. The political decision to dismantle water mills seemed eminently practical considering the effective applications metalworkers made with coal. By the eighth century, Chinese authorities banned waterwheel construction, and in 778 AD the government dismantled eighty mills.¹⁴ While timber depletion allowed certain technological innovations, a continued reliance on an agricultural economy helped prevent a complete energy resource transition.

The shift in Chinese energy use lies in its overall effects. Smelting operations continued to use coal well into the modern era; at the same time agricultural demands stunted a shift to a full-blown fossil-powered society. Rice grew easily in Chinese fields, and developments in wet farming based in the south spread northward. Waterways that had the potential to spur mechanized advances became more important as irrigation and transportation avenues. Chinese dependence on and overconsumption of wood meant recurring timber shortages; coal became indispensable as a source for domestic, for heating and cooking, and manufacturing, for smelting applications. Chinese energy transition was more merger than linear: instead of moving from wood to coal, China's resources formed a partnership. This cooperative effort was not unique, but its utility

¹³ Debeir, *In the Servitude of Power*, 51-6.

¹⁴ *Ibid.*, 58.

helps explain why no industrial revolution occurred in China. Climate and geography also played major roles; the need to use naturally flowing water for irrigation in a semi-arid landscape subverted potential development of hydraulic machinery. Such was not the problem in Great Britain.

Early Modern Great Britain

Even now the devastation is begun,
 And half the business of destruction done;
 Even now, methinks, as pondering here I stand,
 I see the rural Virtues leave the land.

Oliver Goldsmith, "The Deserted Village," 1766

The "Virtues" that English poet Oliver Goldsmith refers to in "The Deserted Village" clearly represent the values lost during the shift from an agrarian economy to an industrial one. From the Glorious Revolution in 1688 until Napoleon's defeat at Waterloo in 1815, British society transformed from an agrarian nation into one based on the open market. This early modern period included Goldsmith's empty village, itself a byproduct of Britain's industrialization. The agricultural system that had helped Britain endure the calamitous Middle Ages included the commons, land held by farming tenants in common ownership that was used primarily for raising crops. Parliament's efforts to "close," or privatize, the publicly-owned fields signals the need for workers in crowded, dirty factory towns that became vital to Great Britain's emergence as a leader in the global market economy of the nineteenth century.

The technology that spurred the Industrial Revolution, the shift from a muscle- and water-based energy sources to a system based on steam power and fossil fuels, stemmed from factors also seen in ancient China. In both China and Britain, technology

had an impact on resource depletion. British engineers mastered the steam engine, which pushed the demand for timber fuel beyond sustainable levels. Economically, Great Britain had to deal with the problems of an agricultural system that functioned within a growing capitalistic economy. Yet unlike their Asian predecessors whose geography forced the government to construct massive public works for agricultural reasons, Britain's fertile land allowed leaders to encourage the nation's traditional affinity for the open market. Despite the different paths that each nation chose, the same three factors – technology, economics, and policy – all had a profound influence on resolving the direction of energy transition.

Agriculture was the driving force behind Britain's technological innovation. Even before the early modern era, machines dotted the British landscape. As with their continental counterparts, British farmers raised grains that required processing beyond harvesting. To produce an edible form of wheat, for example, farmworkers needed to grind the grain into a powder form (flour), a time-consuming task. European farmers had long known the advantages of using milling technology, which used muscle or water, and in a few rare occasions, wind energy, as a fuel.¹⁵ Such machines increased in complexity with time, and people eventually adapted mechanical concepts to other sectors of society. Although British machines had a role in displacing farmer peasants, technology also provided an outlet: by the eighteenth century, several industries (most prominently textiles and transportation) adapted mechanical energy into an efficient, powerful steam-powered idea that could be run by people.¹⁶

¹⁵ Smils, *Energy in World History*, 66-9.

¹⁶ *Ibid.*, 161.

Agriculture influenced British technology by encouraging farmers to create better implements, as well. By the eighteenth century, metalworkers produced iron tools that could clear forests and others that could plow fields. Metallurgists faced a barrier to developing iron implements, though, and the problem centered on the high temperatures needed to work with iron. Charcoal was a reliable fuel, but the demand for timber eventually overtook Britain's supply. Blacksmiths learned that coal produced enough heat to work with iron, and forges across Britain began working with the fossil fuel to create sturdy implements.

In itself, using coal as a fuel was not significant. As noted above, ancient Chinese workers used coal centuries prior to British blacksmiths. Yet the demand for coal triggered two developments important to Britain's technological development. First, metallurgists began to experiment with metals at coal's high temperatures, which resulted in sturdier products.¹⁷ More importantly, coal offered an alternative to the rapidly diminishing timber that resulted from the rapid population growth after the Black Death. While Britain suffered plagues as late as 1665, when a major outbreak occurred in London, the nation's population began to grow after 1500.¹⁸ As the number of people increased, so did the pressure on natural resources, and the demand on timber and food spurred geographic expansion. Forests succumbed to farmland, and eventually Britain experienced severe wood shortages. Coal-based technology relieved some of the pressure on timber demand by offering a reliable, and in some cases superior, alternative to charcoal. Another solution was the literal expansion of Great Britain's economic system.

¹⁷ P.J. Marshall, ed., *The Oxford History of the British Empire, Volume II: The Eighteenth Century* (Oxford: Oxford University Press, 1998), 59.

Britain's agricultural system set the foundation for unprecedented economic expansion. By the eighteenth century, fertile fields and advanced technology reduced the need for farm labor, and a rising textile industry soon emerged to absorb those workers that once occupied the commons.¹⁹ Manufacturing grew in economic importance throughout the early modern period, and by the nineteenth century, steam-powered factories concentrated in several British cities.

Merchants seized the advantage by developing a complex system of commerce and credit that led to empire. After the government halted its strict oversight of private enterprise, publicly-backed corporations reorganized into more venturesome private associations. British historian Patrick O'Brien argues that the British merchant class became the driving force of the nation's economy.²⁰ Daring ventures and huge returns on investments created wealth unparalleled in Europe, as British merchants built the complicated system of credit that formed the roots of modern lending rules and institutions. Credit also played a vital role for private business and public activities alike. British armies saw action throughout the eighteenth century, most of it financed with public debt.²¹ Mercantile confidence in lending stayed high due to the government's faithful repayments, even though they came at taxpayer expense.

Throughout Britain's meteoric rise to global empire, government policy alternated between laissez-faire and protectionist principles. As the political system grew more open to the rising merchant class in the eighteenth century, regulations on internal production remained lax. Labor remained cheap thanks to a system that offered few

¹⁸ Ponting, *A Green History*, 92, 229.

¹⁹ Marshall, *The Oxford History of the British Empire*, 56.

²⁰ *Ibid.*, 60.

protections for those at the bottom of the economic pyramid. Parliament's hands-off approach also applied to the commons. Between 1750 and 1810, twenty percent of the total acreage in England and Wales fell under private enclosure acts, wherein individuals took legal actions to exert ownership rights.²² Historian Paul Langford argues that the "flexible farming" inherent in private ownership dispensed with the need to use arable land for subsistence, opening it for profitable crops.²³ Although the enclosure movement affected much of British society, the process existed solely in the private realm.

The most important public act of the early modern era reflected the will of a powerful merchant class. In 1660, Parliament passed the first of several Navigation Acts that strictly controlled trade among the colonies to the benefit of existing businesses and nascent ventures. Not only did the law require all colonial trade from Europe to pass through Britain, which kept capital inside the nation while effectively taxing imports, all such transportation had to use British or colonial ships.²⁴ Such policies allowed British merchants both an incentive to extract natural resources from colonies, since taxes on shipbuilding items like New England white pine trees stayed low, as well as providing new markets for British-made goods, particularly textiles.²⁵

Despite the complexities of British technology, economics, and policy, the transition to coal was vital to Britain's empire. When forests disappeared, room opened for vital arable land, even though Britain lost a vital energy resource. Coal provided a suitable alternative. Even before the beginning of the early modern era, Britons burned coal as heat for food and comfort.

²¹ *Ibid.*, 64. O'Brien notes that Britain had a debt "more than twice the national income...astonishing even by the standards of profligate borrowing displayed by many governments of the late twentieth century."

²² Paul Langford, *A Polite and Commercial People: England 1727-1783* (Oxford: Oxford University Press, 1989), 435.

²³ *Ibid.*, 436. Langford offers no opinion as to whether this represents the roots of mono-crop farming, but the parallels seem apparent.

²⁴ Marshall, *British Empire*, 10-1.

Industry used coal to make everything from beer to glass, and everyone from shippers to builders tapped into coal's strength. Coal even acted as a nursery for Britain's sailors who navigated coal-bearing ships alongside coastlines, on rivers, and through canals to deliver the resource from its mining origins to urban and manufacturing centers in London, Bristol, and Manchester. Such experience proved vital during times of war. According to Patrick O'Brien, coal was at least as important as agriculture, for the fuel spurred population, urbanization, trade, and industrialization - all of which would have a vital impact on the American colonies.²⁶

Industrial United States

The vast forests of the United States and Canada cannot long resist the improvident habits of the backwoodsman and the increased demand for lumber.

George Perkins Marsh, *Man and Nature* (1864)

By the middle of the nineteenth century, George Perkins Marsh noticed a disturbing trend in his country. Americans pushed their forests to the brink of extinction due to an insatiable demand for timber. At issue for conservationists was whether the country could adapt to dwindling supplies by replacing timber with some other resource. Marsh proposed two solutions that reflect both the idealism and pragmatism of the young nation. Marsh thought that Americans needed to develop "enlightened self-interest," the vague notion that resources should be used only when society deemed them necessary. Marsh also called for industry to find alternatives, reasoning that "a crisis will become

²⁵ Ibid., 78-80.

²⁶ Ibid., 59.

terrible unless the discovery of . . . pit coal or anthracite” emerged.²⁷ True to Marsh’s vision, the United States expanded its resource base to include coal. In 1850, coal accounted for only nine percent of American energy consumption; yet, a half century later, the fossil fuel made up nearly three-quarters.²⁸

The energy resource transition that occurred in the United States occurred over several decades, from the mid-nineteenth to the early twentieth centuries. As with the changes highlighted in China and Great Britain, America’s energy transition depended on technology, economics, and policy. The United States experience differed in a major way, though. Although George Perkins Marsh sensed a pattern of overconsumption in the New England forests, the United States changed its major energy resources without first depleting those on which society had previously depended. Rather than change technology, economics, and policy in an attempt to compensate for a lost resource, America used these three forces proactively to modernize its society. This capacity to change without first running out of an energy source serves as a valuable lesson for the twenty-first century.

Before Europeans began settling in North America, the energy story here echoed that of civilizations elsewhere. Native Americans and Europeans each relied primarily on renewable energy, such as timber and muscle. As the impact of white settlement pushed Indians aside, though, consumption patterns changed. Timber meant money to early colonists, and those emigrating from the British Isles harvested varieties of New England

²⁷ George Perkins Marsh, *Man and Nature, Or, Physical Geography as Modified by Human Action* (Cambridge, MA: Harvard University Press, reprinted, 1965), 255-9.

²⁸ Joseph A. Pratt, “The Ascent of Oil,” in Lewis J. Perelman, August W. Giebelhaus, and Michael D. Yokell, eds., *Energy Transitions: Long-Term Perspectives* (AAAS Selected Symposium 48, Boulder: Westview Press, 1981), 10.

hardwoods in order to participate in Britain's imperial market economy.²⁹ While young industries used wood, mostly as charcoal, to produce iron and glass, depletion of timberlands began at an unprecedented rate in North America. Historian Martin Melosi figures that to produce one thousand tons of iron, people had to use six thousand cords of wood; with American forests shrinking, society struggled to find new sources of precious timber. The United States saw wood as the key to its early success, lending credence to the notion that timber was "the fuel of civilization."³⁰

A major difference between energy transitions in United States and those of ancient China and early modern Britain lay in the constant availability of alternative resources in America. As George Perkins Marsh indicates, forests in the eastern United States suffered rapid over-harvesting, leaving the region depleted by the middle of the nineteenth century. East of the Mississippi River, timber served as a useful barrier to westward expansion in the U.S., as settlers used the wood cleared for farming in construction, heating, and for cooking. This traditional demand coupled with the development of the steam engine to accelerate the demand for timber in America's industrial era. Steam-driven engines initially relied on timber as a power source, especially in terms of water and rail transport. Yet the industrializing process caused a major shift in the American landscape as urban centers exploded with factories and workers, a scene already playing out in Britain. Martin Melosi concludes that the transition from wood to coal mirrors the rush from agricultural fields to urban industrial centers.³¹

²⁹ See William Cronon, *Changes in the Land*, (New York: Hill & Wang, 1983), 9, and 19-33, and Ponting, *A Green History*, 279. Harvests mostly centered on white pines, which were perfect for shipmaking.

³⁰ Melosi, *Coping with Abundance*, 18 and 22.

³¹ *Ibid.*, 17.

Even as Americans consumed timber at an unsustainable rate, the United States did not change its energy resources after complete depletion. Melosi and others argue that economic incentive and technological capability explain America's shift from timber to coal. Historian Alfred D. Chandler, Jr. compared the American and European experiences. Instead of a total lack of timber production, which was a central concern in Europe, American industry heeded the call of consumer demand. Abundant sources of coal allowed American metal workers to make wrought and cast iron more cheaply than charcoal-fired furnaces, causing a shift to the fossil fuel in the 1830s and 1840s.³²

The spike in coal consumption began a trend in America that would put the nation's coal consumption on par with the industrial power Great Britain by the last decade of the nineteenth century. In 1850, the comparison between the two hardly merited attention, as the North American nation barely exceeded one-seventh of Britain's 56.3 million tons of coal consumption.³³ By the 1890s, the US nearly equaled British consumption, and at century's end, America surpassed the former industrial leader, outconsuming Britain by 262.8 million tons to 180.6 million tons.³⁴ The United States completed its transition from timber to coal by 1900.

The explanation for America's resource change has little to do with depletion. Although the country experienced several shortages in its early history, the 1812 Philadelphia wood shortages most prominent among them, problems remained isolated.

³² Alfred D. Chandler, Jr., "Anthracite Coal and the Beginnings of the Industrial Revolution in the United States," *Business History Review*, vol. 46 (Summer 1972), 142.

³³ R.P. Rothwell *The Mineral Industry, Its Statistics, Technology, and Trade*, Volume II (New York: Scientific Publishing Co., 1892), 221; W. S. Jevons, *The Coal Question*, rev. ed. (New York: MacMillan & Co., 1906), 139; and H. S. Fleming, *A Report to the Bituminous Coal Trade Association on the Present and Future of the Bituminous Coal Trade* (New York: Bituminous Coal Trade Association, 1908), 139; quoted in Sam H. Schurr and Bruce C. Netschert, eds., *Energy in the American Economy, 1850-1975: An Economic Study of its History and Prospects* (Baltimore: The Johns Hopkins Press, 1960), 70

³⁴ *Ibid.*, 70.

Localized responses like the Mutual Assistance Coal Company in Philadelphia had little impact on the changing national consumption patterns.³⁵ Industrial development provides a better explanation for the change.

For all its benefits to home and industry, coal's arrival on the American energy scene was anything but smooth. The major problem with the transition from wood to coal was logistical: producers had a tough time getting the product to manufacturing centers, which had previously emerged near major water ways. Early American coal fields lay mostly in northwestern Pennsylvania and in West Virginia's Appalachian region, far away from industrial factories of the Northeast. Ironically, the solution to the transportation riddle lay in transportation. Throughout the mid-eighteenth century, railroads relied on wood burning engines, which engineers could transform into coal consumers without major effort.³⁶ By the 1870s, railroad companies invested in coal mines and the race for economic power took off. Steam-powered water and rail transportation gave coal a stable market, and provided a steady supply for fuel-hungry factories. Soon coal expanded to compete with timber and kerosene for the home heating market.

Coal's widespread use allowed the U.S. to compete with European nations for industrial power, but economic success had its share of problems. Urban centers across industrialized America belched out debilitating pollution, and people living near factories began to take notice. By 1900, various groups, many founded by women, formed to fight for cleaner air, yet most Americans held to the notion that smoke was a sign of

³⁵ Melosi, *Coping with Abundance*, 26-7.

³⁶ *Ibid.*, 24, 27-8.

prosperity.³⁷ A rise in nuisance complaints followed the switch from relatively clean-burning anthracite to smoky, toxic bituminous coal. Technological advances and logistical convenience marked the shift to dirtier urban centers.

By the twentieth century, America transitioned from a wood-based, agricultural society to an industrial, coal-consuming power. Although the US never fully ended its use of timber for domestic heating and other purposes, the nation has not returned to pre-industrial levels of wood consumption either. The notion that a given society does not completely abandon a resource might seem an irrelevant assertion, but the competition that drives one energy source to prominent use also tends to deplete that source. Those societies that maintain a more diverse resource base have the best chance of adapting to new sources when they run out.³⁸

As the United States entered the twentieth century, a new resource competed with coal for dominance. The last half of the nineteenth century saw a shift in domestic fuel demand; people typically depended on costly whale oil or inefficient beeswax or tallow candles for lighting. But just as whales became scarce, people in western Pennsylvania noticed a mysterious black substance oozing from the ground and into streams. Locals dipped rags into the water to collect their contents for a wide range of uses, including indoor illumination.³⁹ Word spread about the mystery fuel, then known as “coal oil,” and before the start of the Civil War, prospectors set up camp in Titusville, Pennsylvania. America in the mid-nineteenth century contained a growing population, abundant resources, and increasing economic wealth, ideal conditions for an energy transition. With the cost of whale oil on the rise and a paucity of sufficient alternatives, scientific

³⁷ *Ibid.*, 32-3.

³⁸ I argue that wind energy technology is one such example in Chapter 4, below.

experimentation combined with business acumen to create a market for petroleum. Oil's first major contribution to American energy came as the refined product kerosene. Refined petroleum produced a fuel that burned cleanly and efficiently, but more importantly, America had abundant supplies that kept prices low.

Oil's utility extended beyond illumination. Laboratories produced a plethora of uses, and petroleum products gained markets in domestic heating and industrial machine lubrication. Still, by 1900, oil was not the nation's dominant fuel source. At the turn of the century, the United States produced a total of one billion barrels of oil; however, by 1920, America produced over a billion barrels every year.⁴⁰ While home lighting and heating provided an early market, companies like J. D. Rockefeller's Standard Oil Company consolidated the petroleum market by buying businesses engaged in all levels of oil production, from drilling to refining to retail. No small producer, refiner, or retailer had enough capital to assure market stability until Standard Oil Company achieved near total dominance of the market.⁴¹ Two additional discoveries of petroleum's utility cemented oil as a major player in the American energy story: electricity and the internal combustion engine. Before the age of oil could take off in the United States, though, the nation had to deal with the problems posed by global conflict.

The Great War placed serious demands on the American infrastructure, and industry grew to supply the burgeoning military market. The period helped spur a transition from coal to petroleum, although the shift was hardly total: oil accounted for

³⁹ Daniel Yergin, *The Prize*, 22.

⁴⁰ Melosi, *Coping with Abundance*, 39.

⁴¹ For an overview of Standard Oil's rise to prominence, see Daniel Yergin, *The Prize*, previously cited; for the postmodernist perspective, see Roger M. and Diana Davids Olien, *Oil & Ideology: The Cultural Creation of the American Petroleum Industry*, (Chapel Hill and London: The University of North Carolina Press, 2000).

about twelve percent of national energy consumption in 1920, while coal production peaked in that year, providing over three quarters of the nation's energy.⁴²

Transportation, mostly automobiles, provided much of the market for petroleum, but burgeoning manufacturing plants used the resource as well, as many American factories began the switch from coal to oil.

The transition from "King Coal" to petroleum represents the abundant nature of America's energy transition experience. The shift occurred largely as a product of a competitive commercial economic system and abundant resources. A central feature of America's growing petroleum consumption lay in the industry's experience with kerosene, which was a popular illuminant in the last half of the nineteenth century. Standard Oil consolidated refining centers and developed a sophisticated delivery system that allowed the company to transport crude oil efficiently from the fields in western Pennsylvania and from the Lima field in Indiana and Ohio. New strikes in the San Joaquin Valley of California and in Texas, Louisiana, and Oklahoma flooded the regions, and subsequently the nation, in oil.⁴³ Thus, at the time the automobile began making a contribution to transportation, the petroleum industry was able to supply the increasing demand. Ironically, prior to the auto's creation in America, refineries had no use for a by-product of heating fuel, gasoline.⁴⁴ Economic demand coupled with sophisticated technology and an abundant new resource to spur an energy transition.

⁴² Bureau of the Census, U.S. Department of Commerce, *Statistical Abstract of the United States* (Washington, D.C., 1968), 702.

⁴³ Yergin, *The Prize*, 82-95. Yergin reports that California production increased from 470,000 barrels in 1893 to 24 million barrels ten years later. Petroleum and natural gas also stunted use of solar energy as a resource in California.

⁴⁴ *Ibid.*, 80.

While economic incentive and technological advancement spurred a shift from timber to coal and petroleum, fossil fuels drew the attention of US policy. Throughout the last half of the nineteenth century, the American government stayed out of industrial affairs, much as Great Britain had done during the early modern period. With the rise of big business and a growing concern for labor and pollution problems, the US government began to address energy issues by the early twentieth century. While “Gilded Age” laissez faire policies tended to ignore industrialism’s side effects, public health concerns actually led government to support increased use of oil and natural gas in urban areas.⁴⁵

The United States also dramatically changed its official position towards monopolies in the late nineteenth and early twentieth centuries. The antitrust sentiment led to a reorganization of the iconic Standard Oil Company in the 1890s, while concern for private utilities spurred growth of publicly owned power plants thirty years later.⁴⁶ Government played an expanding role within the energy sector of the economy during the Progressive Era. By the end of WWI, public utilities competed with private businesses for energy customers, a development that signaled a mercurial relationship between government and business.

The control over petroleum that began with the Wilson Administration would have a lasting effect on the industry. To encourage wartime production, the federal government increased the oil depletion allowance in 1918 , which gave the petroleum industry a decided advantage in the competition to provide energy in the U.S.⁴⁷ The tax break began in 1913 and originally gave oil and gas producers a five percent deduction as

⁴⁵ Scott Hamilton Dewey, *Don't Breathe the Air: Air Pollution and U.S. Environmental Politics, 1945-1970* (College Station: Texas A&M University Press, 2000).

⁴⁶ Melosi, *Coping with Abundance*, 89-90. See also, Richard Rudolph and Scott Ridley, *Power Struggle: The Hundred-Year War Over Electricity* (New York: Harper and Row, 1986).

a way to calm the volatile market.⁴⁸ The decision to provide tax relief for oil and gas production originally resulted from lobbying efforts by the industry in 1913, but the need for oil in the war solidified the allowance in the tax code.

The coal industry saw things quite differently in the 1920s, as industry leaders called on Washington to help preserve the industry.⁴⁹ Throughout the decade, demand for oil soared and signaled a change from the production-focused war years. New industries began to develop around the growing popularity for electricity from both coal- and oil-powered sources, while the automobile boom took petroleum consumption to new heights.

