

“Turn on the Sunshine”: A History of the Solar Future

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Abstract

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This dissertation examines the history of solar energy technology alongside broad changes in the politics and geography of energy since the nineteenth century. I argue that solar technologies evolved as expressions of the anxieties of the fossil fuel age which, while never widely adopted, informed a persistent cultural interest in alternative energy futures that shaped larger developments in energy politics. I link the evolution of common types of solar technologies and ideas about their potential to four additional contexts: late nineteenth and early twentieth century imperial expansion, the advent of the Cold War, the convergence of environmentalism and the energy crisis in the 1970s, and the more recent emergence of sustainability as a framework for global energy and environmental politics. In each of these contexts, solar technologies developed as instruments of politics as well as forms of politics in their own right, reflecting and contributing to new conceptions of the limitations of fossil fuel dependence and the promise of alternatives.

I also address the geographic dimensions of solar politics in each of these periods. My focus on California primarily, but also Arizona, North Africa, and – in the chapter on photovoltaic cells – outer space, reflects the importance of these places as nexuses in the development and global travel of solar technologies. Linked as peripheries of an expansionist

fossil fuel society, they became sites of experimentation in new ways of deriving energy from nature and organizing society around energy.

Overall, this study reveals a higher incidence of geographic variance, contestation, and uncertainty in energy technology politics during the fossil fuel age than historians typically acknowledge. It also complicates common assumptions about the origins and potentialities of existing solar technologies, drawing attention to their early associations with the politics of empire and the Cold War prior to their reformulation in the 1970s as tools promoting countercultural and environmentalist visions of the future. By situating solar technology development in time and place, this study seeks to historicize meanings commonly attached to solar and, in doing so, provide a historical basis for evaluating present debates over energy alternatives.

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Introduction

A Perpetually New Technology

To promote the 1964 New York World's Fair, the *New York Times* asked science fiction author Isaac Asimov to offer his vision of technology fifty years in the future. By 2014, he wrote, machines would perform nearly all the labor in the workplace and the home. Freed from toil, people would enjoy a life of leisure, traveling from place to place in hover cars and on moving sidewalks. Asimov also predicted that people would “continue to withdraw from nature to create an environment that will suit them better.” Houses would be built underground. Instead of windows, residences would be outfitted with luminescent walls that glowed with soft light in various hues. To feed a growing population and provide for more residential space, farms would be replaced by facilities for synthesizing food from yeast and algae. While people would have less direct contact with familiar, tangible forms of nature, this separation would be made possible by their ability to tap into unseen processes occurring at the quantum level. Energy would be the foundation for this smoothly mechanized world. Most day-to-day gadgets would be wireless, running off radioisotopes, the by-products of the nuclear fission reactors which by then would be supplying half of the world's power needs. A few experimental fusion reactors would also be in operation. The remainder of the world's energy would come from sunlight collected at sprawling power stations “in a number of desert and semi-desert areas – Arizona, Negev, and Kazakhstan.” In addition to fusion research, scientists would be working on “models of power stations in space, collecting sunlight by means of huge parabolic focusing devices and radiating the energy thus collected down to earth.”¹

¹ Isaac Asimov, “Visit to the World's Fair of 2014,” *New York Times*, August 16, 1964.

Asimov's vision of a technological utopia powered by a combination of nuclear and solar energy presents a contrast to images usually associated with solar technology. At the time, solar had not yet acquired the reputation as a "subject for eco-freaks" it would carry a decade later.² Nor did Asimov's future reflect the later countercultural conception of solar as "intrinsically democratic" and nuclear energy as the epitome of impersonal, authoritarian technology.³ His vision of space-based solar farms and portable radioisotopes actually suggest how, in another context, the reverse could also be true. For Asimov, technologies to convert direct sunlight to useable energy would contribute to maintaining technological progress and material abundance beyond the end of the age of fossil fuels. They were devices for perpetuating the energy intensive, technocratic society that many later solar advocates sought to challenge.

Prescience or lack thereof aside, what is most surprising about Asimov's vision is that it was commonplace. His "gadgety world of the future" borrowed heavily from a strain of futurist thinking that pervaded American popular culture in the 1950s and early 1960s.⁴ Asimov's conception of solar technology also drew on existing models. Proposals for powering a future society with energy generated from solar collectors covering the desert regions of the world dated to the late nineteenth century. The notion of beaming energy to earth from orbital solar collectors was more recent, appearing initially in science fiction before becoming a focus of government and industry collaboration in the context of the Cold War race for global

² The "Eco-freaks" quote is from *New York Times Magazine*, March 16, 1975. Quoted in Daniel Yergin, *The Quest: Energy, Security and the Remaking of the Modern World* (New York: Penguin Press, 2011), 528.

³ Langdon Winner, *The Whale and the Reactor: A Search for Limits in an Age of High Technology* (Chicago: University of Chicago Press, 1986), 32-33, 39.

⁴ For 1950s and early 1960s futurism see, Lawrence Samuel, *Future: A Recent History* (Austin: University of Texas Press, 2009), 78. For a present assessment of Asimov's vision of 2014, see David Pogue, "Asimov's Predictions from 1964: A Brief Report Card," *Scientific American* 310, no. 3 (March 2014), accessed November 25, 2014 at <http://www.scientificamerican.com/article/asimov-predictions-from-1964-brief-report-card/>; Also see Matt Novak, "Asimov's 2014 Predictions were Shockingly Conservative for 1964," Paleofuture blog, August 29, 2013, accessed November 25, 2014 at <http://paleofuture.gizmodo.com/asimovs-2014-predictions-were-shockingly-conservative-1221478312>.

technological supremacy with the Soviet Union.⁵ That solar technologies would operate in tandem with nuclear reactors was also a common refrain among solar advocates in the 1950s and 1960s. As coal and oil reserves became inadequate to meet increasing demand, they argued, nuclear plants would be necessary to meet needs in urban-industrial nations, while solar technologies would provide smaller amounts of power to rural regions with favorable climates, limited access to fossil fuels, and lower energy use requirements. A commitment to the development of technologies to take advantage of these more abundant energy sources would be necessary not only to create a more prosperous future, but to avoid what Asimov described in a later, darker essay as “the nightmare life without fuel.”⁶

Asimov’s vision of a combined solar and nuclear future provides an entry point for exploring the varied, changing, and sometimes conflicting political meanings attached to the antecedents of today’s “green energy technology.” It also speaks to solar’s historical connection to an older conversation – characterized by a mixture of anxiety and optimism – about how changes in the energetic basis of industrial society might affect the overall character and power dynamics of that society. While never becoming significant as sources of measurable power, solar technologies have attracted recurring interest in the United States and around the world, evolving as pivot points of technical and political discourse over what a non-fossil fuel future might look like.

This dissertation examines the history of solar energy technology – defined here as devices and design concepts for converting direct sunlight to useable energy – alongside broad changes in the politics and geography of energy since the nineteenth century. I argue that solar

⁵ Asimov first described this technology in a 1941 short story. Asimov, “Reason,” *Astounding Science Fiction* (April 1941).; His thinking on solar is further described in Asimov, “The Glorious Sun,” in *The Beginning and the End*, ed. Isaac Asimov (New York: Doubleday & Company, 1977), 74-79.

⁶ Isaac Asimov, “The Nightmare Life without Fuel,” *Time* 109, no. 17 (April 25, 1977): 49.

technologies evolved as expressions of the anxieties of the fossil fuel age which, while never widely adopted, informed a persistent cultural interest in alternative energy futures that shaped larger developments in energy politics. I link the evolution of common types of solar technologies and ideas about their potential to four additional contexts: late nineteenth and early twentieth century imperial expansion, the advent of the Cold War, the convergence of environmentalism and the energy crisis in the 1970s, and the more recent emergence of sustainability as a framework for global energy and environmental politics. In each of these contexts, solar technologies developed as instruments of politics as well as forms of politics in their own right, reflecting and contributing to new conceptions of the limitations of fossil fuel dependence and the promise of alternatives.

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Overall, this study reveals a higher incidence of geographic variance, contestation, and uncertainty in energy technology politics during the fossil fuel age than historians typically acknowledge. It also complicates common assumptions about the origins and potentialities of existing solar technologies, drawing attention to their early associations with the politics of empire and the Cold War prior to their reformulation in the 1970s as tools promoting countercultural and environmentalist visions of the future. By situating solar technology development in time and place, this study seeks to historicize meanings commonly attached to

solar and, in doing so, provide a historical basis for evaluating present debates over energy alternatives.

The study draws its title from a 1921 *Los Angeles Times* article detailing various solar experiments conducted in Southern California, Europe, and North Africa over the previous half-century. In a preview of Asimov's later assessment, the author concluded that while existing methods of converting solar heat for industrial use could not yet compete economically with conventional sources in most places, the engineers working on the problem were poised for a major breakthrough. "It is safe to predict," he declared, "that 'Turn on the Sunshine' will be the slogan for a magnificent period of industrial development."⁷

This statement reflected a blending of confidence and concern about the future of industrial society. On the surface, it exemplified a typical modern faith in technology as means to harness ever increasing amounts of energy from nature for the sake of progress, defined by perpetual material abundance, political stability, and moral improvement.⁸ It also reflected underlying uncertainties about the limits to progress imposed by reliance on finite and geographically fixed supplies of coal and oil. On another level, the author was offering a commentary on California's potential role in a post-fossil fuel future, suggesting that while the state's lack of indigenous coal deposits had constrained its development in the past, its abundance of sunshine could allow for its ascendance as a new hub of political and economic power in the future. From the vantage point of California, the phrase "Turn on the Sunshine" was not simply a statement of technical possibility. It also referred to the possibility of reconfiguring

⁷ "Turn on the Sunshine," *Los Angeles Times*, August 21, 1921.

⁸ Gabriel A. Almond, Marvin Chodorow, and Roy Harvey Pearce, "Introduction," in *Progress and its Discontents*, ed. Gabriel A. Almond, Marvin Chodorow, and Roy Harvey Pearce (Berkeley: University of California Press, 1982), 3.

the economic and political geography of industrial society by introducing a new method of deriving energy from nature.

Such statements of the transformative potential of solar technology have been more prevalent, varied, and influential over a much longer span of time than historians have generally recognized. Perhaps easy to dismiss as hyperbole, they nevertheless speak to a persistent public and professional interest in alternative energy futures that has both reflected and shaped the politics and geography of energy technology development over the entire industrial era. Stemming in part from anxieties about the risks and limitations of existing energy options, especially fossil fuels, this interest also emerged from a deep-seated cultural confidence in the potential for new technologies to remake society for the better.