Although the transition from timber to fossil fuels was largely complete by the end of the 1920s, the Great Depression marks a vital period in the development of American electricity plants.⁵⁰ The era marks an important shift from smaller, independent deployment systems to larger, regional networks of electricity generation and fossil fuel consumption. The transition to centralized utilities also underscores the abundance of resources, technological innovation, and economic pressures, all elements of America's energy transition story. When Franklin Roosevelt took office in 1933, domestic utility companies concentrated their energies on the twenty percent of American households already having electric power. Roosevelt's agenda sought to expand domestic electricity use by extending power to the eighty percent of homes lacking

⁴⁷ Melosi, *Coping with Abundance*, 100-1.

⁴⁸ *Ibid.*, 100. In 2003, the deduction stood at fifteen percent, see warrenresourcesinc.com/drilling_programs.cfm.

⁴⁹ Craufurd D. Goodwin, ed., *Energy Policy in Perspective*, 138-9.

⁵⁰ Most of my thesis involves energy used for electricity production, as opposed to transportation resources.

power.⁵¹ Household modernization was a central feature of the New Deal, and several legislative acts carried out this agenda.

Historian Ronald Tobey likens FDR's domestic electrification efforts to a modern "political enclosure movement" that served to centralize electricity production and transmission.⁵² Measures like the National Housing Act, the Rural Electrification Act, and the Tennessee Valley Authority (TVA) served as catalysts for modernization and a direct role for the federal government in energy use. The haphazard collection of power grids during the 1920s soon gave way to a more systematic approach. The most lasting effect of the New Deal on American energy policies related to production, seen particularly in new dam construction for hydroelectricity and the massive TVA, and regulation, especially over utility companies doing business across state lines.⁵³

The policy to modernize American homes also affected the coal industry, which provided most of the fuel used in power plants. The relationship between government and energy became closer during Roosevelt's presidency, especially given the erratic coal industry. Labor problems affected prices, but FDR built a policy around electrification so that to fulfill his promise of a better way of life, Roosevelt had to rein in costs. The National Industrial Recovery Act of 1933 set prices for coal in the hopes of stabilizing the industry and expanding the reach of power plants. The Roosevelt Administration sought to offset problems of abundance and labor strife by intervening with the market.⁵⁴ Later, the Bituminous Coal Act of 1937 made coal production a profitable business by

⁵¹ Ronald C. Tobey, *Technology as Freedom: The New Deal and the Electrical Modernization of the American Home* (Berkeley: University of California Press, 1996), 95.

⁵² *Ibid.*, 93.

⁵³ Melosi, *Coping with Abundance*, 126-7.

⁵⁴ Goodwin, *Energy Policy in Perspective*, 7.

setting costs artificially high; as a result, an industry that constantly found itself in debt was finally able to turn a profit by 1940.⁵⁵

Overproduction remained a problem for the coal industry throughout the Depression, but the same affliction carried different results for oil. Intervention by the federal government came as a result of oil shortages caused by wasteful competition. Briefly during the late 1930s, an old Progressive ethic re-emerged: conservation. Gifford Pinchot, a public servant since Theodore Roosevelt's administration, continued to influence policy by serving in the Interior Department in both the Franklin Roosevelt and Harry Truman administrations. Pinchot and Harold Ickes became so concerned about the possibility of running out of oil that the two proposed a World Conservation Conference to discuss energy. The Conference, renamed the Scientific Conference on the Conservation and Utilization of Resources, was held in late summer 1949 at Lake Success, NY, and advocated a "(m)ore effective utilization of solar energy."⁵⁶

Aside from conservation, the oil industry asked for government help in stabilizing the volatile market; the government responded by continuing favorable tax breaks and to delve into the realm of interstate regulation. The hodge-podge laws that governed oil production varied from state to state until the Conally Hot Oil Act passed in 1935, which merely transferred the practice of inconsistent policies from the state to the federal level. The legislation gave the federal government the power to enforce state quotas on oil production and effectively stemmed the tide of cut-throat competition.⁵⁷ Still crude production nearly doubled from 1930 to 1945, and the industry found a major boost in the

⁵⁵ Ibid., 139.

⁵⁶ Ibid., 25-6. Indeed solar was an alternative, but cheap, abundant fossil resources, coupled with the promise of atomic energy, effectively squelched solar's development.

⁵⁷ Ibid., 63-4.

American West. In California, coal remained an expensive resource, but the petroleum industry established itself as a primary energy supplier. James Williams reports that California relied first on hydro-power for electricity throughout the Depression; after 1945, steam power, and with it oil, surpassed hydroelectricity as the chief supplier in the state.⁵⁸ Nationally, coal remained a vital source for electricity generation, but other sources continued their march to energy parity.

Natural gas emerged from the fuel-hungry Depression era as a major factor in American electricity generation. The National Gas Act of 1938 legitimized the resource by calling for its regulation by the federal government. Thanks to advances in transmission technology, gas companies could ship their product from the fields, located mostly in the Southern Plains, to refineries, which used the resource to generate electricity.⁵⁹ Inefficiencies continued to mark natural gas's marketability; in the thirties, engineers did not fully understand how to transport natural gas effectively, but by the end of the Second World War, the resource played a prominent role in American energy.⁶⁰ Natural gas made up only twelve percent of US energy consumption in 1940, but by 1960, that number rose to one-third.⁶¹ As with other resources, natural gas depended on abundant supplies, economically efficient transport, and a ready market.

America's energy transition demonstrated characteristics found in ancient China and early modern Britain. Technologically, the US borrowed from its European forbears to institute an industrialized society in North America, while the market economy spurred

⁵⁸ James C. Williams, *Energy and the Making of Modern California*, (Akron, The University of Akron Press, 1997), 146-7.

⁵⁹ Arlon R. Tussing and Connie C. Barlow, *The Natural Gas Industry: Evolution, Structure, and Economics* (Cambridge, MA: Ballinger Publishing Co., 1984), 24.

⁶⁰ Melosi, *Coping with Abundance*, 154-7.

⁶¹ U.S. Department of Commerce, *Statistical Abstract of the United States*, (Washington: Government Printing Office, 1968), 702.

resource production into previously untapped reserves. Government policy vacillated between the British laissez faire model and one based on the public interest. The result of America's shift from timber to fossil fuels stands as a testament to humanity's awesome capacity for productivity and growth. As the energy crises of the 1970s demonstrate, such profligate resource consumption comes at a cost.

Chapter 2



Lessons from Chaco: Passive Solar Technology and Humanity

Ancient China, early modern Great Britain, and the industrial United States changed their energy resources without a plan. The particular geographies offered each society a range of options, and they all drew from available resources for similar reasons. As outlined in the preceding chapter, a combination of economics, technology, and politics worked together to form a broad energy resource policy, yet the patterns of consumption settled upon by the respective societies came after each considered, and in some cases tested, other options. For virtually every nation, no single source proved to be a panacea for energy crises, but societies chose resources based upon compatibility. Economics, technology, and politics all played a role. Availability and familiarity were also important.

Humanity has long held solar energy in high regard. In ancient China, Greece, and Rome, among others, people have used an option still considered viable today. Generally defined, passive solar energy refers to the practice of using the sun's energy for domestic heating and cooling.¹ Most of humanity's efforts to use passive solar energy involves architecture, and today experts continue to illustrate energy savings as the resource's central benefit. Industrial, commercial, and domestic (household) energy consumption makes up nearly three-quarters of the American total, mostly in the form of

¹ This is the modern definition, at least. See the Sustainable Building Sourcebook's "Passive Solar Design" website at www.greenbuilder.com/sourcebook/PassiveSol.html.

electricity.² Passive solar technology reduces the need for electricity production and the environmentally harmful byproducts related to certain methods of making electricity, such as burning coal. This chapter traces the technological development of passive solar technology from ancient societies to the modern era in order to show that energy conservation and passive solar energy are closely linked. Such a connection demonstrates that energy policies of the early twenty-first century should not consider solar resources either new or difficult to understand.

Far from being a recent discovery, passive solar technology has evolved over millennia. In this chapter, I divide the story into three parts. Ancient China, Greece, and Rome all turned to solar architecture when other more conventional resources became scarce. The legacy that developed in Europe throughout the middle and early modern period makes up my second section. I end with a discussion of modern passive solar technology in all its forms by looking at the era in two parts: the industrial US and America in the post-1973 era. I end this chapter with an observation on how Americans viewed solar energy on the cusp of the twenty-first century.

At first glance, such an extensive scope might seem impossible in one mere chapter, yet my methodology makes such an effort reasonable. Using secondary accounts of the ancient and middle eras, I present a synopsis of solar technology. As the story moves into the modern era, my analysis becomes both more concentrated, in terms of historical sources, and broad, in terms of technologies. The number of passive solar technologies far surpasses the room I have here, so I concentrate on those I believe best represent humanity's attempts to reduce the use of fossil fuels and those that best

² Energy Information Administration, *Annual Energy Review 2002*, "End-Use Sector Shares of Total Consumption, 2002," available at http://www.eia.doe.gov/emeu/aer/pdf/pages/sec2_2.pdf.

represent the latest technology. My point in taking on such a methodology centers on the role I see passive solar technology playing in the future. Like the other alternative energy resources in this thesis, passive solar technology has the ability to offset fuels that pose serious problems for modern society. As with active solar and wind energy, developments in passive solar technology make the resource a viable alternative to those fuels Americans most depend upon at the beginning of the twenty-first century. Yet today's alternatives were often among the first choices for bygone societies.

Ancient Societies

Ancient societies in China, Greece, and Rome all embraced the benefits of passive solar technology. In most cases, the turn to solar energy came as a necessary step to warding off threats to the social order caused by fuel shortages. At other points, solar architecture allowed people to enjoy some degree of independence and even decadence. In all cases, passive solar technology allowed people to adapt to their environment, leaving time for other important developments.

Chinese political unification finally brought peace to East Asia in the third century BC. The widespread violence that racked the region threatened to return during the nation's fragile early years, in part due to timber shortages. Wood was essential to ancient Chinese life, as construction material and fuel. The disappearing forests even sounded spiritual chords, as the iconic poet Mencius sang saturnine dirges to the vanishing timberlands of mythical Ox Mountain.

Geography tended to dictate the terms of countering wood shortages. In China's northern loess region, vast coal fields allowed citizens there an alternative source of

domestic fuel. Solar architecture provided another solution. Northern China continues to struggle with a recurring problem: a constant demand for timber prevents the natural recovery of forest lands and allows a foothold for encroaching deserts.³ In ancient China, one effective measure was to build underground homes. These structures used less wood: structural support came from the ground itself. The earth covering also provided good insulation, which offset part of the demand for household fuels. Some ambitious farmers even raised crops on their sod-laden roofs.⁴

Urban planners in other Chinese regions used different methods to preserve valuable timber. An intricate knowledge of seasonal variances allowed architects to build cities amenable to solar energy. Urban plans took on a grid-like quality: builders set houses on an east-west axis to take advantage of low winter sunlight. By contrast, overhangs and silk or rice paper window coverings diffused the sun's heat in the summer months.⁵ These construction methods helped preserve timber for the burgeoning Chinese population, which accounted for a quarter of the world's people at the start of the first millennium.⁶

The demand for timber plagued ancient Greece as well. Just as Mencius wistfully noted the disappearing forests in China, Plato described the metaphorical ““sick man”” of Attica.⁷ The ancient city did not literally turn into a diseased person, of course; instead the description referred to an emerging environmental problem in Europe's classical era,

³ See www.worldwatch.org.

⁴ Richard G. Stein, *Architecture and Energy* (Garden City, NY: Anchor Press/Doubleday, 1977), 35-6; Clive Ponting, *A Green History of the World: The Environment and the Collapse of Great Civilizations* (New York: Penguin Books, 1991), 75-8; J. Donald Hughes, *An Environmental History of the World* (London & New York: Routledge, 2001), 59-66.

⁵ Ken Butti and John Perlin, *A Golden Thread: 2500 Years of Solar Architecture and Technology* (Palo Alto, CA: Cheshire Books, 1980), 12-3.

⁶ Ponting, *A Green History*, 92.

⁷ Plato's *Critias*, quoted in *ibid.*, 76.

Mediterraneanization. Farmers deforested large stands of cedar, oak, and pine, then used the timber for fuel and the ground for grazing. The process forever altered the bounty and function of the landscape, while having an ironically helpful impact on solar architecture.⁸

As timber resources slowly vanished, south-facing homes became more widely used. To offset wood shortages, Greeks built homes oriented to the south to take full advantage of the warming winter sun. Even Aristotle noted the genius of such a building plan, which allowed sunlight in and kept the cold north winds out.⁹

Solar architecture had other benefits, too. In an effort to fend off the growing military threat from Athens, one determined Greek community turned to the rugged cliffs along the Aegean Sea. Olynthus was home to people who bristled under the Athenian economic and political yoke. Olynthus' physical geography contained few resources, except rugged limestone walls that dropped precipitously into the sea. Such a defensible position had its drawbacks, though, as fuel was scarce. To survive, these independent-minded people designed solar buildings in a city planned on an east-west axis. Not only did citizens benefit from warming winter sunshine, they built overhangs to ward off intense summer heat. Construction materials added another benefit: the heat-collecting limestone dissipated daytime warmth slowly over time, keeping residents comfortable in the cool night air.

Romans relied less on solar architecture for military success, but Roman society did adopt practices developed by Greeks. Like their Mediterranean neighbors, Romans built south-facing homes using materials that collected daytime heat and dispersed it at

⁸ *Ibid.*, 75-8 and Hughes, *An Environmental History*, 59-66.

⁹ Butti and Perlin, *A Golden Thread*, 5.

night.¹⁰ Horticulturists also contributed to the growing body of solar architecture by creating innovations in raising food. Roman expansion created a sensation among the Empire's elite; exotic fruits and vegetables became signs of power in Rome. Desperate to provide leaders like Tiberius Caesar with these new-found favorites, such as cucumbers, gardeners built glass-covered heat traps and the prototype of the modern greenhouse came into being.¹¹

The link between solar power and social elites also became apparent in the Roman Empire. While wealthy citizens competed to produce exotic fruits and vegetables, they also turned to the sun for other luxuries. Transparent glass came into the picture to aid the nascent greenhouse industry by the first century AD, and clear coverings soon made their way into expensive Roman housing designs. When timber shortages plagued the imperial city, wealthier citizens fled to their country estates, not for fuel, which was as scarce there as in the city, but for their passive solar homes. Pliny the Elder noted that the "heliocamus," which means solar furnace, was his favorite room in his country home.¹² The taste for heat-trapping rooms, like saunas of today, proved contagious: the idea spilled back into the city, where Roman bath houses used glass to create steamy conditions. Enough wealthy lawmakers frequented these evanescent haunts to inspire solar access laws. The Justinian Code, written in the sixth century, codified Romans's unimpeded rights to the sun; initially, the law stated that no one could build a structure that blocked the popular public baths from the sunshine. Later Romans expanded the rule to protect the rights of private homes to a clear view of the sun.¹³

¹⁰ Ibid., 15.

¹¹ Ibid., 19.

¹² Ibid., 19.

¹³ Ibid., 27.

In ancient societies, solar architecture provided a measure of relief when fuel shortages struck. While ideas passed freely among neighboring cultures, the global reach of passive solar techniques indicates their base appeal. Chinese designs resembled those practiced in Rome at about the same time, even though the two societies scarcely even knew about each other. In Asia and Europe, the turn to solar architecture usually came as a response to other resource scarcity. In both China and Rome, solar buildings came onto the scene when fuel wood supplies ran short, but in the American Southwest, Anasazis built a society in a region that already had few resources.

Anasazis slowly crept into Chaco Canyon around 800 AD, where they found few allies in the natural world. Water and timber remained precious commodities in the Chaco River Valley by the time the region experienced full-blown settlement two centuries later. Lured by an increasingly dependable, if not abundant, rainy season, Anasazis came to the area for its farming potential.¹⁴ A slow trickle of immigrants came from the cliffed regions of southwestern Colorado and southeastern Utah, and within two centuries the humans who settled in Chaco Canyon had created a society teeming with energy.

The social structure that held farming and rituals together formed the basis of Anasazi cosmology, which in turn created Pueblo Bonito. The structure's building plan included strict attention to seasonal patterns. The curved section of the D-shaped building acted as a courtyard that opened to the southwest.¹⁵ Engineers used complex designs that emulated seasonal rhythms. Anasazis considered seasonal variations, as well; archeological evidence reveals that certain rooms within several structures all

¹⁴ David E. Stuart, *Anasazi America: Seventeen Centuries on the Road from Center Place*, (Albuquerque: University of New Mexico Press, 2000), 65.

focused sunlight onto important spiritual icons on the solstice. In Pueblo Bonito, the largest structure in Chaco Canyon (and the largest structure in North America until the late nineteenth century), modern scholars termed the solstice room the “sun dagger.”¹⁶

The building that stood at the center of Anasazi culture, and the cosmology that produced it, was powerless to stop the climate change that drove people out of Chaco Canyon. The contract between spiritual leaders and farmers was irrevocably breached as a result of a series of droughts that began sporadically in the late eleventh century became routine by the thirteenth.¹⁷ The powerful Anasazis, who once controlled a land area the size of modern West Virginia, succumbed to the dry conditions of the Medieval warm period.

Early Modern Europe

In Europe, the faith of millions would be put to the test during the Middle Ages. Shifting climate had less effect on people than disease, as the Black Death decimated populations from the mid-fourteenth century until the early eighteenth and seemed to ignore fluctuating weather patterns.¹⁸ Cathedrals sprouted up throughout the continent, as people prayed for deliverance from the ravages of disease. Glass, which was a mainstay in Venice since the Roman era, began to play an important part in European spirituality. An abundant, naturally occurring salt compound, soda, allowed the Mediterranean glass working trade to flourish. Northern Europe held no such bounty. Driven by demand for stained glass, artisans turned to potash. Unfortunately, workers

¹⁵ *Ibid.*, 92-3. Stuart notes that the courtyard of Pueblo Bonito wasn't walled in until the 1100s.

¹⁶ *Ibid.*, 80.

¹⁷ Ponting, *A Green History*, 99-100.

¹⁸ *Ibid.*, 229-30.

could only produce potash by burning wood, and as cathedrals took on increasing importance, the once-abundant timberlands suffered.

As Europeans turned heavenward for salvation from the plague's onslaught, diminishing resources spurred overseas expansion. Historian Clive Ponting thinks that the dwindling timberlands, which produced Europe's most widely used resource, pushed nations in new directions to search for vital energy supplies. Despite continued reintroduction of plague conditions, Europeans developed natural immunities, thus stabilizing population numbers and spurring demand for natural resources. Climate also played a role, as the Little Ice Age tightened its chilly grip by the mid-sixteenth century, driving demand for timber (and food) to untenable levels.¹⁹

Aside from the conquest of new lands, Europeans turned to two resources to offset the shortages in the seventeenth and eighteenth centuries: coal and sunshine. Prior to the early modern era, wealthy people viewed coal with a certain amount of contempt – only poor people burned the smoky black rocks. Yet during the Middle Ages, people made important technological improvements; some historians suspect these events amounted to a “Medieval Industrial Revolution,” which these scholars define as the start of a mechanical tradition that would later spark the invention of the steam engine.²⁰ While several elites tinkered with the energy potential coal offered, others turned to ancient texts for hints on how to offset the cool temperatures.

Passive solar technology enjoyed a rebirth in the northern regions of early modern Europe. Wealthy farmers began to use heat-collecting construction materials as a way to

¹⁹ Ibid., 97-102.

²⁰ James Burke, *Connections* (Boston: Little, Brown, 1978); Lynn White, Jr., *Medieval Technology and Social Change* (Oxford: Oxford University Press, 1962); Fernand Braudel, *Civilization and Capitalism*,

ripen crops in short growing seasons. South-facing walls found use in France, Holland, and Great Britain, where planters buried seeds alongside heat-absorbing brick walls to give crops a better chance to develop. The “fruit wall” idea was originally used in ancient Rome, but the concept was well-suited for the cold climate of Northern Europe. English horticulturists even nailed branches to the walls in hopes of staving off killer frosts before harvest time.²¹ In France, Fatio de Duillier perfected a fruit wall that tracked the sun’s path during the day, which effectively doubled the plants’ exposure to sunlight. Duillier’s contributions to solar technology exist today in the modern solar collectors engineered with the same concept in mind.²²

Other technological developments stemmed from a combination of other knowledge. In Rutland, the duke developed the first known greenhouse in 1700. The design utilized the slanted angle idea seen in fruit walls, as well as the heat-trap principles perfected by ancient Romans.²³ Dutch engineers expanded on these ideas and created the double-paned glass concept, a vital part of passive solar design today. Even on cloudy days, greenhouses with angled, double-paned glass plates could maintain high temperatures.²⁴ In England the conservatory idea impacted high society. Aristocrats began attaching greenhouses to their homes, and the conjoining rooms, called conservatories, would benefit from the solar heat that poured in. Other designs called for air-tight convection tubes that led from conservatories into homes, supplying heat and mitigating the demand for fuel wood. These concepts fell out of favor when the climate

15th-18th Century, volume 1, *Structures of Everyday Life: The Limits of the Possible* (New York: Harper & Row, 1979).

²¹ Butti and Perlin, *A Golden Thread*, 41-3.

²² *Ibid.*, 46.

²³ *Ibid.*, 47.

²⁴ *Ibid.*, 49.

again warmed. By World War I, aesthetics took over function, and conservatories became fuel consumers. Tight resource supplies spelled doom for these passive solar structures after WWI.²⁵

Industrial United States

Across the Atlantic, Americans took their first steps on a journey to electrification by the mid-nineteenth century. The power lines that obstructed my view at Chaco Canyon came into being thanks to a collective modernizing push in the United States. Throughout the early industrial era, Americans developed a passion for things mechanical. In many ways electricity had to come to Chaco -- as a sort of industrial manifest destiny -- based on consumption patterns that mimicked early modern Europe. Ever the jealous cousins, Americans would try to outdo the European industrial example. Progress in this curious way seems to follow the United States wherever its technological path leads.

A burgeoning country accustomed to abundance grew into a fully modernized society by the late nineteenth century, and the demand for fossil-based goods and services began to take hold. The nation was awash not just in forests but in coal, natural gas, and petroleum, too. America's mechanical tradition extended beyond the use of fossils: even solar power benefited from the new industrial era. Paradoxically, a society marked by innovation still yearned for resources that would provide consistency, and by the mid-twentieth century, passive solar designs could no longer meet such demands.

Even as an era of industrial expansion took hold in the United States, passive solar engineers made significant gains. In 1891 Baltimorean Clarence Kemp started a

²⁵ *Ibid.*, 52-3.

tiny passive solar water heating company. Kemp's brainchild, the Climax water heater, was simplicity defined. The rooftop system operated on the heat trap principle: the Climax ran domestic water pipes through four cylindrical tanks that rested inside rectangular wooden boxes. Sheet glass covered the tanks and the system was painted black to maximize heat absorption.²⁶

Climate spurred Kemp's unique design and it later drove the Climax creator to a warmer region. The freezing Baltimore winters prevented the water heater from working year-round, so Kemp moved his company to Pasadena, California. The allure of Southern California was twofold: first, the sun shone steadily throughout the year; next, competition, which appeared most ominously in the form of electricity, had not made its way there yet. By 1895, Kemp sold the rights to manufacture and sell his solar water heaters to a pair of Pasadena businessmen, while retaining control over the company itself.²⁷ A lack of timber, coal, and natural gas caused sales of the heaters to take off. The traditional resources that most Americans used to heat their water simply did not exist in Southern California, and expense of the Climax more than offset yearly expenditures on such items.²⁸ The price sold a number of customers on new water heaters, which cost about twenty-five dollars; the cumulative total of coal (three-quarters of a ton annually) and wood (about a cord per year) purchased by households amounted to about nine dollars per home every year.²⁹

While the Climax had advantages over traditional heating methods, success was hard to come by. A skeptical public ignored solar heaters until Frank Walker made some

²⁶ Butti and Perlin, *A Golden Thread*, 117-8.

²⁷ *Ibid.*, 120.

²⁸ James C. Williams, *Energy and the Making of Modern California*, (Akron: University of Akron Press, 1997), 86-7.

important technical adjustments that improved the Climax's efficiency. Until Walker tied the Climax to the domestic heating system, people had to heat their water where they used it (ie: in the bathroom or kitchen) when the Climax wasn't operating (at night, eg). The centrality of heating increased convenience and sales took off in California, where a sixty-five dollar system could provide a house's water heating needs for all but a hundred days in 1913. Economic savings was only one side of the coin, though: historian James Williams estimates that domestic fuel consumption fell as much as seventy-five percent thanks to passive water heaters.³⁰ Eventually, electricity and natural gas drove the Climax and its progeny out of favor. Solar's cost-effectiveness diminished in the face of competition from fossil fuel companies, but in California, solar energy later reemerge.

While natural gas drove passive solar water heaters out of business in Southern California, the reverse was true in South Florida after 1918. Miami experienced a post-war population boom, and newcomers wanted all the comforts a modern society could offer, included hot water when they wanted it. Electricity could supply the energy needed to heat domestic water, but these systems were erratic and unsafe.³¹ Sunshine offered a more reliable alternative. Passive solar heaters kept pace with the booming housing market, and by the mid-twenties, Miami was awash with water heated by the sun. Like the stock market, the construction bubble burst by the end of the decade, and the solar heating industry faced some difficult days ahead in the thirties.

The building downturn could have ended solar water heaters in Florida, but two events staved off disaster. Innovation provided the first solution. Miami's dominant Solar Water Heating Company turned from its traditional role as hot water heating

²⁹ Ibid., 87.

³⁰ Ibid., 88.

supplier for new homes into retrofitting specialists. The company's owner, Charles Ewald, could have followed his partner into retirement, yet Ewald couldn't resist a challenge. Figuring that the housing boom included only a percentage of Miami's residences, Ewald began selling his heaters to existing homes that needed water heating systems. Technologically, the design improved to compete with a more modern electricity system. The Solar Water Heating Company began using humidity-resistant metal boxes instead of wooden ones; efficient soft copper replaced steel tubing; and granulated cork, a readily available industrial waste product, provided excellent insulation between the tubing and the metal shell.³²

Even with design improvements, people were hard pressed to come up with the money to afford Ewald's heaters. In 1934, the federal government provided a solution. As part of FDR's New Deal, Congress approved low-interest home mortgages and home improvement loans through the Federal Housing Administration (FHA).³³ The availability of money for housing jump-started the Solar Water Heating Company, which could install and service new units for as little as six dollars per month.³⁴ Federal action not only reinvigorated the solar heating industry; Washington's presence kept shoddy workmanship in check as well. Competition for the solar water heating market produced several fly-by-night operations that sought to capitalize on the demand in South Florida. Solar experts Ken Butti and John Perlin figure there were at least ten solar water heating companies operating in Florida by 1935.³⁵ When customers complained to the federal

³¹ Butti and Perlin, *A Golden Thread*, 143-4.

³² *Ibid.*, 147-8.

³³ Ronald C. Tobey, *Technology as Freedom: The New Deal and the Electrical Modernization of the American Home* (Berkeley: University of California Press, 1996), 117-9.

³⁴ Butti and Perlin, *A Golden Thread*, 149-51.

³⁵ *Ibid.*, 151.

government about poor quality heaters purchased with FHA loans, Washington stepped in and ended the corruptive practice.

Innovation and the FHA helped save passive solar water heaters in the short term, but the nation's direction was headed towards electrification. The Great Depression exposed many Americans to the downside of unchecked capitalism. In the 1930s, the US had abundant natural resources that held promise for a higher standard of living than most enjoyed; unlocking this potential remained a problem, though. Despite an era of unprecedented government intrusion into the marketplace, private interests continued to dominate the household energy market. Large energy corporations began consolidating their power by forming holding companies in the twenties, and despite federal laws designed to prevent monopolistic behavior, these private enterprises proved indispensable for modernization.

While the government maintained an antagonistic attitude towards utility companies, the two entities worked together to provide electricity to Americans that didn't have it. Through the 1920s, private corporations decided where and when electricity would expand, and the companies tended to focus on larger customers. By the end of the 1920s, three-quarters of US factories ran on electric power. The numbers of households with electricity also grew in the twenties, as two-thirds of American homes enjoyed electric power by 1929, although the wiring supplied to most of these houses limited the amount of usable power.³⁶ Throughout the Great Depression, the government sought to bring electricity to homes that lacked it and to improve the quality of power for those already having it. Congress passed laws to expand the reach and scope of the grid:

the Tennessee Valley Act, the National Housing Act (which established the FHA), and the Rural Electrification Act helped establish electricity as a priority to government and private corporations alike. Historian Ronald Tobey notes that the utilities concentrated on modernizing the homes of society's richest sector, while the Roosevelt Administration hoped to provide improved wiring systems -- and the power needed to run them -- for the vast majority of homes without such infrastructure.³⁷

By the second world war, Americans had grown accustomed to abundance, and although the war effort necessitated conservation efforts, postwar consumption boomed. Passive solar designs played a marginal, even ironic, role during the war. Experiments at the Massachusetts Institute of Technology made important advances in solar air heating designs, but most of these developments wouldn't find application for years, if at all.³⁸ Commercially successful passive solar water heaters succumbed to the demands of the military, which halted domestic use of precious copper.³⁹

The postwar era found Americans generally disinterested in passive solar technology, but the same was not true in other nations. In Israel, Levi Yissar researched developments made elsewhere -- primarily (and ironically) in the US -- to develop the nation's first major solar water heating company. Yissar's tale strikes a familiar tone with passive solar's own story: the technology took off when other energy sources were scarce. In 1953, the first year of Yissar's Ner-Yah Company, Israelis imported all of their electricity-generating fuels.⁴⁰ From 1957 to 1967, Israeli solar water companies

³⁶ Martin V. Melosi, *Coping with Abundance: Energy and Environment in Industrial America* (New York: Alfred Knopf, 1985), 112. While modern conveniences, like washing machines, were available, people couldn't typically use them at the same time as something else due to inferior capacity and wiring.

³⁷ Tobey, *Technology as Freedom*, 44-5.

³⁸ Butti and Perlin, *A Golden Thread*, 202-6.

³⁹ *Ibid.*, 154.

⁴⁰ *Ibid.*, 235. Yissar's main contribution was adding a de-humidifier inside the actual heater.

sold nearly fifty thousand heaters and exported tens of thousands more.⁴¹ The Six Day War in mid-1967 allowed Israel to gain oil fields in the Sinai, and the petroleum temporarily stunted solar energy. The secret to Israel's nascent solar water heating industry in the past several decades centers on the government's zoning laws: building contractors are required to offer passive solar heaters in new homes. The mandate has resulted in a healthy industry: nearly fifty thousand heaters are sold each year at an inexpensive one thousand American dollars per unit.⁴² In Australia, Roger Morse developed a government program modeled on the MIT housing experiments undertaken during WWII. As in Israel, government mandate proved vital. In the mid-1950s, Australia's government required that homes constructed in "tropical areas" be equipped with solar water heating systems.⁴³ After resolving design flaws, the solar heating industry took off, selling nearly forty thousand units between 1958 and 1973. Japan experienced a postwar solar honeymoon as well. Designs that bore a striking resemblance to Clarence Kemp's Climax heater sold extremely well; by 1966, solar water heater companies sold a quarter of a million units per year.⁴⁴ Japan's turn to the global market, particularly OPEC, for petroleum spelled doom for the solar heating industry.

The Age of Limits

As the crumbling sandstone and adobe bricks lay as testament to Anasazi society, dusty government records bear witness to the consumptive excess that followed American victory in WWII. Abundant sources of coal, oil, and natural gas obviated the

⁴¹ Ibid., 238.

⁴² Daniel M. Berman & John T. O'Connor, *Who Owns the Sun? People, Politics, and the Struggle for a Solar Economy*, (White River Junction, VT: Chelsea Green Publishing Co., 1996), 14-5.

⁴³ Butti & Perlin, *A Golden Thread*, 239.

need for energy conservation, passive solar's chief asset. Conserving energy never made it into the public debate, as Americans consumed staggering amounts of energy. In 1940, households consumed about thirty-eight quadrillion British thermal units (Btus) of fossil fuel, equal to about seven trillion kilowatts of power.⁴⁵ By 1965, consumption nearly doubled to sixty-eight quadrillion Btus, or about thirteen trillion kilowatts.⁴⁶ In the six following years, the annual rate of demand for energy spiked from three to five percent, which equated to an enormous increase considering America's already gluttonous appetite. The increase pushed American resource production to the brink: as early as 1967, imported petroleum exceeded national reserve capacity; by 1972, the US was producing as much as it could.⁴⁷ The stage was thus set for OPEC's surprising embargo the following year.

As a response to the embargo-induced petroleum shortages, President Nixon launched Project Independence. Calling on "the spirit of Apollo" and the "determination of the Manhattan Project," Nixon pledged that by 1980 "we shall be able to meet America's energy needs from America's own energy resources."⁴⁸ As part of the effort to establish energy independence, Nixon increased federal allocation for solar energy research. In his proposed budget for the 1975 fiscal year, Nixon set aside fifty million dollars for solar energy, specifically calling for research and development of heating and cooling technologies -- a clear attempt to attack the demand side of America's energy

⁴⁴ Ibid., 245-6.

⁴⁵ Bureau of the Census, US Department of Commerce, *Statistical Abstract of the United States* (Washington, DC, 1968), 702. One kilowatt equals 3,413 Btus.

⁴⁶ Energy Information Administration, US Department of Energy, *Residential Sector Energy Consumption, 1949-2001*, from website <http://www.eia.doe.gov/emeu/aer/txt/ptbo201b.html>, last visited 7 July 2003.

⁴⁷ United States Congress, *Executive Energy Documents* (Washington, DC: US Government Printing Office, July 1978), 32.

⁴⁸ Ibid., 86.

problems.⁴⁹ The same year Nixon boosted money for passive solar projects, Congress passed the Solar Energy Research, Development, and Demonstration Act, which tried to forge a relationship between government research and the private market.⁵⁰

The push to foster a partnership between federal researchers and private industry stemmed from policymakers' affinity towards nuclear power. For the previous two decades, every president spoke with the highest praise for atomic energy and in the language Washington insiders have grown to love: appropriations. The attitudes toward solar power reflected those heaped upon the nuclear industry, even if on a smaller scale. Indeed, funding for solar research would remain a "flea on the back of the nuclear elephant."⁵¹ Despite its second-class status, solar research and development received over ten billion dollars in the first five years that followed the OPEC embargo; yet in those five years, most Americans still did not know about, much less adopt, solar energy.⁵²

Policy under the Nixon and Ford administration centered on increasing domestic fuel production, but President Carter tried to encourage mainstream use of solar technology. Carter extended a welcoming hand to alternative energy gurus who emerged from the crisis years as champions for what became known as "the soft energy path."⁵³ Declaring "the moral equivalent of war" on energy consumption, President Carter and the

⁴⁹ *Ibid.*, 139.

⁵⁰ Ronald W. Larson and Ronald E. West, eds., *Implementation of Solar Thermal Technology* (Cambridge, MA: The MIT Press, 1996), 81-2.

⁵¹ Donald A. Beattie, ed., *History and Overview of Solar Heat Technologies*, (Cambridge, MA: The MIT Press, 1996), 34.

⁵² US Congress, *Executive Energy Documents*, 163

⁵³ Carter even met with the "soft energy path" founder, Amory Lovins, in 1977 -- going so far as to display Lovins's book prominently on his White House desk. See Daniel M. Berman and John T. O'Connor, *Who Owns the Sun? People, Politics, and the Struggle for a Solar Economy* (White River Junction, VT: Chelsea Green Publishing Co., 1996).

95th Congress passed a dizzying number of energy-related laws – thirty-eight in all -- culminating in the National Energy Act of 1978.⁵⁴

Three parts of the NEA dealt directly with renewable energies. The National Energy Conservation Policy Act (NECPA) provided billions of federal dollars to promote solar technology. The law included a provision for a one hundred million dollar loan program, available to consumers in eight thousand dollar loans to be used for solar heating and cooling equipment purchases; another one hundred million dollars went to a solar demonstration program for federal buildings.⁵⁵ Most Americans never felt the impact of programs like the NECPA; according to journalist Ray Reece, corporations were the major benefactor of such government contracts. Reece reports that in one eight million dollar disbursement, over half the money went to a mere three companies.⁵⁶

Tax credits made up the second part of the NEA concerning solar energy. The Energy Tax Act gave credits of up to fifteen percent toward the purchase of solar water heaters, which created a boom market within the industry.⁵⁷ A virtual solar craze took off in California, where Governor Jerry Brown created a state cabinet-level position to deal with energy issues, the Office of Appropriate Technology (OAT).⁵⁸ Brown and the California legislature also extended federal tax breaks by allowing an additional fifteen percent.⁵⁹ Swimming pool heaters made up most of the market in new solar hot water

⁵⁴ US Congress, *Energy Initiatives of the 95th Congress* (Washington, DC: Government Printing Office, May 1979), 24.

⁵⁵ US Congress, *The National Energy Act* (Washington, DC: GPO, January 1979), 5-6.

⁵⁶ Ray Reece, *The Sun Betrayed: A Report on the Corporate Seizure of U.S. Solar Energy Development* (Boston: South End Press, 1979), 200.

⁵⁷ US Congress, *The National Energy Act*, 521. The 15% figure applied to the first \$2,000 used in "renewable energy source expenditures," and Congress capped the original rebate amount at \$300.

⁵⁸ Williams, *Energy and the Making*, 321.

⁵⁹ Berman & O'Connor, *Who Owns the Sun?*, 29-30.

heaters. Within two years, state and federal tax breaks produced nearly eighty thousand solar installations in California homes, most of them pool heaters.⁶⁰

The boom years were not without trouble, though. Although water heaters and other passive solar technologies had been around for years, companies new to the solar scene assumed they had to start from scratch. Unfortunately for consumers, solar charlatans produced inferior goods -- often times with design flaws overcome by engineers decades prior. The California Energy Commission, itself a spin-off of the OAT, set up a phone hotline to deal with the flood of complaints about poorly designed solar equipment.⁶¹ The financial incentives that drew interest in solar power ended up souring many people on the sun as an energy source, a result that would have long-lasting consequences.

The Public Utility Regulatory Policies Act (PURPA) made up the third renewable-friendly section of the NEA. By including a section that gives small independent energy producers, called qualifying facilities, the chance to participate in energy production, President Carter and Congress stumbled onto what would become the farthest reaching law of the solar generation. Although the tax credits would stunt a burgeoning, if inefficient, solar technology market, the mandate for equal access to the electrical grid would provide solar and other renewable energy generators an outlet for their power. PURPA's main benefit was forcing utility companies to purchase energy from qualifying facilities at a fair price, and the law's longevity (and judicial affirmation) created a sense of stability in a turbulent electricity market.

⁶⁰ Williams, *Energy and the Making*, 337.

⁶¹ *Ibid.*, 336.

The enthusiasm for solar energy rode a tortuous path during Jimmy Carter's presidency. Amid the giddiness for its new presidential champion, the Solar Lobby -- a group of solar industry lobbyists in Washington -- organized a nation-wide celebration in 1978. Sun Day marked the high point for solar advocates, and at the Washington rally, the Solar Lobby proclaimed that given a fair choice most Americans would choose solar energy over fossils.⁶² Fairness was a major issue confronting passive solar technology. As Carter's regulations promoting solar energy took effect, the president took criticism from all sides. For big business, interventionist policies went too far. Coal companies fought stringent environmental laws, while natural gas producers argued that full federal control over prices created disincentives for domestic gas production.⁶³ Individuals also complained that the massive government expenditures translated into few usable technologies, while Ray Reece argued that Carter's policies favored corporations rather than small businesses and individual inventors.⁶⁴ Former DOE policymaker Donald Beattie thinks the tax incentives were a problem. Rather than creating an avenue for energy savings through solar energy, federal tax breaks simply rewarded the sales of shoddy technology, like water heaters.⁶⁵ More importantly to Beattie, the credits weren't tied to any significant societal cost of fossil fuel use; rather than rewarding people for reducing use of coal or natural gas, the government provided incentive to purchase a technology that wasn't able to fill the demand for energy.⁶⁶

⁶² Berman & O'Connor, *Who Owns the Sun?*, 35.

⁶³ See Goodwin, *Energy Policy in Perspective*, 589-96 and Melosi, *Coping with Abundance*, 291-3. Federal management of natural gas had the added burden of inconsistency. The newly-created DOE warned against serious natural gas shortages, while a department report leaked to the *Wall St. Journal* reported that the US was awash in natural gas, giving people the impression that the crisis was illusory.

⁶⁴ Ray Reece, *The Sun Betrayed*, 12-3. Reece quotes Barry Commoner to illustrate corporate takeover of energy, particularly the nuclear, industries.

⁶⁵ Beattie, *History and Overview*, 240.

⁶⁶ *Ibid.*, 240.

While Jimmy Carter helped popularize and implement some forms of solar energy, the steps he took to promote wiser energy use actually helped exacerbate public perception problems. Ronald Reagan swept into office in 1980 on a powerful anti-government tide, a mood created in part by a sprawling bureaucracy, including the Department of Energy. Despite lawmakers's hope that it would act as a streamlining agency, the DOE remained a bureaucratic quagmire for much of Carter's presidency. Reagan's solution for all the red tape was simple: remove it. While he failed in his goal to abolish the DOE, Reagan did succeed in starving funds for renewable energies. Hostility towards solar power effectively cut budget allocations that centered on research and development, but the tax incentives in Carter's Energy Tax Act would remain in place until after Reagan's first term.⁶⁷ With no interest in renewing the credits, Reagan killed the solar water heating business, not an insignificant act. Many of the heaters purchased between 1978 and 1984 contained design flaws and operated inefficiently, yet the industry had an impact on the American economy, judging by the nearly seven hundred thousand solar heaters people purchased and installed.⁶⁸

Reagan succeeded in killing federal funding for solar energy because, by 1983, the economic fallout from the energy crises had subsided. In the early eighties, the US Federal Reserve Bank policies called for greater restrictions on federal money lending -- with the prime rate reaching as high as 21.5%! -- and high oil prices cut into the spending power of most Americans.⁶⁹ The foreseeable recession of 1982 had subsided by 1983, in part because oil and gas production from non-OPEC nations shot through the roof. Yet

⁶⁷ Clearly solar power wasn't yet a huge election issue, if Reagan's landslide victory in 1984 is any indication.

⁶⁸ Larson & West, *Implementation*, 141. The authors figure that sales dropped by 90% in 1986.

increased production only tells part of the story. The increased availability of fossil fuels came at a time when conservation measures had a chance to impact the overall demand for such energy. Expert Daniel Yergin explains that not only did oil's share of the energy pie shrink as other sources, like nuclear and coal power, rushed to fill the shortage, but the entire pie itself shrank. Conservation, writes Yergin, was "often dismissed or even ridiculed," yet the practice "turned out to have (a) massive impact."⁷⁰

Even amid all of the political and popular rancor that roiled around the debate over alternative energy resources, passive solar technology made some important gains in the age of limits. While several solar water heating companies existed solely to shear a naively sheepish public, some of the more honest companies confronted recurring design flaws. Freezing temperatures and hard water topped the list of problems confronting passive solar water heaters in the 1980s. Adjustments to these units, including introducing antifreeze into a closed-loop system, have made modern heaters more efficient.⁷¹ Improvements to other passive solar designs continue to make the technology attractive. At his high altitude "passive-solar banana farm," Amory Lovins uses a combination of high-tech and common sense. His glazed, double-paned windows include an infusion of insulating krypton, a heavy gas, and his insulation is like most others, except that Lovins uses twice as much.⁷²

⁶⁹ Daniel Yergin, *The Prize: The Epic Quest of Oil, Money, and Power* (New York: Simon & Schuster, 1991), 717.

⁷⁰ *Ibid.*, 718.

⁷¹ See Ken Olson, "Solar Hot Water: A Primer," *Northern California Solar Energy Association Energy Resource Guide*, September 2002, 10-8.

⁷² Amory B. Lovins, "Who Needs a Furnace?," *Orion Afield*, vol. 6, no. 3, Summer 2002, 16-8.

A Modern Perspective

Americans have a love affair with energy. Every year, we spend over two hundred billion dollars just to heat, cool, light, and operate our homes and offices.⁷³ Our buildings consumed thirty-six percent of the total energy used in the US in 1999 and over two-thirds of all the electricity generated.⁷⁴ Transportation, usually viewed as the major culprit behind America's soaring energy consumption, made up only twenty-seven percent of the national total.⁷⁵ Popular perception, it seems, has a misleading view of our energy appetite.

According to the Department of Energy, the United States could reduce its energy consumption by seventy percent by incorporating efficiency and renewable energy measures. Most of what the government recommends deals directly with passive solar technology. The trouble is that when it comes to homes and offices, solar energy suffers from a public perception problem of its own. From both a building and a buying perspective the hangover from the solar party of the seventies and eighties still lingers. In studies undertaken by four major housing groups, ranging from the National Association of Home Builders to the California Energy Commission, the main findings reveal a public that has a blurry view of solar water heaters.⁷⁶ Many people didn't know much about the technology, and the few who did saw it negatively. Various factors contributed to the misperception. Competition from natural gas and electricity, the high costs of

⁷³ Department of Energy, National Renewable Energy Laboratory, "Buildings Research," *NREL Facts*, FS24867, December 1998.

⁷⁴ International Energy Administration, "Energy Efficiency Update: United States," November 2002, 2.

⁷⁵ *Ibid.*, 8.

⁷⁶ P. Ghent and C. Keller, "A Comprehensive Review of Market Research on Solar Water Heaters," Subcontract Report, (Golden, CO: National Renewable Energy Laboratory, October 1999, NREL/SR-550-27123).

heating systems, and unappealing designs all combined to give solar water heaters a bad public image.⁷⁷ Yet when given the chance to see modern heaters at work, most people found them “significantly more appealing,” the homeowners who used new systems became “very committed to solar energy.”⁷⁸ Modern solar technology’s problem lays more with a misguided perception than faulty design: if given the chance, most Americans would likely embrace solar technology.