The belief that the adoption of a new energy source would bring revolutionary changes has not been exclusive to solar.⁹ Many of the specific attributes commonly associated with solar energy – its inexhaustibility, non-polluting nature, and conduciveness to democracy – have also been applied to other sources, most notably hydroelectricity.¹⁰ Solar technologies have nevertheless occupied a singular niche in the history of modern energy politics. The possibility of harnessing the uniquely accessible and essentially limitless energy of direct sunlight has stimulated particularly hopeful visions of the future, while also bringing attention to the limitations of other geographically fixed and less abundant sources. Solar has also been distinguished historically by its perennial status as a future technology, one which (until very recently) has remained marginalized in the industrial economy despite its apparent social,

⁹ George Basalla, “Some Persistent Energy Myths,” in *Energy and Transport: Historical Perspectives on Policy Issues*, ed. George H. Daniels and Mark H. Rose (Beverly Hills: Sage Publications, 1982), 27-38.

¹⁰ *Ibid.*; For a discussion of the utopian expectations applied to hydropower in the 1930s see Richard White, *The Organic Machine: The Remaking of the Columbia River* (New York: Hill and Wang, 1995), 55-58.; White’s discussion primarily refers to Lewis Mumford’s view of hydropower as expressed in *Technics and Civilization* (New York: Harcourt, Brace and Company, 1934), 6, 157, 168-169, 371-372.

economic, and environmental advantages. The reasons for solar's commercial failures are many, deriving from a combination of technical, political, ideological, and economic forces privileging large-scale, centrally-managed energy production and distribution networks based primarily on fossil fuels, but also hydropower and nuclear. The key point here, however, is that as these other sources became established and the discourse surrounding them shifted to a focus on the management and improvement of existing systems, solar retained its image as a "new" technology with the potential to substantively change society.

Solar technology's perpetual newness, in combination with its distinctive physical properties, also made it uniquely adaptable to deployment at multiple scales – from large, centrally-managed power stations capable of supplying large amounts of energy over a wide area; to smaller, local- or community-controlled systems with more diverse components; to a variety of eclectic systems adopted by individuals acting as independent power producers. As they formed, these variously scaled models of solar development each became associated with different, often conflicting, conceptions of humanity's energy future. They also required different government policies, environmental practices, and forms of social and economic organization for their deployment. Throughout the period covered in this dissertation, debates over the appropriate scale of solar development and the relationship between solar technologies and other types of energy technologies were ultimately debates about power – social, economic, and political as well as mechanical and electrical – with a wide range of social and environmental implications. Greater awareness of the historical and geographic contexts in which these previous forms of solar politics took shape, I suggest, can inform discussions about the various models of solar development presently under consideration in California, the United States, and the world.

Rethinking Technological Success and Failure in the Fossil Fuel Age

The importance of energy in shaping human history has long been a topic of interest in popular and academic writing.¹¹ Pertinent to this dissertation, historians in recent years have sought to complicate traditional economic, cultural, and political explanations for the origins and evolution of modern industrial society by emphasizing its energetic and material bases. These authors contend that many of the constituent elements of modernity – including increasing technological complexity, the rise of mass production, urbanization, the growing power of states and corporations, rapid population growth, and accelerated environmental change – were ultimately made possible by humans’ ability to harness large amounts of energy from fossil fuels.¹² And yet, fossil fuel-based energy has also imposed constraints, limiting development to certain regions of the world and creating conditions for the geographic inequalities that defined modern social, political, and economic life.¹³ The history of solar contributes to this discussion by drawing attention to the ways in which cultural, political, and technical responses to the limitations imposed by fossil fuels have manifested in one set of technologies, and how those

¹¹ Notable works include B.L.L., *Matter and Energy: Are there Two Real Things in the Physical Universe? Being and Examination of the Fundamental Conceptions of Physical Science* (London: Kegan Paul, Trench & Co., 1887).; For a summary of German chemist Wilhelm Ostwald’s role in redefining energetics in the late nineteenth century see Crosbie Smith, *The Science of Energy: A Cultural History of Energy Physics in Victorian Britain* (Chicago: University of Chicago Press, 1998), 304-305.; Mumford, *Technics and Civilization.*; Leslie White, “Energy and the Evolution of Culture,” *American Anthropologist* 45, no. 3 (July-September 1943): 335-356.; and Howard T. Odum, *Environment, Power, and Society* (New York: Wiley-Interscience, 1971).

¹² Vaclav Smil, *Energy in World History* (Boulder: Westview Press, 1994).; Alfred Crosby, *Children of the Sun: A History of Humanity’s Unappeasable Appetite for Energy* (New York: W.W. Norton & Company, 2006), 2-5.; Rolf Peter Sieferle, *The Subterranean Forest: Energy Systems and the Industrial Revolution* (Cambridge: White Horse Press, 2001), ix.; and J.R. McNeill, *Something New Under the Sun: An Environmental History of the Twentieth-Century World* (New York: W.W. Norton & Company, 2000), 10-15, 297-305.

¹³ Timothy Mitchell, *Carbon Democracy: Political Power in the Age of Oil* (New York: Verso, 2011).; and Edmund Burke III, “The Big Story: Human History, Energy Regimes, and the Environment,” in *The Environment and World History*, ed. Edmund Burke III and Kenneth Pomeroy (Berkeley: University of California Press, 2009), 33-53.

technologies have in turn produced new conceptions of a future not dependent exclusively on fossil fuels.

Solar technology has received only limited attention in historical scholarship on energy. This is due in large part to a prevailing focus in the literature on accounting for and evaluating the impacts of major historical “energy transitions,” which Martin Melosi defines as the process by which “a single energy source, or group of related sources, dominated the market during a particular period or era, eventually to be challenged and then replaced by another major source.”¹⁴ While recognizing that energy transitions are not singular events, that they involve extended periods of overlap and changes in applications of new and old energy sources, historians typically focus on those energy sources and technologies that are either rising to or descending from a position of economic dominance.¹⁵ For the period covered in this dissertation, historians typically recognized two primary energy transitions: the change from fuelwood to coal in the mid- to late nineteenth century and the ascendance of oil beginning in the early twentieth century. Solar technologies, if they appear at all in this literature, are usually described as

¹⁴ Martin Melosi, “Energy Transitions in the Nineteenth Century Economy,” in *Energy and Transport*, 55.

¹⁵ See especially Sam H. Schurr and Bruce C. Netschert, *Energy in the American Economy, 1850-1975: An Economic Study of its History and Prospects* (Baltimore: Johns Hopkins Press, 1960).; Smil, *Energy in World History*.; Martin Melosi, *Coping with Abundance: Energy and Environment in Industrial America* (Philadelphia: Temple University Press, 1985), 313-314.; Daniel Yergin, *The Prize: The Epic Quest for Oil, Money & Power* (New York: Touchstone, 1991), 541.; David E. Nye, *Consuming Power: A Social History of American Energies* (Cambridge: MIT Press, 1998), 7.; and Christopher F. Jones, *Routes of Power: Energy and Modern America* (Cambridge, MA: Harvard University Press, 2014).; Much of the historical literature on energy in the US focuses on electrification rather than a specific energy source, and as a result, also does not address debates over potential alternatives that did not contribute significantly to electricity production. Notable works include David Nye, *Electrifying America: Social Meanings of a New Technology, 1880-1940* (Cambridge, MA: MIT Press, 1990).; Jay L. Brigham, *Empowering the West: Electrical Politics before FDR* (Lawrence: University Press of Kansas, 1998).; Ronald C. Tobey, *Technology as Freedom: The New Deal and the Electrical Modernization of the American Home* (Berkeley: University of California Press, 1996).; and Ronald R. Kline, *Consumers in the Country: Technology and Social Change in Rural America* (Baltimore: Johns Hopkins Press, 2000).

casualties of the configurations of ideological, technical, political, and economic power enabling the dominance of coal and later oil as the primary energetic bases of industrial society.¹⁶

Much of this scholarship rests explicitly or implicitly on historian Thomas Hughes's concept of "momentum" which holds that while the large technological systems that came to dominate the modern era emerged from a social context, their increasing embeddedness in cultural, political, and economic institutions allowed them to acquire a kind of agency of their own which effectively cut off avenues for the development of alternative systems.¹⁷ Historians' focus on the momentum of large-scale, centralized energy systems based primarily on fossil fuels and to a lesser degree on hydropower and nuclear is clearly justified considering the intractability and significant social and environmental impacts of those systems. However, the recurring professional and public interest in solar technology despite its limited commercial success also demands attention, suggesting that Americans and others have been more open to a diverse energy mix – or even an altogether different one – than is evident from the energy transition model.

While solar technology remains a fringe topic in general histories of energy, a handful of popular works document its longer historical evolution. These works provide a corrective to common misconceptions of the technology as a recent invention, as a product of the 1970s counterculture. Geared toward a general audience, however, they focus primarily on technical developments and avoid confronting more difficult questions about solar's origins in the energy

¹⁶ Yergin, *The Quest*; 528.; Melosi, *Coping with Abundance*, 313-325.; and Nye, *Consuming Power*, 228., 235-236.