Complacency has allured humanity before. A thousand years ago the priesthood in Chaco Canyon seemed settled in its role as spiritual conduit between the rain-granting gods and the harvest-yielding farmers. The road leading out of Chaco Canyon would prove a difficult one for many Anasazis, but the future would not always appear so bleak. Spurred from complacency by drought and hunger, Chacoan farmers moved out to form modern-day Pueblo tribes that live within New Mexico’s northern Rio Grande Valley.

How can a lesson from such an out of the way place hold any importance for societies in the twenty-first century? Certainly modern Americans have taken the lesson of embracing change to heart, given the rapid, almost daily, improvements in technology. The next chapter explains the second half of solar energy’s story, which relies heavily upon scientific knowledge and technological advances. Implicit in these developments are the lessons from Chaco Canyon: to survive, you must adapt.

⁷⁷ Ibid., 3.

⁷⁸ Ibid., 5.

Chapter 3



Voting as if it Mattered: VoteSolar 2001 & the Story of Solar Electricity

My first up-close experience with modern solar energy technology stemmed neither from wisdom of a bygone era nor a genuine interest in renewable energy. In fact the first time I wondered about solar energy, I cursed. After a long day spent winding my way down the spine of the Sangre de Cristo mountain range from Denver, Colorado, I finally made it to my mother's Taos County, New Mexico home. Well, almost. It was a hot summer day, and my brother's directions to mom's new house simply had no basis in reality. I was lost. My supplies of petroleum and patience were running on fumes. For the umpteenth time I swore that the next turn down an unknown lane would be my last.

As I came up with new terms to describe Taos County's high desert terrain, I happened upon an elderly gentleman. When I asked if he knew where the community of "Earth Ships" was, he replied, "You mean those weird houses with solar panels?"¹ Within seconds I was speeding past the Rio Grande Gorge Bridge. Pulling into the driveway, I gazed in bemused wonder. There, shimmering in the overpowering New Mexico sunlight, I saw what appeared to be misplaced siding. Black, quiet, and futuristic, five flat-plate solar panels hypnotized my tired, vulnerable mind. Busily collecting energy to power everything from light bulbs to the washing machine, these strange embodiments of science fiction made me forget my frustration. More importantly, they piqued my interest.

¹ The term "earth ship" refers to off-the-grid homes that use passive and active solar, as well as wind energy, recycled construction materials, and a complex water treatment system. Mike Reynolds takes

Active solar technology achieves a fantastic dream and differs in two important ways from its passive brethren. By converting sunshine into electricity, modern solar equipment goes beyond conserving energy by converting solar energy into usable electricity. The other major difference has less to do with the complex technology that can accomplish this feat and more in common with the imagination that preceded it. Even before humans fully understood electricity, thoughtful scientists and backyard tinkerers experimented with ways to harness the sun's incredible power into a manageable form. The technology that resulted affects energy decisions in places as modern as San Francisco and as isolated as rural Brazil.

This chapter explains how solar technology made the leap from energy conservation to conversion in three sections. The vast majority of human experience with solar technology occurred before the nineteenth century, before Edmund Becquerel discovered that sunlight contains electricity. The first section describes the background and nascency of solar electricity technology. Next, I turn to post-World War Two America, where solar technology played a larger role in Cold War politics than domestic energy policy. The final section analyzes the American government's attempt to merge technology and economics into a cohesive, solar-friendly policy after the 1973 energy crisis and until the expiration of the solar tax credits in 1985. As a postscript I describe the impact of active solar technology on a global scale. Active solar technology was born of a dream to convert sunlight into electricity, and the physical result of that vision manifests itself in some unusual and inspiring ways.

credit for the name; still actively involved in the earth ship trade, Reynolds also runs the "Greater World Earthship Community" in Taos that includes mom's house.

Photoelectricity

Solar technology advanced beyond architectural designs by the eighteenth century. The hot box designs built upon the heat trap principle inspired more than a burgeoning solar water heating enterprise. Other European scientists applied the idea in different ways. European scientist Horace de Saussure built a complex miniature greenhouse with glass plates. The box design, a sort of solar Russian doll, had five square glass walls that fit inside each other with a small gap in between them.² De Saussure used his hot boxes to grow fruits and vegetables, but the idea had other applications as well. Other scientists improved upon de Saussure's design by adding better insulation for higher temperatures and piping systems to heat water.³

Solar engineers experimented with machines into the nineteenth century. In 1839, French scientist Edmund Becquerel discovered that sunlight contained electricity. Becquerel experimented with selenium to produce a low current, solar powered charge, the first of its kind. Electricity was still a relatively unknown entity in the early nineteenth century, and few scientists investigated the possibilities of producing solar electric technology. The incentive for developing sun-powered machines came from a lack of resources in France. The social and economic transformation that occurred with advances in industry depended on creating steam efficiently and most factories relied on coal. In France, the fossil fuel was not abundant, so the French government invested in scientific ventures that promised to create industrial power without coal. In 1860 a French mathematics professor, Augustin Mouchot, noted that industry would eventually

² Ken Butti and John Perlin, *A Golden Thread: 2500 Years of Solar Architecture and Technology* (Palo Alto: Cheshire Books, 1980), 55-6.

deplete all native resources, placing the nation into a disadvantaged position. Rather than import coal from nations like Britain, Mouchot recommended that France “(r)each the rays of the sun.”⁴

Such an impossible dream motivated Mouchot to develop the first solar powered engine. Using advances in heat traps and mirror technology, which Mouchot used to concentrate sun rays, the scientist attempted to build a steam engine powered by the sun. Mouchot eventually struck upon the idea of using parabolic trough mirrors that concentrated sunlight onto copper tubes that held water. To produce steam, Mouchot designed a tank that fit atop these tubes where a small engine ran on solar power. This 1866 design combined several principles of solar engineering and marks a major advance in solar technology, yet the engine Mouchot created was far too small to be considered useful. To create a bigger, more useful machine, Mouchot had to think big. Using funds from Napoleon III’s nationalistic government, Mouchot built a huge solar powered steam engine. Measuring twenty feet by twenty feet, the “Tours motor” used sunlight as fuel and powered a motor with one-half horsepower. Unfortunately for Mouchot’s dreams of creating a useful solar industrial engine, most of the coal-fired engines produced one hundred horsepower. For Mouchot’s machine to be useful to industry, he would need nearly 100,000 square feet.⁵

At the same time he created a steam-driven solar motor, Augustin Mouchot experimented with the effects of concentrating sunshine onto a variety of metals. Disregarding Edmund Becquerel’s element of choice, selenium, Mouchot tried to produce electric current with other metals to no effect. European scientists of the late

³ Ibid., 58-9.

⁴ Quoted in *ibid.*, 63.

nineteenth century distrusted claims that solar energy contained electricity, and by the turn of the century, no European had conclusively proved that sunlight held such properties. In the United States, a group of inventors made some important discoveries in the 1880s. As he bemoaned the paucity of ways to power his telegraph cable testing apparatus, solar pioneer Willoughby Smith experimented with selenium. Smith and his team of inventors, employed by a telegraph company, found that selenium reacted to light. After Smith's late-nineteenth century discoveries, other scientists tested selenium's limits. Dr. William Adams and his assistant, Richard Day, tinkered with flames and batteries, and they concluded that light caused selenium to produce an electric charge. A New York scientist, Charles Fritts, outfitted the world's first solar panels, using selenium, in 1885.⁶ While his colleagues properly congratulated Fritts on his achievement, no one could satisfactorily explain how selenium cells generated electricity just from exposure to sunshine.

About twenty years after Fritts constructed his inefficient and cumbersome panels, in 1904, Albert Einstein published his famous paper on the theory of relativity.⁷ Importantly for solar electricity's development, Einstein proved that light exists in waves that contain packets of energy called photons. Einstein further demonstrated that the amount of force contained in light is relative to its wavelength: the shorter the wave, the more power it has. Why is this important? Because short light waves contain photons that generate electricity. Scientists discovered that electricity forms once a substance can absorb the packets of power. After sunlight gets trapped, its energy transfers to the

⁵ Ibid., 67-70.

⁶ John Perlin, *From Space to Earth: The Story of Solar Electricity* (Ann Arbor: AATEC Publications, 1999), 17-18.

⁷ Ibid., 20.

electrons within the trapping substance. Harnessing those electrically charged electrons is the basis of photovoltaic technology. Two elements contain nuclei with poorly rooted electrons. Selenium is just such a substance. Silicon is another.

After Einstein's discoveries earned him the Nobel Prize in 1921, the scientific community began to test and experiment with principles. Not only did empirical data confirm Einstein's findings, scientists also came up with the term used today to describe photoelectricity: photovoltaics. The telecommunications industry emerged as a leader in PV technology for the next several decades. Most discoveries in the early twentieth century centered on the rare and inefficient element, selenium. The high costs of selenium and the low efficiency of the metal made investment in solar electricity cost prohibitive during through the Great Depression and WWII era.

The Space Race

The marriage between PV technology and economics grew happier after the war. A Bell Laboratories team, headed by PV pioneer Russell Ohls, discovered the utility of silicon as a conductor in 1954; nevertheless, photovoltaics remained in its infancy due to its inefficient transfer of energy into electricity, known as the efficiency rate. The higher the rate that an electricity-producing technology transfers energy into electricity, the more efficient it is. New coal-fueled power plants in the early twenty-first century operate at about forty-five percent, while older plants generally attain roughly twenty-five to thirty-three percent.⁸ To put the technology into perspective, the breakthrough efficiency rate demonstrated by Ohls and his Bell Labs colleagues was only six percent, which was an

improvement at fifteen times more efficient than previous rates.⁹ In the 1950s, most electricity came from coal-fired plants that operated at thirty-six percent efficiency, making solar electricity a non-participant in American electricity generation.¹⁰

Ohls' breakthrough signaled an important change in the resource used in photovoltaic cells. Rather than focus on the abysmal efficiency rate, solar scientists turned their attention to the world's second-most abundant element on the earth's surface: silicon. Unfortunately, PV technology in the 1950s required silicon in incredibly pure form – not that sandy silicon on the beach. So, aside from an encouraging project in Georgia that allowed Bell Telephone to install solar panels to power telephone lines,¹¹ industry leaders could not justify PV's exorbitant expense - \$600 per watt of power by the mid-1950s.¹²

By the time the Soviets launched Sputnik in 1957, photovoltaic technology experienced a lull. The few gains scientists made translated into fewer profits, and the opportunity for advancement in the PV realm seemed to slip from America's collective grasp. The upside of early Soviet superiority in space flight was a rekindled interest in solar technology. The Vanguard I satellite, NASA's second response to Sputnik, came equipped with a chemical battery designed to power the radio that beamed messages back to ground control.¹³ When the battery failed, the backup system began to work, and photovoltaic technology scored its first real victory. Finally the solar industry found a

⁸ Heinz Termuelien and Werner Emsperger, *Clean and Efficient Coal-Fired Power Plants: Development Toward Advanced Technologies*, (Fairfield, NJ: American Society of Mechanical Engineers Press, 2003). This figure includes loss of power that inevitably occurs during transmission.

⁹ Martin A. Green, "Crystalline- and Polycrystalline-Silicon Solar Cells," in Thomas Johansson, et al., eds., *Renewable Energy: Sources for Fuels and Electricity* (Washington, DC: Island Press, 1993), p. 338.

¹⁰ Christopher Flavin and Nicholas Lenssen, *Power Surge: Guide to the Coming Energy Revolution* (New York & London: W.W. Norton & Co., 1994), 41.

¹¹ Perlin, *From Space to Earth*, 36.

¹² Flavin and Lenssen, *Power Surge*, 154.

partner with nearly unlimited funds, which allowed leaders of the solar cell industry to experiment with greater confidence knowing that achievements would find practical and profitable applications.

Solar electricity panels convert sunlight directly into electricity. The futuristic cells I found dancing in the New Mexico sun operated smoothly, quietly, and with no moving parts or exhaust. To understand how a panel transforms sunshine into electricity, we have to go back to Einstein's quantum theory. All the fuss generated by the brilliant Dr. Einstein focused on his contention that light exists in waves (which scientists already knew) and that those waves contain packets of energy, which he called light quanta. Einstein theorized that the shorter the wave, the more powerful its quanta. His colleagues rushed to test his theories, and within a couple of decades scientists proved many of Einstein's ideas.¹⁴ Tests showed that only "absorbed" photons can generate electricity. The photon's energy, once captured by a substance like silicon, transfers its power to electrons that are charged with energy. These charged electrons then escape their orbits around the nuclei and form an electrical current. When an electron leaves its flight path around a nucleus, it leaves a gap. Photovoltaic wafers allow an electrical field to form as a result of the empty spaces; a current results when solar cells absorb sunlight, which energizes loose electrons. For an electric field to be effective, semiconductors must operate efficiently. Solar scientists made an important advance when they discovered an efficient way of manipulating silicon sheets that contain different numbers of electrons. A silicon sheet that houses a "p" layer has more holes than electrons, and an "n" layer has more electrons than holes. The meeting point between the two sheets is called the p-n

¹³ Green, "Crystalline- and Polycrystalline-Silicon Solar Cells," 338.

junction, and this area generates an electric flow.

PV panels consist of two layers of silicon placed together, with a layer of another material that manufacturers affix either behind or between them. These secondary substances help the silicon absorb or conduct the electricity.¹⁵ When electricity forms in solar panels, they form a direct current, DC. Since most electric outlets are set up on an alternating current, or AC, the electricity from the solar panel has to go through an inverter that switches the power from a direct current to an alternating current. From that point, depending on where you are and what you set up the panels for, you have a source of electricity to power your television or computer or electric blanket.

One concern about PV technology centers on manufacturing the silicon cells and other materials necessary for smooth, pollution-free operation. Two substances attract the attention of the Environmental Protection Agency (EPA). Companies that make solar panels containing copper indium and/or cadmium have to use caution when handling these materials. While each may help increase efficiency, they are both potentially dangerous heavy metals. EPA officially designates them as toxic, and concern arises as to what happens to these harmful substances when panels no longer work. In most places where technological infrastructure exists, people can return their PV cells to the companies that sold them. Where such recycling facilities do not exist, the danger that harmful chemicals will enter the environment increases. A similar concern exists for the batteries that store excess power from PV cells.

Photovoltaic technology lagged behind energy consumption from fossil fuels for

¹⁴ Einstein published his paper in 1904, received the Nobel Prize for it in 1921, and his colleagues caught up to him by the mid-Twenties.

half a century. By the time OPEC imposed its embargo in 1973, PV cells appeared almost exclusively on satellites. The space program, locked in competition with the Soviets, had a different agenda regarding cost and efficiency of silicon-based solar electricity. When developed nations finally figured out that they should investigate practical applications of PV cells, efficiency rates, the percent of energy usable after generation, hovered around the unimpressive six percent mark achieved in the mid-1950s.¹⁶ As an alternative to fossil fuels, PV needed to improve its rate of conversion if it was to be a viable option. Thanks in part to an increase in federal spending, American scientists improved on the silicon idea. Up until the mid-1970s, PV technology relied on flat-plate cells, made up of a substance called crystalline silicon. The crystalline silicon cells made in the 1970s and 1980s required a thickness and purity level that made them too expensive to compete effectively with traditional energy sources.

Some ingenious scientists came up with alternatives that can compete with traditional power sources. Options to traditional flat-plate cells include the catchall category called thin-film crystalline silicon, which most of us have seen powering calculators and wristwatches. Since it costs less to produce solar panels that contain less silicon, scientists focused most of their attention on increasing the efficiency of thin-film cells.¹⁷ Today, several conductors compete in the PV market.

¹⁵ Most of these materials help make panels thin and include amorphous silicon, copper indium diselenide, cadmium telluride, and gallium arsenide. These substances factor into environmental concerns in manufacturing. See the Department of Energy's web site at www.nrel.gov for an excellent overview.

¹⁶ Green, "Crystalline- and Polycrystalline-Silicon Solar Cells," 338.

¹⁷ It costs less because the industry can utilize mass production techniques, like spraying silicon onto sheets. See Perlin, *From Space to Earth*, 163-183.

Photovoltaics in Crisis

The technology that emerged from the space race in the Sixties remained above the clouds into the following decade. The popular rise of environmentalism influenced American policy and funding regarding solar electricity. The first celebration of Earth Day occurred in 1970, and the push for non-polluting energy sources began in earnest. Amidst the haze spewed from exhaust pipes of muscle cars, tree hugging took a central role in American energy policy. Even President Nixon jumped on the bandwagon, calling for a comprehensive clean energy program as early as June, 1971.¹⁸

Americans called for cleaner air, water, and land in the early 1970s, but solar electricity continued to play a minor role in national energy policy. While no single event can claim credit for PV's terrestrial application, a series of events jolted industrialized nations out of their fossil fuel-induced stupor. As a response to continued support for Israel, in October, 1973, the Organization of Petroleum Exporting Countries (OPEC) enacted a crippling policy that restricted the sale of petroleum to many western nations, particularly the United States. The ensuing oil embargo meant a dedicated effort to apply the American space program's impressive use of PV technology to everyday life. Prior to actions by OPEC, European and Japanese companies led the way in terms of government spending on solar electricity, but the United States increased its allocation of federal funds, too. The demand for domestically-produced energy rose during the 1970s, and alternative energy technology research and development received millions of dollars in federal funding, with private industry following suit. Tax dollars earmarked specifically for solar cell research barely deserve mention prior to 1971, but thanks to an

¹⁸ Donald A. Beattie, "The Early Years of Federal Solar Energy Programs" in Beattie, et al., eds., *History and Overview of Solar Heat Technologies* (Cambridge, MA: MIT Press, 1997), 27.

earnest effort to reshape American energy policy by Jimmy Carter, the US government set aside \$260 million for photovoltaics by 1981.¹⁹

Spurred by this interest, research and development of PV technology took off. While the solar dreams of many believers failed to materialize, practical applications cropped up everywhere. Silicon technology, also spurred by the well-established telecommunications and the emerging computer markets, gave rise to solar cells on everything from wristwatches to maritime buoys. Even though the Reagan administration quietly abandoned investments in solar electricity, efficiency improved to such an extent that the photovoltaic industry attracted the attention of nonrenewable energy companies on a global scale. In the 1980s, Markus Real demonstrated PV's potency by successfully placing solar panels on 333 rooftops in Zurich. By the 1990s, the technology established itself worldwide. Today, a PV system that can power the average American household is about seventy percent cheaper than it was in 1980.²⁰

The most popular silicon cells, crystalline, typically cost far less than their alternatives. This kind of solar cell operates at about a fourteen percent efficiency rate, depending upon several factors like time of year and amount of cloud cover. Within the crystalline cell branch of PV technology, some interesting advances have been made. Solar panel manufacturers continue to improve upon the popular wafer design. Recent estimates show this style can achieve efficiencies of up to twenty percent.²¹ The biggest knock against wafer cells is that they cost too much to manufacture. Finding cheap silicon wasn't much of a problem well into the 1990s because PV producers could

¹⁹ Beattie, "The Early Years of the Federal Solar Energy Programs," 29; 1981 budget figure from Flavin and Lenssen, *Power Surge*, 170, imposes 1993 dollars.

²⁰ Arlie Hochschild, "Hooray for the Red, White, Blue and Green," *LA Times*, November 11, 2001.

²¹ This figure comes from a number of sources, and it is generally the accepted standard.

purchase unused stocks from computer companies at a cut-rate price. However, the computer industry boom meant that PV companies had to find alternative sources for their silicon. Market forces thus spurred investigation into more cost-effective ways to produce the precious silicon.

A Global Movement

Technological advances by the PV industry impact energy use throughout the world. In Brazil, solar cells help people achieve goals otherwise inconceivable. In 1992, an ambitious program headed by the US Department of Energy (DOE) and Centro de Pesquisas de Energia Electrica (CEPEL) aimed at powering half million homes, schools, and clinics. The project, influenced by the 1992 United Nations Conference on Environment and Development (UNCED) held in Rio de Janeiro the same year, projected an infusion of technological and financial resources from renewable energy industry leaders. While some analysts hoped that involving companies like Siemens Solar and Solarex would increase production – and lower the costs – of alternative energy paths, Brazilians in places like Sertao de Sao Francisco hoped to gain access to electric power for the first time.

In 1997, the National Renewable Energy Laboratory (NREL) estimated that twenty million Brazilians went without electricity.²² In order to get coal-fueled power to rural inhabitants, utility companies expect exorbitant costs; most of this expense stems from removing physical barriers. Rather than resort to destroying Brazil's already rapidly-depleting ecosystems, projects such as the NREL/CEPEL cooperative allow

²² Roger Taylor, "Joint US/Brazilian Renewable Energy Rural Electrification Project," *Renewables for Sustainable Village Power* (Golden, CO: NREL FS-510-24195, 1997), p. 2.

people to plug into a better life without resorting to ecological sabotage. Financially, alternatives make sense, too. NREL estimates that funding PV cells, including installation, batteries, and training, costs half as much as extending existing power lines. How do people with newly found access to electricity use that power? In Sertao de Sao Francisco, the NREL/CEPEL project allowed people in four hundred dwellings to plug in old television sets and radios. These modern inventions let folks know about the vaccinations being housed at the PV-powered health clinic or about the new computers hooked up at the school.²³

South Africa's rural areas also prove difficult to supply with electricity. Like areas in Brazil, rural outposts in South Africa see no hope for electric power from traditional sources. Doug Arent figures that about one in every five citizens shouldn't expect electricity for at least a score of years.²⁴ The World Bank considers South Africa a likely candidate to achieve its national goal of providing PV cells to two thousand clinics and over sixteen thousand schools.²⁵ The same study estimates that one kilowatt per hour (kWh), the amount of energy needed to keep ten 100-watt light bulbs lit for an hour, of solar electricity will cost between eight and ten cents (\$0.08 - \$0.10).²⁶ Fossil fuel-powered plants typically do not exist in rural areas of developing nations, and the costs for constructing large energy-producing plants outweigh renewable alternatives. Thandizwe Frank Gwala, leader of the Kwazulu Natal tribe in the town of Maphephethe, expressed his hope that the solar panels serving his village's twelve thousand members

²³ Ibid., 1.

²⁴ Doug Arent, "Rural Electrification in South Africa," *Renewables for Sustainable Village Power* (Golden, CO: NREL FS-520-24633, 1998), p. 1.

²⁵ Edward M. Petrie, H. Lee Willis, and Masaki Takahashi, "Distributed Generation in Developing Countries," from the Dept of Energy web site, www.rsvp.nrel.gov, 6.

²⁶ Petrie, et al., p. 4.

will “give people independence.”²⁷ Not only do the PV cells power lights at Maphephethe’s schools, electricity means that people can begin to earn their livings closer to home.

The answer to the question, “Can solar electricity really make a difference?” then, is yes. The world houses two billion people that lack electricity.²⁸ Setting up non-polluting electricity sources will help keep carbon emissions from getting out of control, but photovoltaics can do more than help reduce climate-altering carbon dioxide emissions. Robert Foster, head of the Southwest Technology Development Institute, thinks there is something subversively appealing about solar electricity:

The unique aspect of PV is that it is a ‘radical’ or ‘disruptive’ type of technology as compared to conventional power generation technologies. PV is a technology that does not build from the old technology base, but rather replaces that base from the bottom up. PV allows people the opportunity to ignore traditional electrical power supply structures and meet their own power needs locally.²⁹

The independent streak Foster expresses also parallels the sentiments of Thandizwe Frank Gwala. The promise of tomorrow must depend on our willingness to share what we know with other people; equally important is our ability to adapt to a changing world. By learning what we can from each other and pushing for sustainable energy paths other American communities can replicate San Francisco’s success.