¹⁷ Hughes developed this concept as a way to explain the historical development and impact of regional electrical power systems in the late nineteenth and early twentieth centuries. See Hughes, *Networks of Power*, ch. 6.; He later extended the concept to apply to large-scale technological systems in general. See Thomas Hughes, *American Genesis: A Century of Invention and Technological Enthusiasm, 1870-1970*, revised edition (Chicago: The University of Chicago Press, 2004), xviii, 459-460.

intensive, fossil fuel-based industrial culture it was later presented as a challenge to.¹⁸ The few academic histories of solar are more attentive to context, but like general histories of energy, also focus on the question of why the more radical conceptions of the technology's potential that formed in the 1970s failed to stimulate a significant energy transition by the 1980s. Lamont Hempel concludes that this was less a technical or economic failure than the result of political resistance to the ideologies associated with solar following the 1973 Arab oil embargo.¹⁹ Langdon Winner cites the ascendance of conservatism and the election of Ronald Reagan to the presidency in 1980 as the immediate reasons for solar's demise, but also observes that even during the 1970s, solar advocates faced a nearly insurmountable obstacle in attempting to introduce technologies they believed would promote energy conservation and decentralization of political and economic power in a society fundamentally structured around centralized, energy-intensive technologies and a commitment to unending economic growth.²⁰ Drawing from organizational analysis, Frank Laird argues that the more radical "ecological solar advocates"

¹⁸ See especially Ken Butti and John Perlin, *A Golden Thread: 2500 Years of Solar Architecture and Technology* (Palo Alto: Cheshire Books, 1980).; John Perlin, *From Space to Earth: The Story of Solar Electricity* (Ann Arbor: aatec publications, 1999).; Frank Kryza, *The Power of Light: The Epic Story of Man's Quest to Harness the Sun* (New York: McGraw-Hill, 2003).; and Alexis Madrigal, *Powering the Dream: The History and Promise of Green Technology* (Cambridge, MA: Da Capo Press, 2011).; Although focused on wind energy, also applicable here is Robert W. Righter, *Wind Energy in America: A History* (Norman: University of Oklahoma Press, 1996).; While valuable as sources of basic historical information, all of these works (with the exception of Kryza's which offers a more traditional narrative history) are written from an activist perspective, the general argument being that solar (and wind) technologies have a long history that has prepared them to be widely adopted as cleaner, more equitable, and more sustainable alternatives to fossil fuels and nuclear, if society should choose to do so. These works also build on a selection of historically-oriented books on solar written prior to the 1973 oil embargo. See especially Farrington Daniels, *Direct Use of the Sun's Energy* (New Haven: Yale University Press, 1964).; and D.S. Halacy, *The Coming Age of Solar Energy* (New York: Harper & Row, 1973).; Finally, it is again worth pointing out this literature's debts to the early writings of Lewis Mumford, especially *Technics and Civilization* in which he outlined the history of technology in such a way as to substantiate his view of hydroelectricity as the basis of a more democratic and environmentally benign path for industrial society.

¹⁹ Lamont Charles Hempel, "The Politics of Sunshine: An Inquiry into the Origin, Growth and Ideological Character of the Solar Energy Movement in America," Ph.D. diss., Claremont Graduate School, 1983: 195-227.

²⁰ Winner, *The Whale and the Reactor*, 80-81, chapter 5.

failed to frame a consistent challenge to normative ideas about energy and economic growth that remained entrenched in federal institutions through the 1970s.²¹

While useful for illuminating the power dynamics behind Americans' energy and technology choices, these works also rely primarily on economic measures to distinguish between successful and failed technologies. These distinctions are not always as obvious as energy use statistics suggest and are dependent on the criteria used to define technological success and failure. Even if apparent in hindsight, they are also often much less clear at the level of lived experience. Historians of technology have often cautioned against focusing exclusively on technological success stories partly for these reasons.²² But as Graeme Gooday observes, they rarely consider the full implications of judging particular technologies as successes or failures. Applying either label implies a degree of "closure," he suggests, that may not be "as self-evident or consensual as some historians have tended to assume." Rather than evaluating a technology only in terms of measurable performance, Gooday calls on historians to explore the "socially-embedded criteria of what constitutes a success and a failure." To give due attention to "the relentless and mundane problems of fitting technological form to context," he stresses maintaining "interpretive flexibility" when evaluating a technology or a group of technologies historically. This involves examining the meanings different historical actors have ascribed to a technology at different times. It can also mean paying attention to how conflicting assessments

²¹ Frank Laird, *Solar Energy, Technology Policy, and Institutional Values* (New York: Cambridge University Press, 2001).; A few scholars have addressed specific episodes in the pre-1970s history of solar. Two notable works examine the solar house movement of the 1940s and 1950s: Adam Rome, *The Bulldozer in the Countryside: Suburban Sprawl and the Rise of American Environmentalism* (New York: Cambridge University Press, 2001), 45-64.; and Daniel A. Barber, "The Modern Solar House: Architecture, Energy, and the Emergence of Environmentalism, 1938-1959," Ph.D. diss., Columbia University, 2010.; Historian Harvey Strum has also written about solar politics during the 1950s and 1960s. See "Eisenhower's Solar Energy Policy," *The Public Historian* 6, no. 2 (Spring 1984):37-50.; and "The Association for Applied Solar Energy, Solar Energy Society: 1954-1970," *Technology and Culture* 26 (1985): 571-578. These works provide an important foundation for the more synthetic treatment of the subject that this dissertation aims to provide.

²² See for example, John M. Staudenmaier, *Technology's Storytellers: Reweaving the Human Fabric* (Cambridge: MIT Press, 1985): 145-146.

of a technology's merits, shortcomings, and social and environmental impacts can in turn shaped changes in designs and applications over time.²³

Following Gooday's call for greater interpretive flexibility, this dissertation moves beyond the focus on energy transitions and momentum in the existing literature to highlight the importance of solar technologies as indicators, and occasional instigators, of changes in the cultural politics of energy, technology, and the environment in the larger context of the fossil fuel age. While creating few significant impacts on the overall balance of energy use, the solar inventors and advocates profiled in this study pursued new approaches to extending and transforming the geography of industrial society, promoted novel manners of living, introduced new criteria for evaluating future energy scenarios, and contributed to reformulating the role of government in energy resource development. Their activities also addressed weaknesses in the dominant energy systems, exposing the technical, environmental, and social failures (existing and projected) of these supposedly successful systems. In short, I suggest that solar technologies mattered not because of the horsepower or watts they generated but because of the meanings they acquired in different cultural and geographic contexts and the influence of those meanings in modern energy and environmental politics.

Solar Geographies: The California Nexus

This dissertation also considers the imprints not only of time but of place on the life of a new energy technology. The stories that follow span the globe, but at one point or another, nearly all pass through California, a place long considered culturally, politically, economically, and

²³ Graeme Gooday, "Re-writing the 'Book of Blots': Critical Reflections on Histories of Technological 'Failure'," *History and Technology* 14, no. 4 (July 1998): 265-291.

environmentally suited to solar energy utilization. In focusing on California, I follow a general interpretation of the state as a prototype of modernity, a place conducive to technological and political experimentation where the challenges of building a more desirable modern society have often been met “early and intensely,” as literature scholar James Quay writes.²⁴

I also build on existing scholarship detailing California’s role as a point of genesis for several major developments in energy technology and politics including the construction of long distance hydroelectric power transmission systems, the growth of regional oil and natural gas production and distribution networks, the emergence of progressive movements for public power, and the rise of anti-nuclear politics.²⁵ In his broad overview of California energy history, James Williams attributes the particular qualities and significance of the state’s energy systems to its combination of ecological diversity, limited coal reserves, and relative political autonomy.²⁶ These factors also contributed to California’s role as a hub of solar technology development and advocacy.

While there is merit to an interpretation of California as a bellwether in energy history, I do not treat the state as a bounded origin point for solar technology development and politics, but as a nexus in an interconnected global history. In California, the local has also always been global, linked to larger currents of economic, environmental, demographic, and political change.²⁷ At the same time, California has also left distinct imprints on larger patterns of history.

²⁴ James Quay, “Beyond Dreams and Disappointments: Defining California through Culture,” in *A Companion to California History*, ed. William Devereell and David Iglar (Malden, MA: Wiley-Blackwell, 2008), 18.

²⁵ For hydroelectricity see Hughes, *Networks of Power*, chapter 10.; For oil and natural gas see Sabin, *Crude Politics*.; For the battle for public power see Robert M. Fogelson, *The Fragmented Metropolis: Los Angeles, 1850-1930* (Cambridge: Harvard University Press, 1967), ch. 11.; For anti-nuclear politics see Thomas Raymond Wellock, *Critical Masses: Opposition to Nuclear Power in California, 1958-1978* (Madison: The University of Wisconsin Press, 1998).

²⁶ James Williams, *Energy and the Making of Modern California* (Akron: University of Akron Press, 1997).

²⁷ See for example, Thomas J. Osborne, “Pacific Eldorado: Rethinking Greater California’s Past,” *California History* 87, no. 1 (2009): 26-45, 66-71.; Ian Tyrrell, *True Gardens of the Gods: Californian-Australian*

“Peripheries can become hotbeds of innovation,” historian Richard Walker writes, noting that the interaction of global and local forces must be taken into consideration “as we define and outline global California.”²⁸ The state’s legacy in the history of solar technology – like its legacy in other areas – formed from the interplay of geographic specificities and connections with other places in the nation and the world. While aspects of California’s physical geography including its distance from imperial centers, lack of coal, and abundant sunshine structured the development and application of solar technologies in significant ways, these technologies – many of which actually originated outside the state – continued to evolve and acquire new meanings as they travelled between California and other peripheries of fossil fuel society including Arizona, India, North Africa, and even outer space.

Solar’s historical evolution on the physical edges of fossil fuel society also suggests the importance of empire – defined here as a system of social, economic, and political organization by which a central authority exerts power over other people and places – as the impetus for exploration of alternative energy futures.²⁹ Solar technology development formed, in large part, as an imperial strategy by agents of Western industrial nations to exercise power over places where fossil fuels (coal in particular) were absent by taking advantage of a locally available energy resource. In the process, however, solar development also presented a challenge to the power structures of fossil fuel society by establishing a set of tools by which to transition to a future in which coal and oil would become less important. Solar’s potential to disrupt the political geography of energy moved to the forefront of energy politics in the 1970s, most visibly

Environmental Reform, 1860-1930 (Berkeley: University of California Press, 1999).; and Jessica B. Teisch, *Engineering Nature: Water, Development, and the Global Spread of American Environmental Expertise* (Chapel Hill: University of North Carolina Press, 2011).

²⁸ Richard A. Walker, “At the Crossroads: Defining California through the Global Economy,” in *A Companion to California History*, 76.

²⁹ Julian Go, *Patterns of Empire: The British and American Empires: 1688 to the Present* (New York: Cambridge University Press, 2011), 7.; Charles S. Maier, *Among Empires: American Ascendancy and its Predecessors* (Cambridge: Harvard University Press, 2006), 3.

in California where state and local government institutions adopted approaches to solar development aimed at facilitating greater local control of technology and reduced dependence on utilities and the federal government. However, solar's capacity to both enable and contest imperial power relationships is evident in all of the examples in this dissertation, and remains central to present debates over fossil fuel alternatives.