²⁷ Quote in *Siemens Review*, “A Zulu Village Looks to the Sun: An Interview with Thandizwe Frank Gwala,” 3-4/96, p. 25.

²⁸ Petrie, et al., p. 1.

²⁹ Robert Foster, “Photovoltaic Markets and Applications” from the El Paso Solar Energy Association’s web site at www.epsea.org/pv.html.

Chapter 4



Son of Wind, Ready-to-Give: Wind Energy and the Lesson of Constancy

My son, I am your father. I am one of the gods and
I stand in the north. My name is Ready-to-Give.
When the people are hungry for buffalo, I blow my
breath upon the land. My breath drives the buffalo
to the people, and they slaughter many.

Yellow-Bird, Chaui (Pawnee) leader, "The Son of Wind, Ready-To-Give"

With the wind comes the buffalo. Like many of its neighbors on the prairie, the buffalo meant more to the Chaui Pawnees than an animal to hunt. It was a way of life. The sustenance provided by this icon of the American Great Plains meant that several tribes imparted a spiritual aspect to the animal. For the Chaui, wind played a vital role. In the tale related by Yellow-Bird, the wind figure appeared from the north during times of want and "send the people something to eat."¹ The ritual that called forth the wind spirit, known as Ready-to-Give, became a vital part of Chaui life.

From an early point in its history, humanity has given thoughtful consideration to wind. In different places around the world, people have developed technologies designed to harness the power in gales and breezes alike. Part of wind's allure centers on the metaphorical qualities celebrated by Yellow-Bird, that of constancy. When the sun shines on our planet's surface, it warms air as well as land; when warm air rises, cooler air rushes in to fill the void, creating breezes. This chapter tells the story of humanity and wind, while also revealing wind's dependable nature.

Humans first became interested in harnessing wind's power thanks to its

¹ George A. Dorsey, *The Pawnee: Mythology (Part I)* (Washington, DC: Carnegie Institution of Washington, 1906), 94.

regularity. This chapter begins with a brief overview of wind technology in the ancient world. Next, I cover wind energy in the European Middle Ages. Technological developments and social implications merged across the continent as wind energy gained increased attention and importance prior to Europe's quest for empire in the Western Hemisphere. Finally I analyze wind in the modern era. I turn my attention to wind energy in the industrialized world, particularly the United States. As in the Middle Ages, wind technology gained utility in nineteenth century America, yet reliance on other fuels eventually stunted wind energy development. Paradoxically, wind today can thank its present usefulness to the centralized power structure that initiated the resource's early demise.² I analyze this apparent contradiction by tracing wind's transformation from an individualistic power source into one that makes use of the same centralized electrical grid used by other, more environmentally caustic, fuels.

Within the context of this thesis, wind energy might inspire comparison to the passive solar technological realm. People have long used wind as an energy source, and although we in the twenty-first century often refer to wind as an alternative, the practice of harnessing wind's power far precedes the use of fossil fuels. Like passive (and later active) solar designs, wind energy technology has adapted to reflect the needs of societies using it. Exhibiting characteristics more closely associated with active solar and hydro technology, modern applications of wind power produce electricity. For all the characteristics it shares with its renewable kin, wind energy has a story all its own. This chapter relates that tale and emphasizes wind's most compelling trait: constancy.

Washington, 1906), 94.

² Centralized power means electricity generated at a single point then distributed through power lines to end users.

Wind and People – A Long Relationship

Early development of wind energy technology relied, strangely enough, on water. When Egyptians hoisted their first square sails in 5000 BC, they demonstrated a pattern of technological development repeated around the globe from Egypt to China and beyond.³ Some experts think that as early 5000 BC ancient Egyptians used linen or papyrus sails to navigate the Nile River.⁴ The concept at play in these ancient sailing ships is known today as lift, and the design of the wind-catching sails did not change significantly for several centuries.⁵ This does not mean that such sails were particularly efficient. Energy expert Valclav Smils estimates that the Mediterranean square sail, attached to a mast and set at right angles across the ship's axis, did not operate very smoothly. Thus began a long struggle between engineers and the mercurial temperament of the wind. In Smils' estimation, engineers from different parts of the world came up with unique solutions to the problem of how best to capture the wind energy efficiently.⁶

At first glance these developments seem to have little to do with earth-bound wind power as we know it today. Yet, capturing the wind for sailing purposes had a dramatic impact on land-based wind technology. Like their sea-born counterparts, early grounded windmills related to water; unlike wind sails, these small windmills found their nascency in the arid fields of Persia, far from their ocean brethren. Needful of efficient ways to pump water and grind grain, the Persians developed the "carousel" style

³ Polynesians, too, acquired a vast store of knowledge about the winds even though they probably didn't use sails. See Robert Righter, *Wind Energy in America: A History* (Norman: University of Oklahoma Press, 1996), 6.

⁴ See "History of Wind Power" at <http://www.ews.uiuc.edu/~enation/History.html>. Robert Righter puts the date at 3100 BC; see Robert Righter, *Wind Energy in America*, 6.

⁵ Darrel M. Dodge, "Illustrated History of Wind Power Development," from website <http://www.telosnet.com/wind/index.html>.

windmill by 500 AD.⁷ Engineers constructed wind scoops made of reeds or wood then attached the bundles to a vertical shaft. When the wind caught the bundles, they spun on a horizontal plane, much like the horses of a modern carousel, and turned a vertical shaft that created mechanical energy.⁸

In Europe, wind and water parted ways during the classical Greek and Roman eras. Used primarily as power for milling grain, flowing water exhibited a characteristic not as readily found in wind: consistency. As early as the first century BC, a Thessalonian, Antipater, wrote of a simple machine driven by water power.⁹ Later, ancient Roman solar architect Vitruvius reported a design for waterwheels found throughout the Mediterranean world.¹⁰ While technological innovation benefited waterwheels in the Roman world, no European society invested much time tinkering with windmills.¹¹ With a large population and widespread slavery, Rome had little incentive to develop labor-saving machines.

Middle Ages Europe: The Ascendancy of Mechanical Energy

In the centuries following the breakup of the Roman Empire, several powers sought to establish themselves as legitimate successors. An Arabian presence filled the void in the eastern and southern Mediterranean world, and in these regions, wind power continued as an important energy source. Yet in Europe, wind technology development all but ceased. Political turmoil constantly threatened public order; warfare became

⁶ Valclav Smils, *Energy in World History* (Boulder: Westview Press, 1994), 137.

⁷ *Ibid.*, 108; see also, Righter, *Wind Energy in America*, 7.

⁸ Dodge, "Illustrated History of Wind Power Development," 1. We don't really know what these machines looked like, as scribes only mentioned them in writing and didn't draw them. Dodge's website has a speculative illustration.

⁹ Smils, *Energy in World History*, 103.

¹⁰ *Ibid.*, 103.

common for much of the continent; famine sickened many; and those who survived had to deal with disease. Population dwindled, leaving few hands to undertake the burden of harvesting crops and grinding grain.

As Europe moved into the post-Roman era, the economic structure centered on agriculture. The manorial economy that would develop centered on hierarchical allegiances, with the monarch at the top and peasants at the bottom. Nobles, clerics, and other middlemen all benefited from the system because they owned the land used by peasants to raise crops. Agriculture, labor intensive as it was, formed the foundation upon which Europe built its society in the Middle Ages. Low populations meant less available muscle power and a greater demand for alternative forms of energy. While Rome's huge population offset the demand for labor-saving technologies like wind, the sparsely populated nations in the Middle Ages bore such burdens more heavily.

In response to labor shortages, European nations developed two important renewable resources: wind and water. Prior to the Middle Ages, Europeans generally used wind as a way to control water, either by sailing over it or by pumping the resource from the ground. By 1000 AD, the relationship had changed. Water power emerged as a leading energy source in the first millennium thanks to the vertical waterwheel. A departure from its inefficient horizontal brethren, the vertical wheel, also known as the post-mill, was a simple design. Rather than spinning around horizontally, engineers flipped the wheel to an upright position, moving the power-producing axle to a horizontal station.¹² This seemingly insignificant shift made a huge difference in the power

¹¹ Righter, *Wind Energy in America*, 7.

¹² Also known as the Greek or Norse wheel, these machines spun horizontally, along with the rushing water, and generated just enough energy to power a millstone. See Smils, *Energy in World History*, 103; Braudel, *The Structures of Everyday Life*, 354-5.

waterwheels could generate. An undershot machine, whose paddles gathered water at the surface of a flowing stream, could boost the waterflow's energy output eightfold and greatly reduce the amount of people required to accomplish basic tasks, like grinding grain.¹³

Despite an increase in energy capacity, vertical waterwheels had little impact on Middle Ages Europe, where windmill technology materialized slowly. In what historians term the "Medieval Industrial Revolution," a slow series of technological innovations occurred over three centuries.¹⁴ Water technology was the catalyst. The Domesday Book of 1086 reported 5,624 watermills in England, where the manorial economy had taken root.¹⁵ The waterwheels that powered the self-sufficient manors of Middle Ages Europe created a problem when nobility began asserting ownership rights over flowing streams. Resolution of this conflict provided a boost to windmill technology.

In the twelfth century, the papacy mandated that nobles and clerics held the rights to flowing water. The decree bestowed watermill rights as well, and owners could depend upon steady income from a certain market and perpetual control over lower classes. Rivers provided the central feature of towns during the Middle Ages, and the agrarian community, the bulk of European society at this time, depended on waterwheels to mill grain. Manorial control over towns began to suffer challenges from an emerging middle class that grew tired of a stagnant class system.

Across Europe, wind energy became a popular form of economic and social

¹³ Smils, *Energy in World History*, 103. Such machines existed in Rome.

¹⁴ Braudel, *The Structures of Everyday Life*, 353; Righter, *Wind Energy in America*, 8. Braudel reports that water had other applications, as well, including tidal power in the Islamic and European worlds; see Braudel, 354; Righter reports that William the Conqueror's invading hordes saw them in the Norman Invasion of 1066, Righter, 8.

¹⁵ Smils, *Energy in World History*, 103; Braudel, *Structures*, 356.

protest. Small farm owners built wind-powered postmills to avoid costly milling fees. Windmills saved money by milling grain without fuel or time costs, and people could build them cheaply.¹⁶ Northern Europe's environment also had an impact. In communities that relied on smaller streams for their energy supply, cold winter weather could disrupt productivity. People alert to the dangers of freezing could prevent such an interruption of power by building windmills that were less likely to succumb to cold temperatures.¹⁷

Monetary concerns helped develop European wind technology, but wind's ubiquitous character also reflected independence in the people who embraced it. At a time when the daily lives of most people were controlled by a rigid power structure, wind provided an outlet for self-sufficiency. Even though they were cheap to build, windmills entailed a considerable gamble. Raising such machines risked upsetting waterwheel owners, generally the same people responsible for the daily governance of the community. These town rulers held power by rights granted by infallible monarchs and popes. Pope Celestine III, who ruled in the late twelfth century, issued a decree ordering windmill operators to pay tithes, or fees to the church.¹⁸ Hence, the people who dared challenge the local authorities also ran the risk of upsetting the center of European society. As wind energy expert Robert Righter asserts, "(a) tiny ruling class, which thrived on monopoly and privilege, began to lose out to rural entrepreneurs and a growing urban middle class" that saw the technology as a way to better their lives.¹⁹ The growing appeal of windmills also hints at a shifting society. Lynn White, Jr., explains

¹⁶ Debeir, et al., *In the Servitude of Power*, 78.

¹⁷ Lynn White, Jr., *Medieval Technology and Social Change* (Oxford: Oxford University Press, 1962), 88

¹⁸ *Ibid.*, 88.

¹⁹ Righter, *Wind Energy*, 13.

that technologies such as post-mills led to complex cultures founded more on individual freedom than forced labor.²⁰ The success of water and wind power changed European society by freeing its citizens to pursue other ambitions.

In Holland, wind technology became a national icon. The same tower windmills that drained water from the encroaching North Sea also served as symbols of public sentiment. Windmills drained low-lying land, known as polders, and served as living quarters for millers and their families, which often christened their homes with proper names.²¹ Improved blade designs made the machines more efficient and made public displays more prominent. On somber occasions, millers stopped the four blades in a way that reflected a Christian cross. When celebration was in the air, the locals adorned the sails with colorful banners.²² Holland thrived as a global power on the cusp of the modern era; in the golden era of the seventeenth century, windmills played a vital role for the nation. The preindustrial motor had staying power, dominating Holland's power market well into the industrial era. Wind accounted for roughly ninety percent of the country's energy in 1850.²³

Wind Energy in the Industrial World

By the mid-nineteenth century, wind technology could not compete physically or financially with the fossil-powered industry. A century before, several European nations began their evolution from a patchwork of self-sufficient manorial societies into nations competing for resources across the globe. The political structure also saw a shift, as strict

²⁰ Lynn White, Jr., *Medieval Religion and Technology* (Berkeley: University of California Press, 1978), 223.

²¹ Righter, *Wind Energy in America*, 14.

²² Smils, *Energy in World History*, 109; Righter, *Wind Energy in America*, 15.

regimes of the sixteenth century slowly gave way to more enlightened, secular rulers in the eighteenth. This change led to a new era of European intellectual and technological achievement, and the gradual gains made during the repressive Middle Ages gave way to accelerated development in the modern age.

In the United States, the transition to steam power came more slowly. Much of the nation still depended on water and wood for power in the antebellum period, but after the Civil War, industry demanded fossil resources. In the American Midwest, coal had an early influence over industry, but wind technology held the attention of individuals determined to survive on the Great Plains. Connecticut native Daniel Halladay perfected his multi-bladed farm windmill by 1857, and moved his company, the Halladay Wind Mill Company, to Batavia, Illinois shortly after.²⁴ Soon, the farm windmill would head across the Mississippi River and earn a reputation as a symbol of American independence.

The windmill's introduction to the Great Plains came alongside coal-powered railroads. Industry in the East sought the natural abundance and new markets of the American West, and the transcontinental rail line provided a vital link between them. The steamships that journeyed through the Great American Desert constantly threatened engines with overheating, and railroad companies searched for ways to supply cooling water for the boilers. The Halladay windmill proved the perfect solution because it operated without human assistance, and the water-pumping machines could keep railroad station water towers well stocked. The unique design of the Halladay also adapted to the gusty conditions of the Great Plains. Unlike the sturdy four-bladed Dutch tower mill, the

²³ Paul Gipe, *Wind Energy Comes of Age*, (New York: John Wiley & Sons, 1995), 122.

American farm windmill had numerous, feathered blades connected to a central hub that powered the water pump. The spindly, futuristic design allowed the sections to furl inward during heavy winds.²⁵

Windmills may inspire romantic notions as we look back on them today, but in the late nineteenth century people depended on them for survival. In his classic work, *The Great Plains*, Walter Prescott Webb argues that three things made white settlement of the American West possible.²⁶ The first two, barbed wire and the Colt .45, kept some semblance of order out past the reach of the law. The third, the windmill, played a far more important role. Webb notes that the familiar, multi-bladed machines allowed farmers to pump water for thirsty crops and ranchers to water livestock in the good years. When drought hit the Plains in the late 1890s, windmills took on even greater significance because they “enabled the homesteader to hold on when all others had to leave....(windmills) made the difference between starvation and livelihood.”²⁷

Even as homesteaders on the Great Plains turned to the farm windmill for survival, innovators back East pushed the technology in new directions. In northern Ohio, a thousand miles from the arid farms of the West a millionaire industrialist experimented with wind energy. Charles Brush made his fortune by creating the famous Brush arc light in the 1870s, but the inventor’s pioneering spirit was far from satisfied. The next decade, Brush began experimenting with electricity. The nation had taken to this exciting new phenomenon, as people all over the nation lined up at shop windows to

²⁴ Gipe, *Wind Energy Comes of Age*, 124 and Righter, *Wind Energy in America*, 24. Halladay moved his company to Batavia, where he changed its name to the US Engine and Power Company.

²⁵ Righter, *Wind Energy in America*, 24-5. The machines faced away from the wind.

²⁶ Walter Prescott Webb, *The Great Plains* (New York: Grosset & Dunlap, 1931), 320.

²⁷ *Ibid.*, 346.

bask in the glow of electric light.²⁸ During the winter of 1887-88, Brush invented the first electricity-generating windmill in the world.²⁹ The colossal “Brush windmill” stood sixty feet and weighed 80,000 pounds. The Brush windmill had a gear ratio of fifty to one: for every revolution of the tightly-packed blades, the electricity-generating dynamo would turn fifty times, generating about 12 kilowatt hours (kWh).³⁰

While small electricity-generating stations operated in major American cities by the turn of the century, a major development in Chicago proved a catalyst for what would become the nation’s electric grid system. In 1903 Samuel Insull funded installation of a five megawatt (MW) turbine generator that produced electricity in alternating current (AC). Until that time, electricity production came in two inefficient forms. Direct current (DC) was a direct byproduct of late nineteenth century generators. Although easy to produce, the DC current was nearly impossible to transport over distances of more than a couple of miles.³¹ Until 1903, the other alternative was to produce AC power with an inefficient reciprocating steam engine that cost over twice as much per watt than rotating steam turbines.³² First produced in 1884 by Englishman Charles Parsons, the rotating steam turbine could create electricity cheaply and in the more readily transportable AC form. Soon a grid system emerged that included a central electricity-producing station and transmission, or power, lines that transported electricity to end users, much like today’s distributed electricity system.

Mindful of America’s growing dependence on the centralized grid system,

²⁸ See David E. Nye, *Electrifying America: Social Meanings of a New Technology* (Cambridge, MA: The MIT Press, 1990).

²⁹ Righter, *Wind Energy in America*, 43.

³⁰ *Ibid*, 43-5.

³¹ Richard Rudolph and Scott Ridley, *Power Struggle: The Hundred-Year War Over Electricity* (New York: Harper & Row, 1986), 26-8.

Charles Brush turned his considerable energies away from wind-generated electricity. Tying into the grid simply didn't make economic sense for windmills, and sinking the necessary capital into such an enterprise was a risk Brush was not willing to take. As Brush explored other possibilities, Dane Poul LeCour set about proving that wind energy could contribute to the electricity supply. Backed by the Danish federal government, LeCour designed and built 40 electricity-generating windmills in 1906.³³ LeCour's accomplishments set European wind energy on a different course than America's. The Danish government understood wind's potential, and funded studies to determine the best areas for windmills, called siting. Interest in wind energy spilled beyond Denmark's borders, as Germany and Great Britain invested scientific capital in the potential electricity provider.³⁴

While Brush's achievements made wind a viable, if impractical, energy source, at the time of his death in 1929 the nation as a whole wasn't ready to embrace the breezes as a source of electricity. Demonstrated successfully by Samuel Insull in Chicago, championed by corporate leaders, and powered by fossil fuels, the centralized grid system emerged as the main energy providers in American cities.

On the Plains, a significant number of farmers continued to use windmills to pump water, and in some cases, power low voltage batteries. Mail-order catalogs enticed farmers with electric gadgets, and many sold kits that allowed farmers to retrofit their windmills with a generator and a battery. The company that cornered the market,

³² Jeff Hein, "1896 to 1928: Electric Industry Evolves," *Closed Circuit* (vol. 25, no. 20, September 26, 2003), reproduced at website www.wapa.gov/media/cct/2003/sept26/25no206.htm last visited May 8, 2004.

³³ Righter, *Wind Energy in America*, 61.

³⁴ *Ibid.*, 61-5. Part of the explanation for Europe's lead might be that electricity on the continent comes to consumers as direct current (DC), an easier form to generate with renewables like wind and solar, rather than the alternating current (AC) that came into use in the US. See Nye, *Electrifying America* and Ridley, *Power Struggle*.

however, didn't need mass marketing. The legendary Jacobs Wind Electric Company began in 1927, and despite a distaste for advertising, sales numbered in the hundreds of thousands through the thirties and forties.³⁵ The reliable, affordable windmills earned a reputation for reliability, and the company stubbornly remained in business until 1956. The Jacobs model changed the look of rural wind machines (and, later, modern turbines) by using only three blades. The design powered a 32-volt battery for modest home appliances.³⁶

Country windmills retrofitted with electricity-providing generators and batteries couldn't quench the thirst for modern power. As the Great Depression descended upon the nation, a progressive government took power in Washington, DC. The economic squeeze that began on the farm in the twenties, brought on by overproduction, got worse in the thirties, and FDR vowed to lift country folk out of their miserable conditions. The Rural Electrification Act of 1936 created the Rural Electrification Administration (REA) and promised to ease the suffering on American farms by extending the high line out into the countryside. The aim was to allow the people there the same quality of life afforded to those in the cities. As the federal government promised to preserve local control, the effect of hooking farms up to the centralized grid had the opposite effect.

President Roosevelt tapped former Tennessee Valley Authority head Morris Cooke to head the newly formed REA. Cooke quickly learned the prohibitive financial cost of extending electric power, known as the high line, to the countryside. Wisconsin Power and Light assessed the cost of setting up electricity wires at \$1,405 per mile, and

³⁵ Ibid., 99.

³⁶ Ibid., 90-9.

utility boss Samuel Insull figured a range between \$800 and \$2,400 per mile.³⁷ Cooke's REA encouraged farmers to form cooperatives, apply for federal loans, and string the wires themselves.³⁸ Co-ops proved effective in hooking rural America up to centralized power, but cheap electricity also transformed the American farm. With grid-powered tools, "electricity helped make much of the farm population superfluous."³⁹

The REA unwittingly brought big business to the farm and sounded the death knell for wind energy. FDR had hoped that extending power to farmers would save the independent family farm. Even as farmer-led cooperatives provided some semblance of local control, the centralized grid fell under the direction of a powerful federal agency that was unwilling to adopt variations to its theme of supplying electricity to country folks. Wind advocates appealed to administrative and legislative officials for some role for wind energy within the REA to no effect.⁴⁰ Savior of the late nineteenth century homesteaders, the windmill fell out of favor in the 1930s.

Wind energy could not compete with fossil fuels in the Great Depression. The windmill created by Charles Brush generated electricity in direct current (DC) form, which required either immediate use or an efficient storage system. Utilities could not distribute DC electricity more than a few miles without losing potency, so rather than build dams or power plants in the center of town, utilities started generating alternating current (AC) electricity and sending it over insulated wires to customers. Until Samuel

³⁷ *Ibid.*, 108-9.

³⁸ *Ibid.*, 113. The REA received legislative blessing in 1936 by Congress when it signed the Rural Electrification Act; a sticking point for utilities was the danger of the REA acting without congressional assent, thus potentially falling into dangerous constitutional waters.

³⁹ David Nye, *Electrifying America*, 328.

⁴⁰ Robert Righter describes the plight of wind advocate R.F. Weinig and his testimony before Congress in 1945. Weinig pushed for an amendment to legislation amending REA that would allow for individually operated energy plants. To Congress, though, windmills belonged to the history books. See Righter, *Wind Energy in America*, 121-5.