Finally, in emphasizing the geographic bases for solar technology development, this history expands on historians Wiebe E. Bijker's and John Law's discussion of the "heterogeneity of technology" in which they argue that there are no "pure" technologies existing outside of history – that technologies always "embody social, political, psychological, economic, and professional commitments, skills, prejudices, possibilities, and constraints."³⁰ Taking this as a starting point, I argue that solar technologies formed as contingent objects of political and technical activity occurring at multiple geographic scales within the larger context of an expansionist fossil fuel-based industrial society. However, I also go beyond Bijker's and Law's purely social constructivist formulation by suggesting that solar technologies also evolved as hybrid cultural and material constructions – products of social, political, technical, and economic forces operating within non-human environmental contexts comprised of energy flows, landscape features, and raw materials. This combination of cultural and material factors created the conditions of possibility for the various forms of solar technologies described in this study, as well as for the political and cultural meanings they acquired. The larger implication here is that while social conditions strongly shaped the energy and technology choices described in the chapters that follow, those choices were also made within circumscribed physical boundaries not

³⁰ Wiebe E. Bijker and John Law, "General Introduction" in *Shaping Technology/Building Society: Studies in Technological Change* (Cambridge: MIT Press, 1992), 3, 7.

entirely of human making or under human control.³¹ The history of solar technology is, in this respect, part of the history of humans' response to the physical and energetic constraints on the expansion of fossil fuel society.

Organization of the Work

This dissertation is comprised of six chapters and a conclusion detailing the historical evolution of common types of solar technologies and cultural conceptions of their potential through four periods of activity. The chapters are organized both chronologically and topically in order to highlight the different technologies and political meanings appearing in each time period. The first two chapters examine the early development of solar technologies as a response to concerns about coal scarcity and as means to extend industrial capabilities to peripheral regions with abundant sunshine but limited access to low-cost coal. Chapter 1 situates early solar technology development in the context of European imperial expansion and competition, recounting the activities of British, French, and American solar inventors in India and North Africa from the 1870s through the 1920s. Chapter 2 describes parallel efforts to introduce solar irrigation pumps and home water heating systems in California and Arizona. Though originating from a common expansionist context, solar technologies took different forms and acquired different meanings in each of these places. From a European standpoint, solar technologies appealed primarily as means to extend state control over distant colonial possessions in a period

³¹ Scholars in environmental history and history of technology have been especially active in thinking about history in these terms. See especially White, *The Organic Machine.*; Linda Nash, "The Agency of Nature or the Nature of Agency?" *Environmental History* 10, no. 1 (January 2005): 67-69. ; Timothy Mitchell, *Rule of Experts: Egypt, Techno-politics, Modernity* (Berkeley: University of California Press, 2002), ch. 1.; Gabrielle Hecht, "Introduction," in *Entangled Geographies: Empire and Technopolitics in the Global Cold War*, ed. Gabrielle Hecht (Cambridge: MIT Press, 2011), 3.; and James C. Williams, "Understanding the Place of Humans in Nature," in *The Illusory Boundary: Environment and Technology in History*, ed. Martin Reuss and Stephen H. Cutcliffe (Charlottesville: University of Virginia Press, 2010), 9, 20-22.

of intensifying imperial rivalry. In California, meanwhile, they were touted as tools of economic independence that would enable individuals to supersede corporations, collectives, and government as agents of commercial expansion. This adaptability to both centralized and distributed models of economic expansion became a recurring theme in subsequent iterations of solar politics.

The next two chapters detail continuing efforts to the “Turn on the Sunshine” from the late 1930s through the early 1970s, connecting these activities to increasing government involvement in technology and energy resource development, rising concerns about energy and materials shortages during and immediately after World War II, and the advent of the Cold War. Chapter 3 details rising interest in solar architecture and space heating in the United States between the late 1930s and 1950s, the formation of the Arizona-based Association for Applied Solar Energy (AFASE), and the efforts of US and international solar advocates to introduce simple solar technologies for cooking and producing small amounts of mechanical power in rural “underdeveloped” nations in the 1950s and 1960s. Chapter 4 steps back to examine the early development of photovoltaic cells (devices for converting sunlight directly to electricity) at AT&T’s Bell Laboratories and their adaptation, mainly by California-based semiconductor firms, for use in the US space program. Together, these activities recast solar technology according to Cold War geopolitical objectives in science, engineering, and international development. Although generally focused on nuclear and military applications, the expanded role of government as a facilitator of technological change in this period also created opportunities to pursue solar as a potential challenger to the existing energy mix of fossil fuels, hydropower, and nuclear.

Chapters 5 and 6 recount the transformation of solar politics in the United States following the 1973 Arab oil embargo through the early 1980s. Chapter 5 summarizes the numerous, often conflicting, visions of a solar future that emerged during the 1970s, and the struggles of the federal government to develop a consensus approach to solar implementation. Chapter 6 describes the parallel evolution of solar advocacy in California in order to highlight the different priorities and capabilities that took shape at the local and state government levels during a period of declining public trust in federal institutions and increasing fears about the risks of fossil fuel and nuclear dependence. While federal programs were generally geared toward top-down management and research and development of centralized, high-tech solar installations more along the lines of the fossil fuel/nuclear model, in California, deepening opposition to nuclear energy, the state's increasing dependence on imported oil, desire for autonomy in energy decisions, and a general perception of the state as well-suited environmentally for solar created a political climate conducive to a more grassroots approach. Though falling short of expectations by the 1980s, actions by the California Energy Commission, the governor's office, and municipal governments (most notably the city of Davis) established a model for solar development predicated on incentivizing conservation and the commercialization of simple, existing technologies at the local and state levels. The intent was not simply to improve environmental quality and address the problem of scarcity but to wrest some of the power to make choices about energy and technology away from utilities, the coal and oil industries, and the federal government.

The dissertation ends with a conclusion summarizing changes in the politics and geography of solar technology development since the 1970s. I focus generally on the emergence of sustainability as a new framework for global energy and environmental politics. Originating

from efforts to unify the developed and developing world, sustainability created a rationale for adopting solar technologies as means to reconcile the goals of environmental protection, economic growth, and social justice at multiple geographic scales. Growing concerns about climate change, nuclear safety, and instability in the oil market – in combination with developments in photovoltaic technology and economic globalization – stimulated further interest in solar technology worldwide. As existing models of solar development became reformulated to new political, economic, and environmental circumstances, questions about the appropriate scale of solar technology again came to the forefront. These present debates speak to the importance of historical analysis as a basis for better understanding the power dynamics and ideological assumptions that lay behind the various models of solar development currently being deployed in California, the US, and other places worldwide.

In sum, while solar energy has rarely been the centerpiece of modern energy politics, there are benefits to viewing this history from the fringes, through the lens of a new technology. The history of the solar future offers a corrective to a common perception of the inevitability and permanence of fossil fuel dominance, drawing attention to moments in history when energy futures were uncertain, when other ways of using energy and organizing society around energy seemed possible. Additionally, as historians Marita Sturken and Douglas Thomas observe, new technologies frequently become objects upon which a society projects its highest expectations and deepest fears.³² They acquire meanings that reflect the hopes and anxieties of particular times and places. Despite contributing little measurable power to modern energy systems, solar technologies have long captured the imaginations of inventors, engineers, scientists, government officials, and the public as a promising means of creating a better world by resolving social and

³² Marita Sturken and Douglas Thomas, “Introduction: Technological Visions and the Rhetoric of the New,” in *Technological Visions: The Hopes and Fears that Shape New Technologies*, ed. Marita Sturken, Douglas Thomas, and Sandra Ball-Rokeach (Philadelphia: Temple University Press, 2004), 1.

environmental problems related to existing patterns of energy use. As a perpetually new technology, solar has both reflected and shaped Americans' and others' changing and geographically varied views of the problems of fossil fuel dominance and the possibilities of alternatives from the nineteenth century to the present.

Chapter 1

“A Place in the Sun”: The Colonial Origins of Solar Technology

In an 1870 article for *Scientific American*, Swedish-American engineer John Ericsson, inventor of the Civil War ironclad the USS *Monitor*, referred to a 90,000 square mile “rainless region” encircling the globe where he thought solar energy could be profitably used for industrial development.³³ Ericsson’s division of the earth according to the solar energy endowments of different regions drew on a tradition of geographic classification dating back to German explorer-scientist Alexander von Humboldt’s isothermal maps of the world, published in the early nineteenth century.³⁴ It also inspired other inventors and scientists in Europe and the United States to envision solar-powered industrialization as a potentially lucrative development model that could be applied in California, Arizona, India, Algeria, Egypt, and other imperial peripheries with abundant sunshine but limited access to coal. Over the long term, they predicted, the development of more efficient methods of deriving useful energy from direct sunlight would allow for a shift in the geography of industrial society toward the “sun-favored lands,” making these places focal points of imperial competition and commercial investment as coal supplies dwindled.³⁵ Such prophecies continued to attract interest even with the ascendance of oil after World War I. With energy demand continuing its inexorable rise, science journalist Edwin Slosson predicted in 1921, “a scramble for ‘a place in the sun’” would ensue, “and the nation that owned and utilized the largest area of the arid tropics would rule the rest.”³⁶

³³ “The Solar Engine,” *Scientific American* 23, no. 21 (November 1870): 323.

³⁴ For the impacts of Humboldt’s maps on the subsequent development of science and technology in Europe see Michael Dettelbach, “Humboldtian Science,” in *Cultures of Natural History*, ed. Nicholas Jardine, James A. Secord, and E.C. Spary (New York: Cambridge University Press, 1996), 296.

³⁵ “Solar Machinery,” *Scientific American* 49, no. 7 (August 18, 1883), 97.

³⁶ Edwin E. Slosson, “This Changing World V: Harnessing the Sun,” *The Independent* (May 14, 1921): 527.

This chapter examines the early development of solar technologies against this backdrop of the global expansion of industrial capitalism and technology, increasing energy requirements, and intensifying imperial rivalry from the 1870s through the 1920s. I argue that optimism about solar as a future basis for industrial expansion during this period both reflected and shaped imperial ambitions by proposing a technological means by which to overcome the social, economic, and environmental barriers to that expansion. Even in the absence of demonstrated economic viability, the vision of a solar future, as conceived in a colonial context, created an imperative to extend the geography of empire in order to ensure the survival of industrial society beyond the eventual exhaustion of the world's fossil fuels.

The chapter begins with an overview of early American and European responses to the problems arising from increasing dependence on coal as an energy source, followed by accounts of the key episodes of colonial solar technology development. Two themes emerge from these accounts. The first is the role of empire in providing a context for imagining an industrial future that did not depend on coal, and for experimenting with a set of technologies that could provide the energy basis for that future. The second is the reciprocal interaction between solar technologies, colonial politics, colonial environments, and cultural expectations about the future energy basis of industrial society. This was not simply a case of "technology transfer" from core to periphery, but a process of new technology creation resulting from the interplay of colonial ambitions and the actual experiences of developing and testing new technologies in the varied physical and political geographies of the colonial world.

Limits to Progress

As historians Ken Butti and John Perlin amply document, techniques and technologies to harness direct sunlight for human use have origins deep in antiquity.³⁷ With the advent of the age of coal and the rapid increases in industrial capabilities beginning in the nineteenth century, solar technologies took on a new character and meaning. These changes emerged from a belief that harnessing greater and greater amounts of energy from nature was fundamental to achieving the Enlightenment dream of unending material, intellectual, and moral progress.³⁸

The belief that solar energy utilization would herald a new stage in the expansion of industrial civilization can be traced back to John Adolphus Etlzler, a German utopianist who immigrated to the United States in 1831 with the aim of creating a “paradise within the reach of all men.” Etlzler was at once an embodiment of nineteenth century technological enthusiasm and an early proponent of renewable energy sources. For him, coal – the fuel driving Western Europe’s industrial expansion – could be too easily monopolized by those in control of its limited supply. In a world dependent on finite and difficult to transport reserves of coal, Etlzler wrote, “the Many would sweat for wages in the factories of the Few.” As an alternative, he envisioned a future of universal wealth and happiness made possible by technologies to derive power from less material sources: “from wind...from the tide...or the heat of the sun, by which water may be transformed into steam, whose expansive power is to operate upon machineries.”³⁹

³⁷ Ken Butti and John Perlin, *A Golden Thread: 2500 Years of Solar Architecture and Technology* (Palo Alto: Cheshire Books, 1980).

³⁸ See especially Dolores Greenberg, “Energy, Power, and Perceptions of Social Change in the Early Nineteenth Century,” *American Historical Review* 95 (June 1990): 693-714.; For the origins and impacts of the transition to coal as the primary energy source in Western Europe by the mid-nineteenth century see Rolf Peter Sierferle, *The Subterranean Forest: Energy Systems and the Industrial Revolution* (Cambridge: The White Horse Press, 2001).; For a critique of the assumption of the correlation between increasing energy use and progress see George Basalla, “Energy and Civilization,” in *Science, Technology and the Human Prospect*, ed. Chauncey Starr (New York: Pergamon Press, 1980), 39-52.; For a more general treatment of the relationship between technology and progress in American history see Michael L. Smith, “Recourse of Empire: Landscapes of Progress in Technological America,” in *Does Technology Drive History?: The Dilemma of Technological Determinism*, ed. Merritt Roe Smith and Leo Mark (Cambridge: MIT Press, 1994), 37-52.

³⁹ J.A. Etlzler, *The Paradise within the reach of all Men, without Labor, by the Powers of Nature and Machinery* (Pittsburgh: Etlzler and Reinhold, 1833), 4.; The quote regarding coal is from Alexis Madgrigal,

These supplies were not only inexhaustible, he claimed, but were also distributed freely over the face of the earth, available to all.

Etzler's utopian dreams, though eccentric even for the time, reflected a common Enlightenment confidence in technology as a means to overcome barriers to human progress imposed by nature. Like many Europeans of his generation and social standing, Etzler drew much of his vision from philosopher Georg Wilhelm Friedrich Hegel who professed the power of the human mind to transcend the apparent limitations of the material universe. "The cunning of reason," wrote Hegel in his *Philosophy of Nature* in 1817, "enables [Man] to preserve and maintain himself in the face of the forces of Nature."⁴⁰ Though offering little in the way of practical technical knowledge, Hegelian philosophy offered metaphysical inspiration to the architects of the new industrial society by linking human progress, equality, and universal happiness to the quest to harness more and more of nature's abundance. By the 1830s, European scientists and philosophers touted new methods of converting natural sources of energy into useful mechanical power as harbingers of a new stage in history in which humans had triumphed over the constraints of nature.⁴¹

Nature frequently proved more difficult to control than such pronouncements suggested, especially in encounters with the unfamiliar environments beyond the temperate regions of the world. Etzler experienced this directly in 1845 when his attraction to what historian Dolores Greenberg refers to as the "mystique" of unlimited energy led him to embark on an ill-conceived colonizing mission to Venezuela where he and a small group of followers planned to employ an

Powering the Dream: The History and Promise of Green Technology (Cambridge: Da Capo Press, 2011), 15.; For details of Etzler's solar inventions and a critique of his solar advocacy from a contemporary environmentalist standpoint see Lamont C. Hempel, "The Original Blueprint for a Solar America," *Environment* 24, no. 2 (March 1982): 25-32.

⁴⁰ Quoted in Stephen Stoll, *The Great Delusion: A Mad Inventor, Death in the Tropics, and the Utopian Origins of Economic Growth* (New York: Hill and Wang, 2008), 31.

⁴¹ Greenberg, "Energy, Power, and Perceptions of Social Change in the Early Nineteenth Century," 701, 703.

elaborate wind and water powered mechanism he deemed “the Satellite” which he claimed could clear the land, plow the soil, and maintain crops with minimal labor and no imported energy source. The cumbersome apparatus proved to be no match for the Venezuelan jungle, however, and several members of the colony perished from starvation and disease while attempting to clear and plant the heavily-forested strip of land Etzler had acquired for the colony. Five months into the debacle, Etzler sailed off alone, ostensibly to seek financial support. He was never seen or heard from again. Whether he escaped into anonymity or perished at sea remains a mystery.⁴²

Etzler’s disappearance coincided with the start of a revolution in the science of energy which by the 1860s resulted in the codification of the first two laws of thermodynamics. These laws accorded with the prevailing mechanistic view of nature in physics and were heralded as a scientific foundation for improving the efficiency of industrial processes. They also established a basis for better understanding the physical constraints on human efforts to harness energy from nature for industrial uses. The first law encompassed the law of conservation of energy which stated that while energy could not be created or destroyed, it could change forms and move from place to place. The second law qualified the first, stating that the conversion of energy from one state to another led toward “entropy,” which for practical purposes meant that as energy changed states it became less capable of performing work.⁴³

Confronted with the inevitability of entropy, many scientists began to see the search for new ways to derive energy from nature as essential for the long term survival and continuing progress of humanity. As early as 1851, Scottish mathematician William Thomson (later Lord Kelvin), one of the founders of the science of thermodynamics, warned that society might be allowing valuable energy go to waste. While energy could not be destroyed, he wrote,

⁴² Stoll, *The Great Delusion*, chapter 3.

⁴³ P.M. Harman, *Energy, Force, and Matter: The Conceptual Development of Nineteenth Century Physics* (Cambridge: Cambridge University Press, 1982), 4-5, 64-71.

“transformations take place which remove irrecoverably from the control of man sources of power which, if the opportunity of turning them to his own account had been made use of, might have been rendered available.”⁴⁴ For Thomson, to fail to take advantage of all of the energy that could conceivably be harnessed for human use would be to commit, in historian Crosbie Smith’s words, “a sin of ‘dissipation,’ with respect to human beings rather than in nature.”⁴⁵

The search for new energy supplies became more urgent as uncertainties emerged about the extent of the world’s coal reserves in the 1860s. Opinions on the matter varied, but the fundamental importance of coal as the driver of industrialization meant that even the most pessimistic estimates could not be easily ignored. The most alarming predictions came from British economist William Stanley Jevons who, in his 1865 treatise *The Coal Question*, described Britain’s industrial ascendance as dependent on a finite natural resource and therefore transitory. “We must not dwell in such a fool’s paradise as to imagine we can do without coal what we do with it,” he warned.⁴⁶

Responses to Jevons’ concerns about the physical limits of Britain’s coal reserves varied. Some economists and engineers stressed the need to improve the efficiency of industrial processes. Others questioned Jevons’ estimates of the extent of the remaining coal, suggesting that conservation measures and the development of new technologies for tapping deeper coal seams would minimize the threat.⁴⁷ Few late nineteenth century industrialists took his warnings seriously, however. As historian Steven Stoll observes, they often failed to grasp or take

⁴⁴ Quoted in Crosbie Smith, *The Science of Energy: A Cultural History of Energy Physics in Victorian Britain* (Chicago: University of Chicago Press, 1998), 110.

⁴⁵ *Ibid.*, 101.

⁴⁶ William Stanley Jevons, *The Coal Question: An Enquiry Concerning the Progress of the Nation and the Probably Exhaustion of our Coal Mines* (London: MacMillan and Co., 1865), xvi, 50.

⁴⁷ Nuno Luis Madureira, “The Anxiety of Abundance: William Stanley Jevons and Coal Scarcity in the Nineteenth Century,” *Environment and History* 18, no. 3 (2012): 397.; Sierferle, *The Subterranean Forest*, 197-202.

seriously the limiting function of entropy, and tended to interpret the law of conservation of energy beyond what its physics actually allowed.⁴⁸

Still, many scientists and engineers saw Jevons's predictions as concerning enough to warrant consideration of the matter of scarcity. Historians have identified his work as an important stimulus for the early development of root concepts in neoclassical economics including efficiency and the optimal use of resources.⁴⁹ Anticipation of the exhaustion of coal supplies also stimulated exploration into alternative sources of energy, which because of the increasing energy demands of industrial society, appeared as a potentially lucrative business opportunity. Others saw more compelling reasons to pursue solar energy utilization. In response to John Ericsson's unveiling of his prototype solar motor, the *New York Times* announced that "to introduce a new motor into mechanism marks a new era in civilization." While still in an early stage of development, the solar motor promised to become "a revolutionary agent in science, industry and in commerce."⁵⁰

Investigations into solar energy utilization also aligned with imperial ambitions, involving considerations about the energy sources available in different regions of the world. As he refined his solar motor during the 1860s and 1870s, Ericsson became convinced that solar technologies would eventually make possible a global dispersal of industrial manufacturing toward previously unproductive regions on the geographic edges of the European and American empires. In touting solar's potential, Ericsson drew on and contributed to what historian Diana Davis describes as an "environmental imaginary" of deserts in particular as "wastelands," places

⁴⁸ Stoll, *The Great Delusion*, 145-151.