Insull consolidated power plants into large, capital-intensive corporations in the 1910s, cities had several power plants that supplied power to a small number of customers. The centralized grid was well established in American cities after 1910, and by World War II, electricity had transformed the American farm.⁴¹

Wind advocates tried to create machines that generated alternating current. In 1944, on Grandpa's Knob, Vermont, Palmer Putnam tried to provide the answer. Putnam addressed two, interrelated issues: converting wind energy into AC and doing so affordably. With its huge size, the Smith-Putnam wind turbine looked like a descendant of the Brush windmill, itself the product of a unique partnering effort between academia and private interests, was an enormous machine. Its diameter stretched 175 feet; even at 16 tons, the rotor weighed a fraction of a single blade.⁴² Putnam operated on the economy of scale principle that had previously directed utility companies, like Samuel Insull's General Electric. For Putnam, Insull, and others, the object was to find a way to generate electricity cheaply, which usually meant making it in large quantities. The idea worked for Insull, but not for Putnam. While the Smith-Putnam managed to operate for about sixteen months, it could not live up to its fiscal promise.⁴³ A blade came loose in early 1945, tumbling into the Vermont woods. The wind plant already cost its financial backers one million dollars, and the bill for fixing such a mammoth problem was \$300,000 and exposed a weakness of relying on the economy of scale theory. The project had failed, but it did set a precedent.

⁴¹ Nye, *Electrifying America*, 382. The reluctance to build power plants in urban areas probably had more to do with transportation issues than health, although that's only an educated guess (the power plant near my hometown lay right on the rail line).

⁴² Darrell M. Dodge, "Illustrated History of Wind Energy," 4.

⁴³ "Economy of scale" refers to large-scale projects with inputs of capital large enough to bring the consumer cost of such technology down.

For wind energy to compete with other fuels, advocates had to draw upon a familiar characteristic, reliability. Technologically, engineers had to solve the problem of generating AC electricity, which requires rigid speed regulation. The wind blows at different speeds, but alternating current generators need a steady energy input. For all its shortcomings, the Smith-Putnam turbine managed to break through this engineering barrier. Federal Power Commission officer Percy Thomas thought he could improve Putnam's design. Thomas proposed linking windmills to hydro plants to ensure steady fuel input: when the breezes stopped blowing, water would take over the job of feeding the grid. When the dams weren't generating electricity, they would store water until it was needed. The American West was best suited for such a relationship, Thomas thought, because of its abundant wind and limited water supply.⁴⁴ Federal funding for research and development took a different turn in the post-World War II years, however, as success with atomic weapons spurred scientists and engineers to apply nuclear power more peacefully.

The story was different in Europe, where tenacious Danish farmers did their best to offset the oppressive German regime during WWII. Tapping into knowledge gained over several centuries, common people turned to wind power when Nazi administrators cut citizen access to the centralized grid, building over 90 electricity-generating turbines.⁴⁵ Fossil fuel remained sparse in the immediate postwar years, but by the 1973 OPEC oil embargo, Denmark had embraced the global market, importing over ninety percent of its energy.⁴⁶ In the early seventies, the nation's long history of using wind energy helped the nation counter fuel shortages. Engineers developed the three-bladed

⁴⁴ Righter, *Wind Energy in America*, 139. Despite its merit, policymakers have yet to implement the idea.

⁴⁵ *Ibid.*, 317, note 33; Gipe, *Wind Energy Comes of Age*, 53.

windmill based on medium-sized turbines designed in the 1950s, known as Gedser mills; the new look quickly became the flagship of the Danish windmill fleet. The modest size converted wind into electricity efficiently, and repairs costs remained affordable. The Danish government also spurred private investment by offering energy production incentives. The approach differed greatly from that in the US, where most federal investment financed huge research and development projects. Denmark funded a paltry ten percent of that amount on R&D in the same period.⁴⁷ Despite its small size and tight budget, Denmark could brag of owning over half of the world's wind market share by 1992.⁴⁸

In the 1940s, American political leaders urged scientists to think big. The fate of the world depended on which nation could unlock the atomic door first. After the bomb ended the war, the federal government poured billions of dollars into peaceful uses for nuclear power. Atomic power promised to provide so much energy so cheaply that “it wouldn't pay to meter it.”⁴⁹ As Congress waited patiently for nuclear power to come of age, the federal government financed another big dream. President Kennedy challenged scientists and engineers to land an American on the moon by 1970, a fantastic goal in 1961, yet the huge financial investment paid off in 1969. The lesson for American policy makers became clear. Given big enough dreams, with enough cash to chase them, and Americans could accomplish anything. Such was the logic in Washington when the oil embargo rocked the nation in 1973.

In response to the OPEC embargo and ensuing energy crisis, the United States

⁴⁶ Gipe, *Wind Energy Comes of Age*, 51.

⁴⁷ *Ibid.*, 72.

⁴⁸ *Ibid.*, 73.

rejuvenated its stagnant wind energy program. Federally-funded partnerships enlisted the collaboration of aerospace and defense industries in a sudden surge of research and development. Almost immediately the well-established contractors set about spending exorbitant amounts of money on risky designs. The logic that drove companies like Boeing and McDonnell Douglas was to adhere to the economies of scale principle: build big machines that could generate huge amounts of power and profit. Unlike Danish designers, who relied upon proven modest success, American researchers scrapped earlier, proven designs in favor of larger projects. At Sandia National Laboratory in New Mexico, the Alcoa Corporation tried to replicate the French vertical-axis, Darrieus-type wind turbine. Designers hoped the prototype, which resembled a giant egg-beater, would make an immediate impact. The best that the well-funded modern Darrieus could manage was operation as a water-pumping machine at the federal research facility in Bushland, Texas.⁵⁰ Other projects had similar ambitions. Unfortunately, they also had similar results.

The highly publicized MOD (modification) program sought to impact American wind technology immediately. Begun in 1975, these first generation large turbine, two-bladed windmills made legendary performances. NASA designed and built the MOD-0 (zero) machine, which was rated at 100 kWh – enough energy to power about 27 homes. Engineers sited the million dollar MOD-0 machine near Sandusky, Ohio, where it operated for a mere thirty hours in 1976.⁵¹ Three years later, federal contractors started another project in Boone, North Carolina. Although the MOD-1 used none of the

⁴⁹ David Lilienthal, first head of the Atomic Energy Commission, quoted in Righter, *Wind Energy in America*, 144.

⁵⁰ Gipe, *Wind Energy Comes of Age*, 85, 171. The project received \$28 million from 1974 to 1985.

valuable data gathered from the earlier MOD project, problems did not have a chance to surface. Noisy blades raised concerns of nearby residents who eventually shut the project down.⁵²

By the time MOD-2 appeared, the American wind energy program had achieved little success. Despite discouraging data, project managers pushed forward with a similar design on a grander scale in what they hoped would be a breakthrough. In 1982, NASA and the Department of Energy sank millions into turbines twice the size of the MOD-1, with a capacity of 2.5 megawatts.⁵³ The Bureau of Reclamation sponsored a plan to bring two MOD-2 machines to Medicine Bow, Wyoming. Once in place, the turbines almost immediately ran into problems. After running a mere eighteen months, one windmill developed a fatal problem when a vital mechanical part, the main bearing, burned out. After the Bureau received a repair bill for \$1.5 million, it decided to scrap the windmill, dumping it to a junkyard for \$13,000. The other MOD-2 remained in operation for over four years. A bolt eventually came loose, burning up the generator, and the Bureau was forced to dump the turbine to a local man for \$20,000.⁵⁴

For wind energy experts, the federal investments of the 1970s and 1980s leads to very different conclusions. For National Renewable Energy Laboratory (NREL) wind technology development manager James Thresher, all the failures of the period merely reflect a growing period for American wind technology.⁵⁵ Research and development

⁵¹ Ray Reece, *The Sun Betrayed: A Report on the Corporate Seizure of U.S. Solar Energy Development* (Boston: South End Press, 1979), 87.

⁵² Dodge, "Illustrated History of Wind Power," 6 and Gipe, *Wind Energy Comes of Age*, 103-4. Gipe reports that the noise problem made MOD 1 the first wind project to generate national attention.

⁵³ Gipe, *Wind Energy Comes of Age*, 104.

⁵⁴ Righter, *Wind Energy in America*, 175-8. The purchaser of the larger turbine eventually got it running again; in 1994, one of the two blades came loose, sailing a hundred feet above the 250 foot tower.

⁵⁵ Gipe, *Wind Energy Comes of Age*, 70.

critic Ray Reece argues that the corporate influence stunted meaningful progress.⁵⁶

The MOD projects illustrate the problems with American wind energy technology in the 1970s and 1980s. Familiar companies suddenly appeared as wind experts. General Electric built the 2 megawatt (MW) MOD-1 machine that failed in Boone, North Carolina. Boeing got the contract to design and build the enormous 2.5 MW MOD-2 windmills, one of which famously failed at Medicine Bow, Wyoming. United Technologies Corporation subsidiary, Hamilton Standard, bears responsibility for the other Wyoming failure. The respective companies earned most of the sixty million dollars that taxpayers paid for the MOD-2 program. Yet for all the time and money put into the wind program, American companies continued to lag behind their European counterparts. While Boeing, United Technologies, and General Electric all benefited from federal investment during the energy crisis, none of these big companies made America the leader in wind technology. Paul Gipe puts a cynical spin on the American wind energy experience through the mid-eighties, arguing that American policymakers focused on research and development when they should have tried market incentives.⁵⁷

As the United States poured millions into research and development after the energy crises of the seventies, other nations sought to rebound from the shock of limits. Across the Atlantic, the Danish government turned to native expertise to offset Denmark's woeful dependence on foreign oil. At the time of the OPEC embargo, farming accounted for most of this Indiana-sized country's industry, a factor that would impact Denmark's rise to prominence in wind technology. Danes had a long tradition of using wind energy. Poul LeCour designed an electricity-generating windmill, and the

⁵⁶ Reece, *The Sun Betrayed*, 87-8.

⁵⁷ Gipe, *Wind Energy Comes of Age*, 92.

world's first wind power plant came on line by 1920.⁵⁸ Danish farmers turned to the breezes during World War II by constructing windmills based on LeCour's machines.

In the postwar years, two leaders emerged from Europe. German scientist Ulrich Hutter relied on the most modern equipment available to power the largest turbines he could design. Hutter's huge, two-bladed machines topped 100 feet in diameter. The German's success would lead countless other engineers into a futile chase to replicate his success half a century later.⁵⁹ In Denmark, Johannes Juul created a revolutionary design. Stressing a common-sense, empirical approach, Juul first experimented with two- then four-bladed windmills. Ultimately concluding that three blades would work best, Juul built an inexpensive prototype. Juul built the Gedser mill, forerunner of virtually every successful, three-bladed design in use today. Unlike those nations that sank millions into high-tech research, Juul and his compatriots enlisted a bottom-up approach that emphasized durability and modesty.

The partnership between Denmark's government and industry also explains Danish success. Danish agriculture provided a vital market for wind energy technology in the late 1970s. Operating through cooperatives, farmers banded together to raise the necessary capital for generating wind electricity. By the mid-nineties over a quarter of a million Danes owned some interest in a windmill co-op.⁶⁰ The central government played an important role, too, by providing capital subsidies and performance incentives. The landmark Windmill Law requires Danish utilities to purchase electricity from

⁵⁸ *Ibid.*, 53.

⁵⁹ *Ibid.*, 77-80. When NASA started its work on the wind turbines in the 1970s, they purchased Hutter's blueprints. The success of the MOD program indicates Hutter's complexity and genius: Hutter's two-bladed machine ran for 12 years for a total of 4,200 hours, far longer than most of the MOD turbines.

⁶⁰ *Ibid.*, 59.

windmills at eighty-five percent of the price that consumers pay.⁶¹ In this way, the Danish government provides an incentive based on energy output, rather than enticing consumers to purchase wind-powered equipment. Denmark also provides grants and loans tied to projects undertaken in other countries. The Danish International Development Agency allows generous payback periods for purchasing Danish equipment or the cost of setting up Danish-owned manufacturing facilities. Denmark's relationship with India proves the success of the program. The export assistance regulations sparked interest in India during the 1990s, while simultaneously keeping Denmark's position as a leader in the international wind industry.⁶²

American Responses to Crisis

In the US, California took the lead as the biggest promoter of wind energy technology. Governor Jerry Brown created the Office of Appropriate Technology (OAT) in 1976. Working with the California Energy Commission (CEC), itself established as a result of the OPEC oil embargo, OAT set the stage for wind energy's boom in the 1980s.⁶³ Using funds from the Mello Act of 1978, a California law mandating investment in wind energy, the CEC set about mapping the state's wind potential. While other states provided tax incentives similar to California's, none allocated money to provide data for potential wind sites.⁶⁴

The state also enticed investment by working with federal legislation. The

⁶¹ Louise Guey-Lee, "Wind Energy Developments: Incentives in Selected Countries" (Washington: Energy Information Administration, 1999, from website www.eia.gov), 6.

⁶² *Ibid.*, 6-7. India quickly became the "developing" nation with the most wind capacity in the world and ranks fourth among all nations, behind Germany, the US, and Denmark.

⁶³ CEC was formed in 1974 as a result of pressure from the anti-nuclear power wing of the California legislature. See Williams, *Energy and the Making of Modern California*, 311, 322-4.

⁶⁴ Righter, *Wind Energy in America*, 204-7.

National Energy Tax Act of 1978, one of five laws in the landmark National Energy Act, allowed investors to write off one quarter of a wind system's cost.⁶⁵ California allowed another twenty-five percent for non-residential systems, clearly hoping to spur investment in large-scale wind power plants. Taken together, state and federal tax breaks allowed investors to write off half a wind system's cost. All the encouragement led to a transformation of California's landscape. By the mid-eighties, over twelve thousand windmills graced California's golden hillsides, generating over 900 MW of electricity.⁶⁶ At the height of the wind rush, Danish turbines flourished: in 1985 over half the windmills installed in the United States came from Danish companies.⁶⁷ California's leadership allowed the state to lead the nation in wind energy production, despite it being only the seventeenth best state in terms of wind potential.⁶⁸

Despite its tremendous resources, the US has fumbled its advantages away. In 1997, Germany wrested the lead from America: the Germans had installed a generating capacity of over six thousand MW, while the US stood at about half that.⁶⁹ By October 14, 2002, Germany had cemented its role as world leader with over 10,500 MW installed capacity.⁷⁰ The US government released a study in 1998 that shows the breezes that blow across the nation could provide 10,777 billion kWh of electricity every year, far surpassing the capabilities in Denmark and Germany. In the same year of the report, the

⁶⁵ *The National Energy Act*, Printed at the Request of the Committee on Energy and Natural Resources (Washington, DC: Government Printing Office, January 1979), 540-7.

⁶⁶ Righter, *Wind Energy in America*, 215.

⁶⁷ *Ibid.*, 218. The CEC reported in 1993 that 43% of the turbines in California were Danish. See Gipe, *Wind Energy Comes of Age*, 36.

⁶⁸ Christine Real de Azua, "The Future of Wind Energy," 14 *Tulane Environmental Law Journal*, 485 (2001), 507.

⁶⁹ *Ibid.*, 506.

⁷⁰ "German Wind Market up 35 pct/yr," Reuters News Service, October 14, 2002, from the website www.planetark.org. While Germany holds the global lead, Denmark provides most of the hardware; that explains my emphasis on the latter nation in this chapter.

US consumed 3,629 billion kWh of electricity.⁷¹ With all of this potential, why has the country not pursued cheap, wind-generated power? Since President Carter's 1978 National Energy Act, three characteristics have emerged that help explain America's reluctance to embrace wind energy: resistance from utilities; environmentalist opposition based on aesthetics and avian mortality; and allegations that wind energy prohibits economic stability.

The most significant act of the five-part National Energy Act also caused the most controversy. The Public Utility Regulatory Policies Act (PURPA) includes a provision that requires utilities to purchase power generated from an independent, "qualifying" facilities (QF).⁷² Congress intended to break the stranglehold that utilities had over energy by allowing diverse sources to contribute to the nation's energy supply. The legislature also knew it had to figure out how much these qualifying facilities could charge utilities, which fought PURPA regulations strenuously. Political compromise eventually produced a workable solution. The Federal Energy Regulatory Commission (FERC) established the way utilities interconnected with independent producers as well as advise state regulatory commissions on the rates that QFs could charge utilities, known as "avoided cost," the rates equated to the amount a utility would have paid for energy produced elsewhere.⁷³ Utilities fought these provisions, arguing that such high costs would make basic energy unaffordable. When power companies were not instigating legal action, they were cheating alternative energy producers.

⁷¹ Christine Real de Azua, "The Future of Wind Energy," 493.

⁷² *The National Energy Act*, Printed at the Request of the Committee on Energy and Natural Resources (Washington, DC: Government Printing Office, January 1979), 304 (Public Law 95-617, Title II, §210(a)(2)). A "qualifying facility" falls under several categories, the most important for independent alternative energy is a "small power production facility:" one in the original act could not surpass 80 megawatts but now exceeds that amount. The largest turbines in operation today are rated at 1.65 MW.

⁷³ *Ibid.*, 305.

Delay tactics worked for utilities. The Supreme Court upheld two separate challenges to PURPA by the time the Reagan administration had come to power, while many investors withheld much-needed investment capital.⁷⁴ With Reagan's pro-utility regulators heading FERC, oversight of PURPA's most progressive provision loosened considerably, but President Carter's last significant energy contribution, the Crude Oil Windfall Profits Tax Act of 1980, boosted residential and business energy tax credits and extended those tax breaks through 1985.⁷⁵ Reagan's successor, George H.W. Bush, provided a huge boost to wind energy in the Energy Policy Act of 1992 (EPACT). The production tax credit (PTC), extended through 2003, allows qualifying projects to take 1.5¢/kWh tax credit.⁷⁶ In some cases utilities used PURPA and the PTC to prevent wind energy from coming on-line. In 1996, Southern California Edison convinced FERC that the state didn't need any more energy production, thus voiding contracts with wind energy providers.⁷⁷ Ironically, blackouts caused by insufficient energy supply plagued the state five years later.

Utility opposition to renewable energy sources probably didn't come as a surprise to most in the alternative energy industry, but wind advocates did find opposition from what seemed a staunch ally. Citing concerns for aesthetic diminishment and for undue bird deaths, some environmentalists have challenged the spread of wind power plants. On Cape Cod, Massachusetts, the issue has grown into a national debate. Cape Wind Associates has proposed a \$700 million project intended to develop an offshore wind

⁷⁴ *FERC v. Mississippi* was decided in 1982; the *American Paper Institute v. American Electric Power Service Corporation* decision came a year later.

⁷⁵ "Legislation Affecting the Renewable Energy Marketplace," from website www.eia.doe.gov/cneaf/solar.renewables/page/legislation/impact.html, last visited October 6, 2003.

⁷⁶ *Ibid.*

⁷⁷ Christine de Azua, "The Future of Wind Energy," 510.

power plant three miles offshore, but opposition from Robert F. Kennedy, Jr., Walter Cronkite, and David McCullough has slowed the project. Along with the Alliance to Protect Nantucket Sound and Save Our Sound, Kennedy and his supporters appeal to aesthetic sensibilities. Just as people are not allowed to build oil derricks in Yellowstone National Park, so those same energy interests should not be permitted to sully Cape Cod with futuristic visual pollution.⁷⁸

Wind advocates have confronted “not in my backyard” (NIMBY) arguments before. A decade ago, a similar struggle emerged in the desert of Southern California. Irked by turbines that generated noise and visual pollution, Palm Springs mayor Sonny Bono led an anti-wind campaign in 1989.⁷⁹ A year later, encouraged by public opinion polls favoring wind energy, Bono switched his position. Less publicized, but perhaps more persuasive, Mayor Bono pointed to the enormous financial benefits of having the wind industry in Palm Springs.⁸⁰ The fiscal argument has yet to convince Cape Cod residents, but planning for the project continues.

The average windmill today stands nearly 250 feet high with blades that span nearly 150 feet in diameter.⁸¹ Grouped together, these mammoth machines deter birds and other flying creatures from passing by unharmed, a point often made by anti-wind advocates. Referred to as “Cuisinarts of the sky,” windmills certainly seem a menacing presence to we featherless humans, yet appearances can deceive. A report by the National Wind Coordinating Committee (NWCC) indicates that wind generation

⁷⁸ Kennedy wrote an op-ed piece in the *New York Times* this past August; Cronkite appeared in a TV ad opposing the project, and McCullough provided the voice in a radio spot.

⁷⁹ Some of these turbines were left over from the boom years of the eighties; many did not work.

⁸⁰ Righter, *Wind Energy in America*, 227-34. Paul Gipe thought Bono should be praised for raising wind energy as an issue, which Gipe thinks invariably helps.

facilities kill between 10,000-40,000 birds every year, a seemingly significant number. The study also analyzes the results of other investigations that calculate avian mortality rates from vehicles, airplanes, buildings and houses, as well as other bird killers. Researchers disagree about exact numbers, but the range of deaths caused by non-windmill structures far exceeds that of birds killed by turbines. As far as danger to avian species go, bird feeders cause more deaths than windmills: the NWCC cites a study that found an average death rate of 0.85 per house in wintertime. Most species in the study were “passerines,” or perching songbirds, commonly seen at bird feeders.⁸² In comparison to other electricity-generating sources, wind power remains safer. A study in Citrus County, Florida revealed that two smokestacks killed about 500 birds per year between 1982 and 1986.⁸³ However, the wind energy community remains concerned about avian mortality, especially in the Altamont Pass area in Northern California, where several endangered California condors roam the skies. Altamont’s wind turbines kill more raptors, about 250 per year, than anywhere else.⁸⁴

Until wind energy technology became a profitable venture in the mid- to late-1990s, a major criticism of wind power centered on its unprofitability. In February, 2003 Northwest Economic Associates wrapped up its study of the wind energy industry.⁸⁵ The group reported three case studies that offer some insight on the economic impact that

⁸¹ National Wind Coordinating Committee, “Avian/Wind Turbine Interaction: A Short Summary of Research Results and Remaining Questions,” from the website www.nationalwind.org, last visited September 25, 2003.

⁸² National Wind Coordinating Committee, *Avian Collisions with Wind Turbines: A Summary of Existing Studies and Comparisons of Avian Collision Mortality in the United States*, 9. From the website www.nationalwind.org, last visited September 15, 2003.

⁸³ *Ibid.*, 9.

⁸⁴ *Ibid.*, 12-3.