⁴⁹ Michael V. White, "In the Lobby of the Energy Hotel: Jevons's Formulation of the Post-classical Economic Problem," *History of Political Economy* 36 (2004): 227-271.

⁵⁰ "The Coal Problem and Solar Engines," *New York Times*, September 10, 1868: 4.; Also see "Ericsson's Solar Boiler," *Railway Times* 20, no. 44 (October 31, 1868): 347.; A portion of Ericsson's speech at the Swedish University of Lund was printed in "The Solar Engine," *New York Times*, October 6, 1868: 2.

that required “improvement,” “normalization,” or “repair” in order that their untapped resources could be profitably used for the benefit of both colonizers and colonized.⁵¹ His work also addressed a realization that the technologies and methods of resource exploitation that had been the source of prosperity in Europe and the eastern US were not ideally suited to arid and tropical regions where coal, water, and other essential resources were scarce. During the late nineteenth century, the problem of developing arid lands on the imperial periphery became a powerful stimulus for ecological thinking and creativity in the development and demonstration of new technologies adapted to the specific environmental and energetic potentialities of desert regions.⁵²

In 1870, Ericsson wrote that solar radiation “wasted” on the vast, sparsely-populated tropical and desert regions of the world constituted “an amount of dynamic force almost beyond comprehension.” He calculated that these areas could accommodate approximately 22,800,000 solar motors, each producing 100 horsepower of usable power.⁵³ Maintaining continual increases in industrial productivity beyond the age of coal, Ericsson believed, would involve reorganizing the geography of industrial capitalism in accordance with the natural energy endowments of these regions. Egypt, India, and California were not just ideal locations for solar energy demonstrations, he believed, but future hubs of a solar-powered industrial civilization.⁵⁴

Ericsson also anticipated a new era of imperial rivalry as coal supplies dwindled and nations competed for control over the sunny regions of the world. “Due consideration cannot fail

⁵¹ Diana K. Davis, “Imperialism, Orientalism, and the Environment in the Middle East: History, Policy, Power, and Practice,” in *Environmental Imaginaries of the Middle East and North Africa* ed. Edmund Burke (Athens, OH: Ohio University Press, 2011), 4.

⁵² William Beinart and Lotte Hughes, *Environment and Empire* (New York: Oxford University Press, 2007), 203, 213.; Also see Peter Anker, *Imperial Ecology: Environmental Order in the British Empire, 1895-1945* (Cambridge: Harvard University Press, 2001).

⁵³ “The Solar Engine,” *Scientific American* 23, no. 21 (November 1870): 323.; “Ericsson’s Sun Motor,” *Scientific American* 50, no. 20 (May 17, 1884): 310.

⁵⁴ William Conant Church, *The Life of John Ericsson*, volume 2 (New York: Charles Scribner’s Sons, 1911), 270.

to convince us that the rapid exhaustion of the European coal fields will soon cause great changes with reference to international relations, in favor of those countries which are in possession of continuous sun power,” he wrote. The transition to solar energy would, according to this view, require the industrial nations to maintain control over distant colonial possessions into perpetuity. “The time will come when Europe must stop her mills for want of coal,” he predicted. “Upper Egypt, then, with her never-ceasing sun power, will invite the European manufacturer to remove his machinery and erect his mills on the firm ground along the sides of the alluvial plains of the Nile, where an amount of motive-power may be obtained many times more than that now employed by all the manufactories of Europe.”⁵⁵

Ericsson’s speeches and writings on solar energy gained wide appeal, appearing in most of the major science and engineering journals in the United States and Europe. *Scientific American* was especially active in printing information on solar technology. The journal’s interest in Ericsson’s work and the work of other solar inventors reflected its role in a larger trend of enlisting scientists in the project of improving society through the development and introduction of new technologies.⁵⁶

A number of prominent scientists echoed Ericsson’s call to apply engineering expertise to the problem of harnessing the energy of sunlight in arid lands. Doing so, they predicted, would allow industrial civilization to thrive beyond the exhaustion of the coal fields while also restoring the ancient centers of civilization in the Middle East and North Africa to their former glory, but in an industrial cast. In an 1879 article for *Scientific American*, Samuel Pierpont Langley, the director of the Allegheny Observatory in Pittsburgh and one of the nation’s leading atmospheric scientists, posed this challenge to the engineers of the future:

⁵⁵ Quoted in William Church, “John Ericsson,” *Scribner’s Monthly* 17 (1879): 844.

⁵⁶ Bruce Sinclair, *Philadelphia’s Philosopher Mechanics: A History of the Franklin Institute, 1824-1865* (Baltimore: Johns Hopkins University Press, 1974).

Whoever finds the way to make industrially useful the vast sunpower now wasted on the deserts of North Africa or on the shores of the Red Sea will effect a greater change in men's affairs than any conqueror in history has done, for he will once again people those waste places with the life that swarmed there in the best days of Carthage and of old Egypt, but under another civilization, where man no longer worships the sun as his god, but has learned to make it his servant.⁵⁷

Such statements reflected a mixture of anxiety about the world's limited supply of coal – what Jevons called “the Mainspring of Modern Material Civilization” – and continuing confidence in Europeans' and Americans' capacity to overcome apparent environmental limits to the expansion of industrial society through advances in science, better technologies, and the continuing expansion and consolidation of their empires.⁵⁸ Factors influencing how this vision played out included the engineering challenges of deriving significant heat from diffuse, periodic, and frequently intermittent sunshine; the difficulties of securing financial backing for a new technology; and the challenges of adapting solar technologies to perform specific functions in specific places to the satisfaction of investors and the colonial regimes which they were meant to benefit. The result was that solar technologies became situated in time and place, with both their designs and cultural meanings reflecting European and American encounters with colonial geographies.

A Colonial Technology

William Adams, an engineer and patent officer from London, became one of the most vocal early proponents of solar energy development in the colonial world. Adams's career

⁵⁷ S.P. Langley, “The Sun as a Source of Power,” *Scientific American* 61, no. 5 (August 1879): 67.

⁵⁸ Jevons, *The Coal Question*, vii.

unfolded during a period of dramatic technological, social, and political change resulting from the interrelated forces of fossil fuel-based industrialization and empire. By the time he departed for India to serve as the deputy registrar of the High Court at Bombay in 1870, the mechanization of agriculture, mining, and manufacturing had transformed culture and society in Britain. Working with patents in the decades prior had given Adams an inside perspective on how the technologies powering the new industrial society had come into existence. He came to view the coal-powered steam engine not as a singular, isolated invention, but as a product of centuries of creative clambering to overcome limitations in the capacity for human and animal bodies to perform work. It represented not the pinnacle of industrial technology, he believed, but an indicator of humanity's ever-increasing ability to make use of the energy flows running through the natural world.⁵⁹

For Adams and many of his contemporaries, the impediments to unlimited mechanical power were not technological or environmental but social and political. Only if engineers, inventors, and scientists were allowed the autonomy to experiment could industrial technology fulfill its potential. Experimentation required not only freedom from political obstruction, but also considerable financial resources, manpower, and space to operate. Remote colonial posts, as historian Richard Grove observes, often made desirable vantage points for environmental observation and scientific experimentation.⁶⁰ They were typically perceived as lacking the entrenched private property rights and legal protections which constrained scientific and technical experimentation in Europe. Colonial science could also potentially benefit the empire by providing new methods for increasing productivity or lowering labor costs. For these reasons,

⁵⁹ Adams' early interest in the history of energy is described in Frank T. Kryza, *The Power of Light: The Epic Story of Man's Quest to Harness the Sun* (New York: McGraw Hill, 2003), 91-106.

⁶⁰ Richard Grove, *Green Imperialism: Colonial Expansion, Tropical Island Edens, and the Origins of Environmentalism, 1600-1860* (New York: Cambridge University Press, 1995).

India and other colonies were often viewed as laboratories for the development of new industrial technologies, new methods of harnessing energy from nature, and new ways of capitalizing on natural resources.⁶¹

When not engaged with official duties to the court, Adams experimented with a variety of technologies to derive useful energy from Bombay's sweltering sunshine. His initial devices were modest. The first was a cooker consisting of a reflective octagonal dish that directed solar heat to a four- by five-inch "cooking vessel." Adams touted his solar cooker in an 1878 letter to the editor of *Scientific American*: "The rations of seven soldiers, consisting of meat and vegetables, are thoroughly cooked by it in two hours, in January, the coldest month of the year in Bombay," he wrote, adding: "the men declare the food to be much better than cooked in the ordinary manner." The device also kept the food warm for a long period of time. The Surgeon General of the Service reported that a leg of mutton he had cooked on the device had stayed warm for four hours. Adams also built a solar-heated steam boiler consisting of ten, three-tiered wooden shelves, each containing eighteen 15 x 10 ½-inch mirrors mounted on swivels. With this, he was able to bring to a boil nine gallons of water placed at the focal point twenty feet away in thirty minutes. His ultimate aims were more ambitious. Adams planned to double the number of shelves, stacking them in two rows to form a segment of a circle forty feet in diameter. He predicted that the five hundred mirrors would generate a temperature of more than 7,616 degrees Fahrenheit within a two-foot diameter focal point.⁶²

⁶¹ Roy M. MacLeod, "Advice for British India: Imperial Perceptions and Administrative Goals, 1898-1923," *Modern Asian Studies* 9, no. 3 (1975): 343-384.

⁶² William Adams, "Cooking by Solar Heat," *Scientific American* 38, 24 (June 1878): 376.; Adams described his experiments in detail in *Solar Heat: A Substitute for Fuel in Tropical Countries for Heating Steam Boilers, and other Purposes* (Bombay: Education Society's Press, 1878).; His estimation of the heat produced by his proposed machine were later questioned. British engineer A.S.E. Ackerman thought the mistake may have been "due to a confusion of 'temperature' with 'quantity of heat'." A.S.E. Ackerman, "The Utilization of Solar Energy," *Smithsonian Institution Annual Report* (Washington D.C.: Government Printing Office, 1915), 155.

India, Adams believed, was ideally suited for solar power both because of its particular environmental qualities and its vast potential labor force which could supply cheaply produced goods to Britain. He was well aware of past scientific research on solar radiation; but for him, it was “a matter of astonishment” that the idea of using solar heat to do mechanical work had never been tested on a large scale in India “where there is by no means a lack of solar heat to concentrate.” India’s shortage of reliable coal deposits had long been considered a major impediment to schemes for mechanized transportation and large-scale manufacturing. For Adams, this feature of the environment made it unlikely that the colony could follow the same development path as Great Britain. This did not mean India was incapable of industrializing. He envisioned solar devices as alternative enabling technologies, attuned to tropical nature and thus capable of powering a modern India. “There is no limit whatever to the extent to which solar heat can be concentrated by reflection from a combination of flat mirrors,” he wrote. A solar powered industrial India was simply a matter of political will and the provisioning of enough funding, materials, and space.⁶³

Adams promoted his vision of India’s energy future in a series of letters to the editor of *The Times of India* in 1877. His aim was to promote solar’s potential to elevate India’s importance in the world market. Responding to skeptics, he argued that his current inventions were only first steps towards a revolutionary change in the energy basis of society, one that would give India a significant advantage over coal-dependent Europe. The discovery of improved methods of harnessing industrial energy from sunlight, he proclaimed, would constitute “a discovery more important to the people of this country than any truth that has ever been discovered, because it shows them that they possess in their glorious skies an inexhaustible source of wealth which the peoples of the West have to dig from the bowels of the earth with

⁶³ Adams, “Cooking by Solar Heat.”

infinite pain and labour; and which is destined to make India the seat of the principal manufactories of the world.”⁶⁴

Adams’s identification of the potential for solar technology to transform tropical and arid regions formed in part in the context of imperial competition. Much of his work in India was motivated by rumors of French experiments with solar technologies in North Africa. French scientists, he wrote in 1878, “are said to be making experiments with the object of using solar heat, concentrated by gigantic revolving burning glasses, as a motive power for railway locomotives on a line that they propose to construct across the desert of the Sahara.” Adams regarded such “purely utopian” projects – however unrealistic in the short term – as contributing to the long term commercial development of arid regions. “Very important discoveries have been made in striving for the impossible,” he wrote, “and if no further success is achieved than that of utilizing the rays of the sun for driving stationary steam engines, an important addition to physical science will have been made, and a great commercial revolution will have been effected.”⁶⁵

French professor of mathematics Augustin Mouchot became the most important figure in the early development of modern solar technologies. In the early 1860s, he designed and built a number of prototype devices for cooking food and distilling liquor. Like Adams, Mouchot had higher ambitions. Not content to build mere “curious devices,” he aimed to adapt solar technologies “in a practical way” to serve the nation and bring about a more just, prosperous, and

⁶⁴ William Adams, “Solar Heat: To the Editor of the Times of India,” *The Times of India*, April 19, 1877: 2.; This article was a response to a challenge by Raja Sir Madhava Rao, a prominent administrator in the Indian government, who questioned whether Adams’s solar devices could ever be more than “toys.” “Rajah Sir T. Madava Row’s Views on Solar Heat: To the Editor of the Times of India,” *The Times of India*, April 17, 1877: 2.; This critique was prompted by Adam’s earlier letter “Solar Heat: To the Editor of the Times of India,” *The Times of India*, April 11, 1877: 3.

⁶⁵ Adams, *Solar Heat*, 1.; Adams also mentioned his debt to French solar inventions in Adams, “Solar Heat.”; and “The Utilisation of Solar Heat: To the Editor of the Times of India,” *The Times of India*, November 23, 1877: 2.

rational society.⁶⁶ His immediate concern was that the limited coal deposits of Alsace and Lorraine might be insufficient to sustain French industrial ascendancy. “One cannot help coming to the conclusion that it would be prudent and wise not to fall asleep regarding this quasi-security,” he warned in 1869. “Eventually industry will no longer find in Europe the resources to satisfy its prodigious expansion...Coal will undoubtedly be used up. And what will industry do then?” His answer was to harness the free and ubiquitous rays of the sun.⁶⁷

As he became more familiar with methods of concentrating solar heat, Mouchot took on the more ambitious project of designing and building a solar-powered steam engine. By 1866, he had overcome most of the obvious difficulties, constructing a mirror-lined trough collector which concentrated solar rays on a water-filled, one-inch diameter copper pipe. A year later, Mouchot displayed the device at the Exposition Universelle in Paris, the largest international exposition of technology yet held. Emperor Napoleon III was so impressed that he authorized a generous grant for the development an industrial-scale machine.⁶⁸

Mouchot continued to refine the design over the next three years, but was forced to halt work in the summer of 1870 following France’s ill-advised invasion of Prussia. Mouchot’s funding evaporated as a result, and his machine disappeared “in the midst of our national disaster.”⁶⁹ The war also created opportunities in the field of solar energy. The debacle gave Prussia control of France’s only coal fields in Alsace and Lorraine, sparking renewed interest in solar collectors as a possible way to make up for the anticipated energy deficits. In 1874, the

⁶⁶ Butti and Perlin, *A Golden Thread*, 63, 64.

⁶⁷ Quoted in *Ibid.*, For more on Mouchot’s life and work see Kryza, *The Power of Light*, chapter 6.; Mouchot’s own treatise on solar energy remains one of the most important resources for data on various methods of concentrating solar heat. A. Mouchot, *La Chaleur Solaire et ses Applications Industrielles*, 2nd ed. (Paris: Gauthier-Villars, 1879).

⁶⁸ Kryza, *The Power of Light*, 157-158.; For data on some of his early experiments see Augustin Mouchot, “Sur les Effets Mecaniques de l’Air Confine et Chauffe par les Rayons du Soleil,” *Comptes Rendus de l’Academie des Sciences* 59 (1864) : 527.

⁶⁹ Quoted in Kryza, *The Power of Light*, 159.

French government provided Mouchot with funding to build a much larger, cone-shaped solar collector, powerful enough to drive a half-horsepower engine at eighty strokes per minute. When he put the model on display at the library at Tours that year, the “strange looking apparatus” attracted immediate attention from the scientific and popular press. Not only could it drive a steam engine, it was also capable of operating a distiller that vaporized water at a rate of five gallons per minute.⁷⁰

Despite the good publicity, Mouchot was acutely aware of the limitations of solar energy in frequently overcast Paris. He also realized that in such a densely packed metropolis, “sun machines would take up too much space...and therefore could not be profitably used.” He estimated that in the Paris climate, operating a typical 100 horsepower motor would require at least 200 solar machines spread out over as many as 100,000 square feet of valuable urban real estate.⁷¹ As early as 1869, he had described the significantly greater benefits that could accrue from solar development in the “torrid zones” such as Vietnam where “the matter of hygiene comes to the fore.” In Saigon, he wrote, “water has to be boiled to be made potable. What a savings in fuel one could realize using a [solar still] in the ardent heat of those climates!”⁷² Arid regions appeared even better suited to solar development. Referencing the work of British astronomer Sir John Herschel and others who had recorded the intensity of solar radiation in various places around the globe, he predicted that “the invention of ‘sun-receivers’ will, someday, enable industry to establish works in the desert, where the sky remains very clear for a

⁷⁰ Leon Simonin, “L’Emploi Industriel de la Chaleur Solaire,” *Revue des Deux Mondes*, May 1 1876. ; Ackerman, “Utilization of Solar Energy,” 149-152.

⁷¹ Mouchot, *La Chaleur Solaire*, 257.

⁷² *Ibid.*, 263.

long time, just as hydraulic engines have enabled them to be established by the side of water courses.”⁷³

The opportunity to test his devices in a more favorable environment came in 1877 when the Ministry of Public Education sponsored an expedition to Algeria to test practical applications for solar energy. Government officials saw Mouchot’s work as a way to extend French control over the Algerian landscape and its indigenous inhabitants by bringing more of the desert under productive use. The specific goal was to provide for the expansion of French settlement beyond the city Algiers while alleviating some of the costs and political compromises involved in importing coal from Great Britain. Mouchot arrived in Algiers on March 6, 1877 full of optimism. His initial aim was to “provide our soldiers in Africa with a small and simple portable solar stove, requiring no fuel for the cooking for food.” He predicted that his device would “be a big help in the sands of the desert as well as the snows of the Atlas Mountains.” In the first test, Mouchot impressed a group of colonial officials by baking a full meal consisting of a pound of bread, two pounds of potatoes, a beef stew, and roast “whose juices fell to the bottom of the pot.” Following this, Mouchot modified his solar cooker to serve as a pasteurizer to kill the bacteria that frequently plagued shipments of Algerian wine. He predicted that by adopting solar technologies on a large scale, Algeria would soon “be able to ask from the beautiful sun not only to care for the ripening of her vineyards, but also to improve her wines and make them transportable, which would be for her a new source of prosperity.”⁷⁴

Colonial officials were especially impressed by Mouchot’s next demonstration, a solar-powered groundwater pump – similar to the Tours device – which promised a relatively simple solution to the problem of irrigating the fertile but arid lands along the Mediterranean coast.

⁷³ Augustin Mouchot, “Solar Heat as Motive Power,” *Scientific American* 20, no. 15 (April 1869): 227.

⁷⁴ Mouchot, *La Chaleur Solaire*, 235-236.

Even though the device was too small to make a significant contribution, he found it operated much better in sunny Algeria than in Paris. With additional government support, he believed, larger machines could be built, and solar-powered irrigation could eventually open up the region for French settlement, transforming it into a major food-production center for Western Europe and the Mediterranean.⁷⁵

Upon his return to Paris in 1878, Mouchot resumed teaching. While he continued to investigate methods of storing solar heat, which he viewed as the primary obstacle to more widespread application of the technology, his experiences in Algeria also left him ambivalent about solar's potential to address deeper social and economic problems in the colony in the immediate future.⁷⁶ During his travels across the Sahara, evidence of past failures at technological improvement were everywhere in the form of dried up canals, abandoned rail lines, and desiccated fields, none of which appeared to have elevated living conditions, least of all for Native Africans. It increasingly seemed to him that technology had become an instrument of impoverishment rather than a source of uplift. This was especially evident in Algiers where the striking contrast between the poverty and hopelessness of the city's indigenous population and the comparative luxury of the French quarter affected him profoundly. The local Berbers and Arabs, Mouchot wrote, "lived and died without either memory or hope, happy for the crusts that kept them alive or the sleep that brought them the brief, uneasy solace of dreams."⁷⁷

As Mouchot tempered his earlier ambitions, his student M. Abel Pifre took up the task of further promoting his mentor's existing designs. In 1878, Pifre attracted the interest of the

⁷⁵ Kryza, *The Power of Light*, 169-170, 175.; "A Solar Printing Press," *Nature* (September 21, 1882): 503-504.; For technical details on his Algeria experiments see Augustin Mouchot, "Re'sultats d'Experiences Faites en Divers Points de l'Algerie pour l'Emploi Industriel de la Chaleur Solaire," *Comptes Rendus de l'Academie des Sciences* 86 (1878): 1019-1021.