⁸⁵ Northwest Economic Associates, *Assessing the Economic Development Impacts of Wind Power*, prepared for the National Wind Coordinating Committee, February 12, 2003. Located at website www.nationalwind.org.

recent wind development has had on the local communities. In Minnesota, Oregon, and Texas the wind industry invested millions of dollars in projects designed to provide grid-boosting electricity from the breezes. For Morrow and Umatilla Counties, Oregon, located in the northeastern part of the state, the project represented a boost to the economy. Four people found jobs building the thirty-eight turbines, and six more stayed on with the company, Florida Power & Light, as maintenance workers or operators. For the two Oregon counties, the FPL project didn't represent a major boost to the economy, but the installation and operation of the new wind park did help fill the counties' tax coffers by nearly \$243,000.⁸⁶

The story played out differently on the windswept plains of Minnesota and Texas. In Lincoln County, MN, the new wind plant created thirty-nine jobs, putting over a million dollars into workers' pockets. The county benefited, too, gathering over \$600,000 in both 2000 and 2001. For the farmers who feared watching their way of life slip away, the windmills provided a welcome cash infusion. Local landowners netted a total of more than half a million dollars from the project.⁸⁷ Near Guadalupe National Park, at Delaware Mountain, Texas, thirty-six people found work building, operating, and maintaining forty new windmills. The former mineral and oil county once had a, with a per capita average income at fifty-five percent of the statewide norm, yet wind farms there allowed locals to find work.⁸⁸

In the dry country of West Texas, wind energy contributes more than jobs and income. By generating electricity from the breezes, a local power company provides local people with energy without using the local community's most precious resource:

⁸⁶ Ibid., ES-3-4.

⁸⁷ Ibid., ES-2-3.

water. Unlike fossil fuel power plants that use thousands of gallons per day keeping boilers from overheating, wind energy requires only the breezes and some mechanical know-how. Historian Robert Righter thinks this fact might help push wind energy over the hump in the trans-Mississippi West, where water has grown increasingly scarce in the last few years.⁸⁹

By 2004, wind energy reemerged on the Great Plains. The perspective differs from the view taken by Pawnee leader Yellow-Bird, but certain characteristics endure. Once a spiritual guide for grateful hunters, wind now has a new appeal. Using grants from the Vermont-based NativeEnergy, the Rosebud Sioux Tribe in South Dakota launched a major wind project in 2003. With a generating capacity of 10 MW, the “Rosebud Sioux Tribe St. Francis Wind Farm” generates enough electricity for nearly two hundred homes annually.⁹⁰ The project replaces earth-warming gases like carbon dioxide and sulphur generated when burning fossil fuels with no emissions and dozens of new jobs. By reinvesting in the wind, the Rosebud Sioux also pay homage to a lasting legacy of the Great Plains.

⁸⁸ *Ibid.*, ES-4-5.

⁸⁹ Interview with Robert Righter, September 26, 2003; notes in author’s possession.

⁹⁰ [Http://www.nativeenergy.com/wind-farms.html](http://www.nativeenergy.com/wind-farms.html), last visited May 11, 2004.

Chapter 5



Ready for Prime Time? VoteSolar's Role in America's Energy Transition

In the 1970s policy makers faced tough questions about the constant state of energy crisis in the United States. For answers, pundits alluded to metaphorical bridges. Using fossil fuels wisely today, the logic ran, we can buy time for technologies that will solve our economic and environmental energy problems. Solar expert Denis Hayes said that “(o)il and natural gas are our principal means of bridging today with tomorrow, and we are burning our bridges.”¹ “Soft energy” advocate Amory Lovins asked whether we had the time to pursue fossil and renewable sources contemporaneously. “Some people think we can use oil and gas to bridge to a coal and fission economy, then use that later, if we wish, to bridge to similarly costly technologies in the hazy future.” For Lovins, the future could not wait. “What if the bridge we are on now is the last one?”²

In an effort to make the difficult transition from fossils to renewables go more smoothly, the Solar Energy Research Institute (forerunner of the National Renewable Energy Lab) published several informational guides. Among them was a piece by attorney Sharon Stanton White, a municipal bond expert who practiced law in San Francisco. White’s contribution was part of SERI’s “Legal Reconnaissance Papers,” a series of publications designed to aid the commercialization of alternative energy technologies. Published in 1979, White’s manual, “Municipal Bond Financing of Solar

¹ Ray Reece, *The Sun Betrayed: A Report on the Corporate Seizure of U.S. Solar Energy Development* (Boston: South End Press, 1979), 192.

² Amory B. Lovins, “Energy Strategy: The Road Not Taken,” *Foreign Affairs*, vol. 55, no.1 (October 1976), 65-96, 96.

Energy Facilities,” states that the “long-term outlook for the future prices and supplies of our traditional energy sources has forced us to begin to consider other potential energy sources.”³ White detailed how revenue bonds could finance city renewable energy projects. Distinguished from taxpayer-supported financing, payment for revenue bonds came from the “users or beneficiaries of the improvement, rather than the taxpayer.”⁴

At the time her study was published, the United States was in the midst of an energy crisis. Gasoline filling stations had no fuel, the nuclear reactor core at Three Mile Island nearly experienced meltdown, and natural gas and home heating oil prices hit all-time highs. Two years before, President Carter announced the “moral equivalent of war” on energy problems, themselves influenced by spiraling inflation, increased consumer prices, and huge national trade deficits.⁵ Given the context of the times, the “hazy future” Amory Lovins referred to seems understandable, yet the late 1970s also held promise for solar energy. America’s first and only celebration of “Sun Day” occurred in 1978, the same year that saw passage of legislation that would shape the alternative energy community for decades. The federal budget that year included an allocation of over five hundred million dollars for, among other things, demonstration projects designed to inform and excite the public about solar energy technology.⁶ With several years of congressional backing and a vocal solar advocate in the White House, the nation’s solar energy prospects appeared all but assured.

This chapter explains what happened to the alternative energy dreams of the

³ Sharon Stanton White, *Municipal Bond Financing of Solar Energy Facilities* (Golden, CO: Solar Energy Research Institute, December 1979), 1.

⁴ *Ibid.*, 12.

⁵ Crauford D. Goodwin, ed., *Energy Policy in Perspective: Today’s Problems, Yesterday’s Solutions* (Washington, DC: The Brookings Institution, 1981), 556, and Martin V. Melosi, *Coping with Abundance: Energy and Environment in Industrial America* (New York: Alfred A. Knopf, 1985), 292.

⁶ Reece, *The Sun Betrayed*, 197.

1970s. Beginning with an overview of federal policy since the seventies, I argue that expectations for solar and wind technology remained out of balance with actual capabilities. Through the 1980s and early 1990s, alternative energy development lagged in the United States because it could not compete with conventional fossil fuels. By the late nineties, solar and wind energy gained new attention. Improved technology, continued government incentives, and a growing market all helped transform public opinion about solar and wind energy.

In the next section, I analyze an energy crisis within a more recent context. The California electricity crisis of 2000-01 brought energy issues back into the national debate. While the global market, deregulation, and improved technology helped alleviate the energy problems of the 1970s and 1980s, new predicaments emerged. For Californians, supply-side economics induced state policy makers to deregulate the electricity market with disastrous results. The rolling blackouts during the summers of 2000 and 2001 presented an opportunity for solar and wind energy advocates. San Francisco's VoteSolar Initiative proposed a city-wide \$100 million revenue bond initiative that financed alternative energy projects for municipal buildings.

VoteSolar's success had an impact on energy policy across the country. In the final section, I analyze the success of the VoteSolar Initiative and what such achievements have meant to energy policy throughout the US. By demonstrating that the technology finally balances the expectations, the solar and wind industry has finally shown that alternative energy can have a positive impact in the United States.

American Alternative Energy Policy Overview

Even before the watershed 1973 OPEC oil embargo, energy held the attention of national policy makers. President Richard Nixon faced the difficult task of balancing various concerns. Regulation of fossil fuels, growing concerns over economic policy, and popular environmental reforms all reflected the haphazard nature of America's energy strategy. The three major fossil resources each had different regulations administered by various agencies. Nuclear energy had its own government overseers, and alternative energy technologies had programs in a variety of government bodies. The Clean Air Act of 1970 and the Environmental Protection Agency, formed in the same year, signaled a serious federal effort to control industrial pollution. With pressure from the Watergate break-in mounting and threats of embargo coming from the Middle East, Nixon announced an ambitious program designed to free the US from its overdependence on foreign energy sources. "Project Independence" called on the nation "to meet America's own energy needs from America's own energy resources" by 1980.⁷ A key part of Nixon's plan was streamlining federal energy policy.

Project Independence appeared amid an era when energy policy was anything but cohesive, even within specific industries. By 1970 the natural gas industry was in disarray. The 1938 Natural Gas Act continued to place federal regulators in control over gas that traveled across state boundaries, yet for gas that remained in-state, a different set of rules applied.⁸ The effect of federal regulation was to shield gas consumers from the market forces, unlike state rules. Gas companies had little incentive to sell gas across

⁷ Committee on Energy and Natural Resources, United States Senate, *Executive Energy Documents*, Printed at the Request of Henry M. Jackson, Chairman, (Washington, Government Printing Office, July 1978), 86.

state lines, leading to a serious shortage by the early seventies.

The oil industry likewise suffered from incohesive federal regulation. The US began the Mandatory Oil Import Program (MOIP) in 1959 as a protectionary measure designed to bring the high cost of domestic oil into balance with cheaper foreign petroleum.⁹ Regulators limited the amount of imports, which forced consumers to pay more for oil in general.¹⁰ Prior to the embargo, President Nixon planned to modify MOIP by increasing import quotas over time. In 1970, the US used petroleum for nearly half of its total energy consumption, and the high domestic prices led to inflation. Nixon's controlled incoming petroleum as a way to ease the US into global market realities and to counter inflation, but the quota system had the opposite effect.¹¹ Cheap oil continued to flood the market, leading Nixon to impose his Economic Stabilization Program, a four-phase policy that added to federal regulatory inconsistency. In the program's fourth phase, instituted in 1973, the government set two different prices for oil, one for "old" and a lower price for "new." Producers had little incentive to produce new petroleum, even though a cold winter saw demand for home heating oil rise dramatically.¹²

As the federal energy policy came to a virtual halt during the Watergate crisis, American energy consumption did not change dramatically. Between 1972 and 1973, national use rose four percent; the next year, consumption fell just two percent.¹³ Even though the OPEC embargo ended in the spring of 1974, Americans feared that cheap

⁸ In 1954, the *Phillips Petroleum Company v. Wisconsin* decision by the Supreme Court held that federal regulators in fact had authority to set prices on gas that entered "interstate commerce," or traveling across state lines. See Melosi, *Coping with Abundance*, 262-4 and Goodwin, *Energy Policy in Perspective*, 261-5.

⁹ Melosi, *Coping with Abundance*, 260.

¹⁰ Some experts argue that this policy led to the rise in inflation that occurred in the late sixties and into the seventies.

¹¹ Melosi, *Coping with Abundance*, 283.

¹² *Ibid.*, 284.

imported oil was a thing of the past. The crisis atmosphere served as a catalyst for streamlining federal policy administrative bodies as well as for boosting alternative energy research and development budgets.

One effect of the 1973 OPEC oil embargo was to spur an interest in alternative energy. When solar energy began attracting attention from Washington, no single agency was in charge of implementing policy, several were. Nixon first charged the National Science Foundation with developing solar technology, a task the NSF undertook until late 1973. Nixon then placed the Atomic Energy Commission's Dixie Ray in charge of the solar budget. Ray likened solar energy to a "flea on the back of the nuclear elephant," which alienated many in the research and development community. She quickly fell out of favor and handed control over to the newly created Solar Energy Task Force.¹⁴ President Ford attempted to consolidate alternative energy policy further still when he established both the Energy Research and Development Administration (ERDA, 1975) and the Solar Energy Research Institute (SERI, 1975). These agencies eventually folded into President Carter's Department of Energy, created in 1978.¹⁵

In terms of legislation and funding, the post-Nixon era made significant progress even without relying on the ambitious Project Independence.¹⁶ The 93rd Congress, which served from 1973-4, passed seven bills related to solar energy.¹⁷ Four years later, Congress worked with America's first (and only) pro-solar president, Jimmy Carter, to

¹³ Department of Energy, Energy Information Administration, "Energy Consumption by Sector, 1949-2002," *Annual Energy Review 2002*, accessed at website www.eia.doe.gov.

¹⁴ Donald Beattie, ed., *History and Overview of Solar Heat Technology*, (Cambridge, MA: The MIT Press, 1996), 31-4.

¹⁵ *Ibid.*, 55-9, 97-100.

¹⁶ *Ibid.*, 138.

¹⁷ Beattie, *History and Overview*, 45.

produce 15 related to the solar industry.¹⁸ On May 3, 1978, the nation celebrated Sun Day. Demonstration projects flooded the Washington Mall, and President Carter promised to make solar energy “a cornerstone of this nation’s energy policy.”¹⁹ Certainly, the 1970s stands out as a banner decade for federal funding of solar energy. Throughout the decade, policymakers assumed that simply pouring money into research and development projects would somehow change the way Americans would get their energy. The public made the same mistake.

Amid the whirlwind of agencies, the path to a solar society was hard to find. The hodge-podge nature of administering R&D money echoes the unclear goals associated with such projects. While we can look back to the Carter years with a degree of sentimentality, the record shows that a lot of money produced little in the way of cheap technology. As government insider Donald Beattie points out, though, solar energy met a hostile crowd of bureaucrats almost from the start. Many foresaw the difficulties of implementing an unready technology into an enthusiastic marketplace.²⁰ In fact, most of the funding eventually went to larger corporations that already had relationships with other sectors of the government, particularly the Defense Department. Arthur Allen reports that some familiar names received some early funding: General Electric won a \$2.8 million award, and Martin Marietta got \$3.5 in the mid-seventies. In a move reminiscent of the auto industry’s post-WWII chicanery, oil companies lined up to buy patents on solar panels in order to remove a threat.²¹ Because the R&D funding was

¹⁸ Ronald W. Larson and Ronald E. West, eds., *Implementation of Solar Thermal Technology* (Cambridge, MA: The MIT Press, 1996), 96.

¹⁹ Quoted in Ray Reece, *The Sun Betrayed: A Report on the Corporate Seizure of U.S. Solar Energy Development* (Boston: South End Press, 1979), 195.

²⁰ *Ibid.*, 1-2.

²¹ Arthur Allen, “Prodigal Sun,” *Mother Jones*, June/July 2000.

never tied to market applications, the ideas that came from the effort never impacted the American energy situation.

Solar and wind technology could not deliver on the promises made in the late seventies and early eighties by policymakers. In 1978, Congress passed the Solar Photovoltaic Energy, Research, Development and Demonstration Act that committed \$1.2 billion over ten years to help make photovoltaics more efficient and competitive with fossil fuels.²² The same year, the federal government began a photovoltaic commercialization program that installed PV units on federal facilities, and in 1980, the Crude Oil Profit Windfall Tax increased tax credits for residential PV applications to forty percent and extending the credits to the end of 1985.²³ By 1984, the price per watt of PV energy fell to less than ten dollars, and efficiency rates increased to nearly ten percent.²⁴ Although solar water heaters experienced a boom in the 1980s, the eighty thousand units delivered and installed in California between 1980 and 1981 had serious problems.²⁵ Companies with no expertise in solar technology suddenly appeared, and unsuspecting consumers fell prey to charlatans. The once positive public image of solar energy suffered due to the criticisms of scams.²⁶ The wind energy industry also benefited from state (particularly California) and federal legislation, and by 1985, California installed nearly one thousand megawatts.²⁷ Unfortunately, the technology designed to reap the benefits of the wind also experienced problems, and in 1988 wind energy

²² The monetary figure is translated to 2002 dollars.

²³ Energy Information Administration, Department of Energy, "Photovoltaic Milestones," last modified March 7, 2003, accessed at <http://www.eia.doe.gov/cneaf/solar.renewables/renewable.energy.annual/backgrnd/chap11i.htm>.

²⁴ Ibid.

²⁵ James C. Williams, *Energy and the Making of Modern California*, (Akron: University of Akron Press, 1997), 337.

²⁶ Ibid., 336.

²⁷ Robert Righter, *Wind Energy in America: A History* (Norman: University of Oklahoma Press, 1996), 215.

companies removed a significant number of windmills.²⁸ While some new turbines replaced the faulty models, the public image of wind energy suffered.

The second category that explains the failed policies of the 1970s revolves around tax incentives. A prominent part of President Carter's declaration of the "moral equivalent of war" was the Energy Tax Act of 1978. One of the five pillars that supported the pathbreaking National Energy Act, the ETA allowed taxpayers to write off up to 50% of the cost of a solar or wind equipment purchase.²⁹ Aside from the accurate criticism that such a tax policy mainly benefited the wealthy,³⁰ the incentives fall under scrutiny for their goals. Rather than increase national *production* of solar energy, the tax breaks instead rewarded *consumption*. Expert Donald Beattie astutely points out that the credits "created more jobs for door-to-door salesmen than factory jobs."³¹ While he deems Carter's presidency largely as a missed opportunity, Beattie figures that ten years of federal support yielded a total savings of 1.2 billion barrels of oil.³² The market fell out from under the solar industry in 1986. Sales of solar water heaters, the most widely adopted technology, fell by ninety percent the year after the credits expired.³³

The true test for alternative energy came during the free market era of the 1990s. Renewable energy producers managed to use PURPA to gain access to the grid, and the 1992 Energy Policy Act (EPACT) allowed even more alternative energy producers to contribute to energy market. The costs for solar systems reflect their staying power: the

²⁸ Energy Information Administration, Department of Energy, "Wind Power Milestones," last modified January 7, 2004, accessed at <http://www.eia.doe.gov/cneaf/solar.renewables/page/wind/wind.html>.

²⁹ United States Senate, *The National Energy Act*, Printed at the request of the Committee on Energy and Natural Resources (Washington: Government Printing Office, January 1979), Publication 96-1, 521.

³⁰ Larson, *Implementation*, 89.

³¹ Beattie, *History and Overview*, 232.

³² *Ibid.*, 169.

³³ Larson, *Implementation*, 128.

price of solar energy has dropped seventy-one percent in price since 1980.³⁴ Still the free market limits individual solar systems to people in developing countries, where the costs of constructing huge power plants remain prohibitive. The entrenched nature of fossil and nuclear power effectively squelched any enthusiasm for solar or wind energy in the US.

The California Electricity Crisis and the VoteSolar Initiative

The direct inspiration for Prop B came in 1996, when California Governor Pete Wilson signed Assembly Bill (AB) 1890 into law. Also called “The Electric Utility Industry Restructuring Act,” AB 1890 sought to open the electricity market for competition by reorganizing the way the government regulated the utility industry in California. Prior to AB 1890, the California Public Utilities Commission (CPUC) regulated electricity supply by dictating the amount that power companies could generate, transmit, and distribute; CPUC also determined retail prices amenable to both producers and consumers.³⁵ To balance demand, the California Electricity Commission helped plan resource consumption and pushed consumer conservation efforts. The balance of these and other regulatory bodies produced reliability, which was the hallmark of American power generation for a half century.³⁶

The push towards deregulation came incrementally after the energy crises of the 1970s. In the seven previous decades, American policymakers linked economic growth

³⁴ The Center for a New American Dream, “April 2002 Profile: David Hochschild,” archived at website www.newdream.org/bulletin/hochschild.html.

³⁵ I use power companies and utilities interchangeably throughout this text to mean distributors who deliver electricity to customers; I use the term “power producer” to describe entities that make electricity.

³⁶ See Christopher Weare, *The California Electricity Crisis: Causes and Policy Options* (San Francisco: Public Policy Institute of California, 2003), 19.

with energy consumption, which was thought to require consistent government oversight.³⁷ Free market advocates continued to chafe under what they saw as unnecessary regulations in the seventies, but lawmakers did widen the scope of American power suppliers. While the National Energy Act of 1978 is awash with oversight, the law did attempt to expand the circle of electricity generators to include those that used alternative forms of energy.³⁸ Later American policy widened the scope still further with the Energy Policy Act of 1992, which allowed exempt wholesale generators access to the electricity grid.³⁹ Opening the market to independent (or, non-utility) power suppliers had its intended effect in California, where by the mid-nineties, non-utilities supplied almost a quarter of the state's energy needs.⁴⁰ The market was opening to renewable energy sources, but uneven incentive policies and resistance to alternatives by utilities, which still controlled over half the state's power plants, kept solar and wind energy on the fringes.⁴¹

While legislative efforts pointed California's electricity ship downstream, high prices acted as a powerful current that swept the state towards deregulation. Despite California's exemplary conservation efforts, which made the state efficient economically and environmentally, electricity consumers paid higher prices than any neighboring

³⁷ See Richard Rudolph and Scott Ridley, *Power Struggle: The Hundred-Year War over Electricity* (New York: Harper & Row, 1986) who argue that the tension between public and private interests led to compromises that included government oversight; and Melosi, *Coping with Abundance*.

³⁸ The Public Utilities Regulatory Policies Act (PURPA) forced utilities to buy electricity from qualifying facilities.

³⁹ See Christine Real de Azua, "The Future of Wind Energy," 14 *Tulane Environmental Law Journal* 485 (2001), 497-507, who points out that the wind industry may not have survived the nineties without EPACT.

⁴⁰ California Energy Commission, "Total California Electricity Generation" (from website <http://www.energy.ca.gov/electricity>, last visited October 13, 2003).

⁴¹ Weare, *The California Electricity Crisis*, 8-10.

state.⁴² Free market advocates claimed vertical integration was the culprit: utilities owned power plants that generated electricity, the transmission lines that criss-crossed the state, and the ability to distribute the power to consumers. Despite this stability, prices climbed ever higher.

Pressure on the state's lawmakers finally succeeded in creating change. When Governor Wilson signed AB 1890 in late September 1996, many around the state thought the time had finally come for a fair, free market that would produce cheap power for all. The legislation called for a brief period of oversight, to allow the three major utilities time to adjust, followed by competition based on the free market. Utilities gave up control over the transmission lines they owned to ensure fair competition; the Independent System Operator, a centralized state agency, would ensure equal access to the grid from all producers. The Power Exchange served as the open market for electricity, where generators would sell power to distributors acting on the orders of presumably informed consumers. The hope was that competition among different power producers would drive prices downward.⁴³ The reality was that no one in 1996 could foresee all that would befall California in 2000 and 2001.

The restructuring law operated without a hitch for its first three years. Regulations continued to protect distributing utilities and their customers by capping wholesale and retail prices, while electricity supplies seemed ample enough to keep up with demand. Once the market opened, California would experience a harsh reality of

⁴² *Ibid.*, 7-8. The Department of Energy's Distributed Energy Resources (DER) website figures that in 1996, California ranked tenth in the states with the highest electricity prices. See www.eere.energy.gov/der. Chris Weare points out that Californians need only 0.22 kWh for every dollar earned, while the national average is 0.40 kWh/ dollar; Weare also notes that residents use only 6,400 kWh per resident per year; the national average is 11,900.

⁴³ James C. Williams, "Strictly Business: Notes on Deregulating Electricity," *Technology and Culture* vol. 42.3, 2001, 626-30.

the electricity industry. During times of increased demand, supplies don't always keep up, no matter how much money power producers could make. Slow lag times exist between state approval for power plants and actual energy production, and the hostile approach that the power industry took toward renewables continued. About the time AB 1890 became law, a leading utility, Southern California Edison (SCE), convinced a court that the state had ample power supplies, thus voiding long-term supply contracts with a wind energy producer.⁴⁴ Just as full deregulation was to kick in, three major developments caused California's electricity demand to reach untenable levels. First, the state imported much of its electricity from neighboring states, but drought again struck the region during the winter of 1999-2000 reducing the capacity of vital hydroelectric dams. The West also experienced a population boom, which translated into a spike in demand for power outside California, and many states that had previously exported power instead re-directed electricity supplies to meet the needs of their own burgeoning population.⁴⁵ Finally, most of California's power plants ran on natural gas, but a nationwide shortage of the fuel prevented supplies from getting to generators.⁴⁶

California entered the deregulation wilderness just as howls for electricity reverberated throughout the West. AB 1890 contributed to the energy crisis in two major ways. First, the law forced utilities to purchase electricity on the open market. The idea was to allow consumers to choose their electricity providers; lawmakers hoped that the competition to provide inexpensive (even renewable) power would keep costs low. This

⁴⁴ Azua, "The Future of Wind Energy," 510. SCE convinced FERC that the low bids from independent producers exceeded the utility's avoided costs, a violation of PURPA. Azua's conclusion seems appropriate: "Legislation that was intended to encourage the use of renewable energy was, ironically, being used to throttle...renewables."

⁴⁵ Weare, *The California Electricity Crisis*, 19-23. Enough time had passed since utilities trimmed their energy conservation programs to add to the demand, as well.

market approach worked effectively for the first couple years of its existence, but in 2000, wholesale prices unexpectedly skyrocketed by 270% over the previous year.⁴⁷ Utility restructuring not only forced utilities to operate in this volatile setting, the wholesale market itself came under siege by the power generating industry. Some energy experts argue that companies willfully withheld electricity by taking plants off-line by shutting them down for maintenance at critical times.⁴⁸ The shortage often worked to the advantage of producing companies because the higher prices benefited all sellers, even those that owned relatively few plants. Power generators defend the plant shut-downs by pointing to the unusually high demand of the preceding winter, which was drier and warmer than was typical.⁴⁹

Faulty oversight also contributed to energy shortages. An inherent benefit of AB 1890, deregulation, ironically caused confusion among the government agencies charged with implementing and overseeing the law. The agency responsible for reducing demand, the California Energy Commission, saw many of its innovative energy-saving programs fade into the background as other state and federal regulators allowed utilities to slash their conservation budgets. The Union of Concerned Scientists reports that the halted programs translated into an increased demand of nearly 1,800 megawatts (MW) of power at a time when supplies became scarce.⁵⁰ The California Public Utilities

⁴⁶ *Ibid.*, 28-32. In addition, natural gas prices rose thanks to an explosion at an El Paso Co. pipeline in late summer 2000 that disrupted supplies by 15% going into the winter.

⁴⁷ Energy Information Administration, "The California Electricity Crisis: Subsequent Events – California's Energy Crisis" (from the website www.eia.doe.gov/cneaf/electricity/california/subsequentevents.html, last accessed October 16, 2003).

⁴⁸ P.L. Joskow, *California's Electricity Crisis* (Cambridge, MA: Massachusetts Institute of Technology, 2001) and P.L. Joskow and E. Kahn, *Identifying the Exercise of Market Power: Refining the Estimates* (Cambridge, MA, 2001).

⁴⁹ Weare, *The California Electricity Crisis*, 33-4.

⁵⁰ Union of Concerned Scientists, "California Energy Crisis: Causes and Solutions," from the website http://www.ucsusa.org/clean_energy/renewable_energy/page.cfm?pageID=68, last visited July 28, 2003.

Commission, in charge of ensuring that utilities competed for power among various suppliers, also forced power companies to buy electricity on the wholesale market, rather than allow long-term contracts. The CPUC incorrectly assumed that supplies would remain constant through deregulation's first few years and that projects slated to come online in 2002 and after would help meet demand concerns.⁵¹ Unfortunately for consumers and utilities, ensuring fair competition overrode concerns for potential demand increases; the Commission's adherence to its long-term contract preclusion forced utilities into an unfamiliar and highly volatile market.⁵²

While regulators failed to anticipate the major problems of demand spikes, utilities bear some responsibility for the crisis, too. During the summer of 2000, power companies utilized only half of the available long-term supply contracts.⁵³ AB 1890 charged the Federal Energy Regulatory Commission with overseeing the wholesale marketplace. FERC officials had long supported a free market setting, and hesitated to act quickly when wholesale prices skyrocketed. Had FERC capped wholesale prices in the crisis's early days, California's current financial outlook may not look so bleak.⁵⁴ FERC's reluctance to interfere with the open market has certain philosophical merit, but in reality, market manipulation was rampant. As prices soared ever higher, generating companies like Enron raked in huge profits. One report notes that the scandal-ridden corporation made over \$20 million in a single day on several occasions.⁵⁵

Government agencies and private companies bear some responsibility for

⁵¹ Weare, *The California Electricity Crisis*, 38-9. Supplies actually were stable from 1998-2000.

⁵² CPUC figured that allowing long-term contracts would contravene the point of AB 1890, which was competition.

⁵³ Weare, *The California Electricity Crisis*, 44.

⁵⁴ *Ibid.*, 45-6.

⁵⁵ Richard A. Oppel, Jr., "Report Voices Suspicion on Energy Crisis," August 14, 2002 from a Reuters News Service report disseminated by www.planetark.org on August 15, 2002.

exacerbating a crisis situation, but California lawmakers did nothing to salvage this difficult situation. Crisis expert James Sweeney argues that Governor Gray Davis had an opportunity to respond to certain market flaws, yet Davis instead blamed the problem on market manipulation and unresponsive federal regulators.⁵⁶ To an extent, Davis was right. State lawmakers had no authority to cap wholesale prices; AB 1890 left wholesale market regulation to FERC, a federal agency. Yet the state legislature placed enormous pressure on utilities by capping the rates they could charge retail customers. By forcing distributors to buy power on the wildly fluctuating wholesale market and capping the amount end-users had to pay, lawmakers forced utilities to operate at a potential loss if wholesale prices exceeded retail limits.⁵⁷ When the crisis reached full-blown, rolling blackout status, the state intervened to become a participant in the electricity market. Davis authorized expensive, long-term contracts that put the state on the road to its current financial crisis. In the midst of an economic downturn, California must now figure out how to finance its \$42 billion contractual obligations.⁵⁸

Not all of the repercussions from the rolling blackouts were negative. In San Francisco, a nonprofit organization, VoteSolar, turned the electricity crisis into an opportunity. Solar technology would form the centerpiece of the group's agenda, which was to organize a ballot measure designed to make San Francisco a leading consumer of solar energy. Proposition B, a \$100 million dollar bond initiative, went from idea to the ballot box in a matter of ten months. The success of the vote would spill over into similar

⁵⁶ James L. Sweeney, *The California Electricity Crisis* (Stanford, CA: Hoover Institution Press, 2002). Sweeney defends utilities, which he says were placed in a bind by being forced to buy electricity on the wholesale market and sell that power on a retail level at a loss: Davis's position, that generators willfully withheld supplies, has gained merit since several lawsuits have revealed a level of truth to the former governor's assertion.

⁵⁷ Weare, *The California Electricity Crisis*, 38-40.

⁵⁸ *Ibid.*, 55.

efforts organized elsewhere. At the heart of the VoteSolar Initiative lay a dedicated group of advocates who took advantage of an opportunity to implement the latest solar technology through democratic means. VoteSolar's response to the electricity crisis began with the campaign to pass Proposition B, and the Initiative's work continues to impact communities around the country. Here I cover VoteSolar's campaign for Prop B in three phases: the movement to get the initiative on the ballot; the actual campaign; and momentum into other work.

David Hochschild came up with the idea for VoteSolar while he was part of San Francisco's parks department. As an expert on the city's parks bond process, Hochschild had an intimate knowledge about how this form of financing operated. Hochschild ran the numbers and discovered that a bond initiative could pay for a massive overhaul of San Francisco's electricity infrastructure. Difficulties lay ahead for the new group, but VoteSolar figured it could achieve its goal to place an initiative on the ballot in ten short months by dealing with two realities. First, the group learned that adding a new transmission line to the city's sole line would cost \$100 million. Such a project would still leave San Francisco at the mercy of a distant, volatile market.⁵⁹ By using "fog maps" created by the San Francisco Public Utilities Commission, VoteSolar made an important discovery. Despite its foggy reputation, San Francisco receives a lot of sunshine.⁶⁰ The eastern part of the city actually gets about ninety percent of the solar radiation as the sun-drenched Central Valley.⁶¹ This potential translated into a major selling point: people

⁵⁹ At least one power plant existed near to San Francisco, called Hunter's Point Power Plant, but the city got the majority of its electricity from elsewhere. In periods of high demand, customers who sat closer to sources tend to get power first, hence San Francisco was at the mercy of the market.

⁶⁰ The fog map is available on the internet at www.solarcat.com/sfsolar/main.htm.

⁶¹ Kendra Mayfield, "'Fog City' Catches a Few Rays," *Wired* magazine, January 7, 2003 from the website www.wired.com/news/technology/0,1282,57046,00.html. See also Karina Garbesi and Emily Bartholomew, "The Potential for Solar Electricity Generation in San Francisco: A Report to the

love solar power. As Hochschild said, “(w)e could position solar energy as a window of opportunity to build San Francisco’s energy independence in a way that fights global warming rather than worsens it.”⁶²

Proposition B came together as a bond initiative quickly. That such a measure took place at all reveals an anomalous quality about San Francisco; whereas most cities issue city-improvement bonds through an internal process at city hall, San Francisco requires voter approval for such improvements. Getting such an initiative onto the ballot can occur in one of three ways in San Francisco: the mayor make the proposal; advocates can gather the requisite number of signatures in support; or the Board of Supervisors can approve a measure.⁶³ For VoteSolar, the idea for solar power had a strong advocate in Mark Leno, a member of the Board of Supervisors. Leno encouraged Hochschild to prove the fiscal soundness of the project and eventually introduced the measure to the Board.

VoteSolar again proved up to the challenge. By requesting a \$100 million, the group promised to deliver solar energy that could pay for itself. Yet electricity gathered from rooftop photovoltaic (PV) panels remained an expensive alternative: San Francisco paid between 5.5¢-9¢ per kilowatt hour (kWh) of natural gas-generated power in 2001, compared to 18¢/kWh for solar.⁶⁴ In terms of the costs for installed capacity, solar panels cost about \$5.50 per watt, a number that continues to put PV panels out of reach for most

Environmental Law and Justice Clinic of Golden Gate University Law School,” June 1, 2001, from website www.californiasolarcenter.org/pdfs/SFPV.pdf.

⁶² David Hochschild interview with the Center for a New American Dream, www.newdream.org/bulletin/hochschild.html, last visited October 20, 2003.

⁶³ David Hochschild interview with author, June 17, 2003. Notes in author’s possession. The requisite number can be either 10,000 signatures or 5% of voters participating in the most previous election.

⁶⁴ Jane Kay, “SF Could be Leader on Solar Energy: Props. B and H being backed by businesses and environmentalists alike,” *San Francisco Chronicle*, Saturday October 27, 2001, found at newspaper archives at www.sfgate.com.

consumers.⁶⁵ Undeterred, VoteSolar struck upon the idea of “bundling” solar energy with cheaper wind power and cost-effective energy efficiency measures; this process yields two key benefits. First, cities have the ability to raise the amount of money needed to make such investments. Next, tying solar electricity to other economically viable, if less sexy, alternatives brings the overall cost of the technology down.⁶⁶ The budget analysis figures presented to the Board in mid-July assumed a very conservative 20 year payback period.⁶⁷

While the Board of Supervisors approved the bond initiative for the ballot, the campaign for Prop B still had a long way to go. Still VoteSolar had a lot going for it. Rolling blackouts hit California hard that summer, making energy a front burner issue with voters. The crisis proved critical for raising awareness, but the key to the campaign’s success was its ability to offer a viable alternative. Although a mere one hundred days stood between the Board’s approval of the bond initiative and the election, VoteSolar managed to rally a diverse group of San Franciscans to its cause. Opposite ends of the political spectrum endorsed the proposal, prompting Hochschild to wonder “where else you would find the Chamber of Commerce agreeing with the San Francisco Labor Council?”⁶⁸ Help came in other ways, too; VoteSolar’s Charlene Garland points to the 200 volunteers who hung signs, knocked on doors, and manned the phone banks, which coincidentally helped raise \$100,000 for the effort. One volunteer, a well-known

⁶⁵ San Francisco Board of Supervisors, “Proposed Solar Bond Initiative: Illustrative Bundle of Projects: \$100 Million Revenue Financing,” 1. Hochschild thinks this number must fall to about \$1.50/watt for solar to compete with fossils.

⁶⁶ Hochschild interview, June 17, 2003.

⁶⁷ “Proposed Solar Bond Initiative,” 1. The proposal sets aside money in an interest-bearing account calculated to cover the costs of debt service through the course of the bond’s repayment.

⁶⁸ *Ibid.*

graphic designer, even came up with the campaign's image.⁶⁹

Not everyone embraced VoteSolar's message. Hochschild took his message to the Republican County Central Committee, a group of 16 members charged with charting the course taken by the Bay Area GOP. Dressed in his most conservative suit, the VoteSolar founder headed off to argue his case before the committee. Stressing the fiscal soundness of the bond, Hochschild managed to persuade four members that his idea was a good one, a decent showing given the frosty audience.⁷⁰ Later, Hochschild took his message to television. In a debate shown on public access TV, Hochschild sparred with former Board Supervisor John Bartis, whose argument centered on the general fiscal risks he believed inherent in bond initiatives. While television exposure helped VoteSolar's cause, it didn't compare to what followed. Sensing that their message would resonate with the public, VoteSolar's opponents funded an advertisement arguing against the initiative. The ad backfired. San Franciscans reacted with resounding support for the measure. Hochschild figures the response to the single opposition ad translated into forty to fifty pro-Prop B ads.⁷¹

While the solar message added a certain allure to Prop B, the campaign itself consisted of four key components. First, the issues that resonated with voters tended to center on air quality. Polling data revealed that people in the Bay Area attached more importance to local air quality than greenhouse gas emissions generally.⁷² VoteSolar tailored its "Clean Air, Clean Energy" slogan accordingly. Next, the energy crisis raised voter awareness. Rather than join the pundits that decried the policy blunders, VoteSolar

⁶⁹ Interview with Charlene Garland, February 14, 2003. Notes in author's possession.

⁷⁰ Hochschild interview, June 17, 2003.

⁷¹ Ibid.

⁷² Ibid.

could point to a positive solution. The energy independence theme carried force, as well. Hochschild points out that a single transmission line serves the entire city; to build another one would cost \$100 million.⁷³ VoteSolar offered an energy source that didn't pollute or require a complicated system of power lines.⁷⁴

The fourth and perhaps the most innovative approach taken by the Prop B campaign was the idea of "bundling." While the cost of solar panels had fallen since the last solar era of the 1970s, PV systems remain out of reach for most people. Even big cities like San Francisco can't afford to go solar all by itself. The bundling idea finds a way around such a dilemma through large-scale bulk purchases.⁷⁵ Another key to making a project like Prop B affordable is tying expensive solar power to other, cheaper alternatives. Prop B allocates \$30 million for wind energy, and a mere \$2 million on energy efficiency measures.⁷⁶ Ironically, cheaper energy efficient technologies "have a very short payback period and are key to making projects cost-effective," according to VoteSolar co-founder Adam Browning, who estimates that Prop B will pay for itself in a mere six and a half years.⁷⁷

November 6, 2001 found San Franciscans keen on the idea of going solar. A whopping 73% of the voters turned their hopes skyward and sent a message that continues to resonate across the nation. The momentum from the victory has spurred VoteSolar on to grander projects. The group, which changed its name to the VoteSolar Initiative as of March 2002, has set its sights on starting similar bond projects in ten

⁷³ Ibid. Hochschild referred to a study undertaken by the utility Pacific Gas & Electric (PG&E), which is available at its website, www.pge.com.

⁷⁴ Hochschild also noted the disadvantages of nuclear power.

⁷⁵ VoteSolar often refers to the "economies of scale" theory, which holds that large purchases would drive up demand, thus lowering costs of supplies via competition.

⁷⁶ San Francisco Board of Supervisors, "Solar Bond Illustrative Bundle of Projects: Project Assumptions," July 17, 2001 from website www.votesolar.org.

American cities over the next two years.⁷⁸ By most accounts, things are going well. A bond initiative has gathered momentum in Oakland and San Diego, while other cities may soon join the list. New York and Hawai'i are also considering statewide solar bond projects, a coup for the Initiative's public image and a testament to the group's ability to mend fences. The two governors pushing for solar bonds are both Republicans.

Solar and Wind Energy in America

It is clear to us that the leadership for promoting renewable energy is not going to come from the White House or Congress. The action really is at the local level.⁷⁹

The VoteSolar Initiative splashed onto the energy scene with an electrifying message that generated enthusiastic support. Prop B presented a fresh approach to a stagnating problem, but solar energy is nothing new in the US. Since the OPEC embargo in 1973, the federal government has poured billions into solar research and development projects. Tax incentives have cost the US even more. The efforts have not averted America's taste for fossil fuels, and solar continues to play a limited role in the American energy supply.

Thirty years ago, enthusiasm for solar energy swept across the United States. Everyone from politicians to off-the-grid hippies basked in the warm glow of the sun's potential. Time managed to temper hopes and leave the people with several issues to ponder. Uneven federal support for solar and wind energy ultimately deterred growth, but many still see a role for Washington. Solar advocate Tor Allen thinks Washington can provide leadership in the way of nationwide interconnection and net metering rules,

⁷⁷ Quote from Kendra Mayfield, "'Fog City' Catches a Few Rays."

⁷⁸ The VoteSolar Initiative, "The VoteSolar Initiative: A Clean Energy Movement Led by Cities," original publication in author's possession.

which would allow more people to profit from independent energy production.⁸⁰ As for funding, Allen likes VoteSolar's approach. "The more local control the better."⁸¹ However the experts choose to view the past 30 years, one thing is certain. The momentum created by the VoteSolar Initiative gives us reason to hope. For me, that's a welcome change.

⁷⁹ David Hochschild, quoted in Dean E. Murphy, "For Solar Power, Foggy City Maps Its Bright Spots," *New York Times*, 24 November 2002, Section A, page 18.

⁸⁰ Net metering refers to a two-way system of measuring electricity flow, which would track contributions to the grid; today most meters simply track the amount of electricity taken from the grid.

⁸¹ Email message from Tor Allen, July 10, 2003; original in author's possession.

Conclusion



In 1998, the US Department of Energy celebrated a landmark occasion by doing what federal agencies have a knack for doing. It published a study. Entitled “The 25th Anniversary of the 1973 Oil Embargo: Energy Trends Since the First Major Energy Crisis,” the Energy Information Administration (EIA) presented evidence of how American energy consumption and production reacted to what remains the most significant energy challenge to date. Little data supports the argument that US energy policy changed significantly since the OPEC embargo, yet hidden among the charts and graphs lay two important pieces of information.

The publication reveals that there remains a difference between national wants and national needs. First, American consumption of OPEC petroleum fell by twenty-five percent between 1973 and 1985, showing that the United States can survive, even thrive, without oil from the Persian Gulf region.¹ In the twelve years after the first energy crisis, the nation raised domestic resource production, cut its dependence on foreign sources, and vastly improved energy efficiency.² Such evidence points to America’s ability to adapt to the realities of resource scarcity, although the changes hardly signal a complete shift away from what are now traditional energy sources.

The study also shows that Americans can easily fall back into old patterns. US petroleum consumption peaked in 1978 at nearly nineteen million barrels of oil per day.

¹ Department of Energy, Energy Information Administration, “The 25th Anniversary of the 1973 Oil Embargo: Energy Trends Since the First Major Energy Crisis,” (Washington DC: US Dept of Energy, 1998), 2, available at <http://www.eia.doe.gov>.

² Ibid., 1-2.

Five years later, the nation trimmed about four million barrels from its consumption (even as the population grew at a steady rate) by building more efficient cars, by heating homes with natural gas instead of oil, and through general energy conservation measures. As the global market and domestic production filled American demand for oil, though, the nation began consuming at pre-1978 levels.³ The binge continued through the twenty-fifth anniversary, so much so that by July 2002, the US consumed forty percent more energy than it had since 1970.⁴

According to the National Energy Act of 1978, the Department of Energy must produce an annual energy review. Four years after its assessment of federal policies since the OPEC embargo, the EIA published an overview that included detailed data not included in the twenty-five year review. According to several figures, much had changed since the trying days of the 1970s, but for the better.⁵ The rate at which Americans consumed energy per dollar of the gross domestic product fell significantly. In 1970, Americans spent nearly nineteen dollars (in 1996 terms) per every thousand Btu's consumed, while in 2002, that number neared ten dollars.⁶ Other indicators show that America's fossil consumption has increased to over eighty quadrillion Btu's, up from just near seventy quadrillion in 1978.⁷ Another important figure shows that energy consumption per person approached the all time high in 1978 and 1979, when energy use per person stood at 360 million Btu's; in 2002, that figure approached 338 million Btu's.⁸

Lost among the evidence that the US continues to consume fossil energy at a

³ *Ibid.*, 4.

⁴ Anders Hove, *A Brief Guide to US Energy Policy* (Cambridge, MA: MIT, July 2002), 2.

⁵ Whether this rosy picture relates to the different administrations remains to be seen.

⁶ Department of Energy, Energy Information Administration, *Annual Energy Review 2002*, Figure 3, "Energy Use per Dollar of Gross Domestic Product," xvii.

⁷ *Ibid.*, Figure 4, "Energy Consumption by Source," xvii.

⁸ *Ibid.*, Figure 2, "Energy Consumption per Person," xvii.

rapacious rate stands encouraging figures for alternative energy. The American Wind Energy Association reports that global installations of wind energy generating capacity grew by twenty-eight percent in 2002.⁹ Shipments of photovoltaic cells have also risen in recent years as prices have fallen. In 1982, total shipments of PV cells was nearly seven thousand kilowatts, while in 2001, that number rose to nearly 98,000 kilowatts.¹⁰

Groups like the VoteSolar Initiative should take pride in their accomplishments. Thanks to pressure from alternative energy advocates, over a dozen states have adopted renewable energy portfolio standards (RPS), which set statutory requirements for the amount of alternative energy a state must use by a set date.¹¹ Several cities have also committed to solar and wind energy. According to VoteSolar's David Hochschild, San Diego has agreed to get 35 MW of power from photovoltaics by 2013, while the city has agreed to give PV projects accelerated permitting and inspections.¹²

As these and other efforts demonstrate, humanity can change its view of sunshine and the breezes. Even within the past thirty years, the shape and function of solar and wind technology has gone from loud disappointment to quiet success. Past experiences have a tendency to mute grand proclamations of an energy future powered by the two renewable resources, yet optimists can take heart. If the VoteSolar Initiative is any indication, technology, economics, and policies all hint at a brighter future for solar and wind energy.

⁹ American Wind Energy Association, "Global Wind Energy Market Report," published at www.awea.org, last visited October 15, 2003.

¹⁰ Department of Energy, Energy Information Administration, "Photovoltaic Cell & Module Shipments by Type, Trade, and Prices, 1982-2001," available at <http://www.eia.doe.gov>, last visited May 27, 2004.

¹¹ See www.irecusa.org for a complete list.

¹² David Hochschild presentation to the Solar Forum, Anaheim, CA, November 20, 2003; notes in author's possession.

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