⁷⁶ Mouchot's changing view of Algeria is described in Kryza, *The Power of Light*, 169-170.

⁷⁷ Quoted in *Ibid.*, 169.

international science press with his display of a sun powered printing press adapted from Mouchot's Algeria irrigation pump on the steps of the Jeu de Paume in Paris.⁷⁸ He also established a Society for the Utilization of Solar Energy which, in addition to conducting demonstrations, also offered devices of different sizes for sale. In 1883, *The Times of India* carried a report by Indian ambassador J.R. Royle on a visit to the society's Paris facility. Although he was not able to see a device in operation (it was December and "the sun was not seen once"), Royle was impressed. He wrote back that since the machines "are said to have been worked successfully in Algeria, Morocco, Senegal and other parts of Africa," it would be worth "procuring one...for experimental use in India."⁷⁹

Hoping to capitalize on the international attention generated from Mouchot's and Pifre's work, French solar inventors continued to focus on Algeria. In 1890, engineer Charles Tellier published *The Peaceful Conquest of Africa by the Sun*. The title was an adaptation of the French government's earlier slogan of "peaceful conquest" (Pénétration Pacifique) which, historian Benjamin Claude Brower explains, masked and systematized a legacy of colonial violence in Algeria.⁸⁰ In an attempt to revise the concept in light of new developments in science and technology, Tellier proposed using solar-powered groundwater pumps as a way to avoid the failures of past efforts to irrigate the Mediterranean coast by taking advantage of the "natural forces" already extant in the African environment. In the Sahara, he wrote, the sun was "the natural power of choice, since it exists everywhere, with a powerful intensity." Harnessing the sun's energy would serve a "triple purpose," he maintained. It would enable the extension of French industry and settlement into the region, contribute to "making this extension easy and

⁷⁸ "A Solar Printing Press," *Nature* (September 21, 1882): 503-504.

⁷⁹ J.R. Royle, "The Utilization of Solar Heat," *The Times of India*, June 21, 1884, 6.

⁸⁰ Benjamin Claude Brower, *A Desert Named Peace: The Violence of France's Empire in the Algerian Sahara, 1844-1902* (New York: Columbia University Press, 2009).

profitable,” and apply the sun’s heat to what he saw as the “humanitarian work” of commercial expansion. Tellier’s optimism was based on his assessments of the intensity of sunlight in the region, reports of the existence of a great reserve of water beneath the desert surface, and his belief in Africans’ natural ability to labor in a “torrid climate” for which Europeans were “ill-adapted.”⁸¹

Although Tellier never tested a prototype in Algeria, his concept of a low-temperature, flat-plate collector that vaporized ammonia, a liquid with a low boiling point, appealed to later inventors in Europe and the United States who touted his design as a more practical, cost-effective approach than Adams’s and Mouchot’s high-temperature, water-based solar steam engines.⁸² His enthusiasm for solar energy as a “valuable auxiliary to civilization” in North Africa, where extreme heat, aridity, and limited access to coal had impeded industrial development for decades, also reflected France’s ambition to make use of and profit from colonial nature, and by doing so, to justify the whole colonial enterprise.⁸³

*Egypt: “The Power Station of the World”*⁸⁴

Philadelphia inventor Frank Shuman made the most serious effort to adapt Tellier’s concept of a flat plate, low-temperature solar motor for commercial purposes in the colonial world. His work culminated in the construction and demonstration of a sprawling, 65-horsepower solar irrigation pump on the Nile River outside of Cairo in 1913. The product of

⁸¹ Charles Tellier, *La Conquête Pacifique de L’Afrique Occidentale Par Le Solier* (Paris: Librairie Centrale Des Sciences Mathématiques, 1890), 1-6, 14, 89.

⁸² For brief descriptions of Tellier’s design in English see “The Utilization of Solar Heat for the Elevation of Water,” *Scientific American* 53 (August 15, 1885): 214.; and Ackerman, “The Utilization of Solar Energy,” 158.

⁸³ Tellier, *La Conquête Pacifique*, 87.

⁸⁴ Quoted in “Harnessing Phoebus: Sun Works Machinery,” *Egyptian Gazette*, July 12, 1913: 6.

several years of design, testing, redesign, and promotion, Shuman's Egypt sun machine was the largest functioning solar power plant built prior to World War II. Its history also pointedly illustrates the colonial context for the early development and demonstration of modern solar technologies.

Shuman's interest in solar energy derived from his early work on glass. His 1892 invention of "wire glass," a reinforced glass for use in skylights and other large windows, had made him a wealthy man by the turn of the century. His familiarity with the heat concentrating properties of glass led him to take a more serious interest in solar energy as a source of motive power beginning in 1906. Shuman's early experiments with flat plate, glass-covered collectors in his home town of Tacony outside of Philadelphia soon convinced him that solar technology could be the next great innovation in a society that had learned, in his words, "to manufacture power."⁸⁵

By the turn of the century, many influential scientists and engineers shared Shuman's sense of urgency regarding the development of solar technologies. In 1885, an editor for *Scientific American* grouped solar energy with "those wasted powers of nature which we have had under consideration several times of late." Echoing William Thomson, he added: "The idea of allowing energy force which we can use without expense to our grasp is exceedingly unpleasant, and yet we are doing it constantly."⁸⁶ In a review of recent developments in solar science, another author predicted that while "sun machines" had not yet proven commercially viable, "the day is not unlikely to arrive before long when the thing will be done and the orb of

⁸⁵ Quoted in Kryza, *The Power of Light*, 28.

⁸⁶ "Solar Machinery."

day fairly harnessed for working all the engines of the earth.”⁸⁷ In 1901, Smithsonian scientist Robert H. Thurston warned that US coal reserves would last only about another century, and that the outlook was even bleaker for England. “Within a few generations at most,” he wrote, “some other energy than that of the combustion of fuels must be relied upon to do a fair share of the work of the civilized world.”⁸⁸ Other alternatives to coal including wave power and wind power also attracted attention during this period.⁸⁹

Hoping to capitalize on this interest, in 1908 Shuman created the Sun Power Company and began soliciting for investors. While his demonstrations in Tacony generated excitement among scientists and engineers, investors proved harder to impress, especially in Philadelphia.⁹⁰ Pennsylvania was the nation’s coal heartland, and not surprisingly its most prominent financiers showed no interest in supporting an operation that might eventually compete with the industry that was the source of their wealth.⁹¹

Spurned in his home state, Shuman honed his target audience and sharpened his rhetoric, publishing letters in scientific journals and delivering speeches emphasizing the benefits of his design in “those regions in the tropics where the sun practically shines throughout the years, and where fuel is expensive, coal costing in some localities \$30 per ton.” In 1911, he argued that solar motors could produce at least a half a million horsepower “in such tropical fields as the

⁸⁷ “Solar Energy: What the Sun’s Rays can do and may yet be made to do,” *New York Times*, July 20, 1891, 2.; For a review of European experiments with solar and solar patents issued in the United States by 1897 see “Sun’s Rays to Work: Many Recent Inventions to Utilize Solar Heat,” *The Washington Post*, September 5, 1897, 18.

⁸⁸ Robert H. Thurston, “Utilizing the Sun’s Energy,” *Annual Report of the Board of Regents of the Smithsonian Institution for the Year ending June 30, 1901* (Washington D.C.: General Printing Office, 1901), 263-270.

⁸⁹ Vaclav Smil, *Energy in World History* (Boulder: Westview Press, 1994), 168-173.; For the promise of wind, wave, and direct solar energy also see Peter Townsend Austen, *The North American Review* (June 1895): 758.; For the benefits of taking advantage of these “intermittent natural sources of energy” outside of Europe and eastern North America see the report on a paper presented by Canadian electrical engineer Reginald Fessenden “Natural Energy: Power from Sun and Wind,” *The Times of India*, October 14, 1910: 10.

⁹⁰ Frank C. Perkins, “A New Solar Power Plant.” *Scientific American* 98, no. 6 (February 8, 1908), 97.; For a detailed account of Shuman’s demonstration and his hot box design refer to “Power from the Sun’s Heat,” *Engineering News* 61, no. 19 (May 13, 1909), 509.

⁹¹ Kryza, *Power of Light*, 26.

nitrate district of Chile, the borax industry in Death Valley, and for general purposes in places where the outside temperature runs from 110 to 140 degrees Fahrenheit.” An investment in solar energy was more than a business decision, Shuman insisted, but an opportunity to contribute to an energy revolution that would enable industrial society to overcome the limitations imposed by coal and other existing energy sources. “The future development of solar power has no limit,” he proclaimed in *Scientific American*. “Where great natural water powers exist, sun power cannot compete; but sun-power generators will, in the near future, displace all other forms of mechanical power over at least 10 percent of the earth’s land surface; and in the far distant future, natural fuels having been exhausted, it will remain as the only means of existence of the human race.”⁹²

In 1911, with the assistance of prominent British engineer A.S.E Ackermann, Shuman turned his attention to colonial Africa where the climate was conducive to solar energy utilization and where the price of coal was as much as fifteen times greater than in England and the eastern US. That year he sailed to London where he met with members of Britain’s most prestigious science and engineering societies, investors, and members of Parliament to promote his idea of building a massive solar-powered water pump on the banks of the Nile in Egypt. His sun machine, he argued, would provide an immediate economic benefit while also demonstrating the practicality and profitability of solar energy for a variety of applications throughout “most of the tropical regions.” Shuman’s pitch appealed to the British regime in Egypt which for nearly two decades had made controlling the waters of the Nile its central aim both for the purpose of

⁹² Frank Shuman, “Solar Power,” *Scientific American* 71 (February 4, 1911), 79.; Also see Frank Shuman, “The Generation of Mechanical Power by the Absorption of the Sun’s Rays,” *Mechanical Engineering* 33 (December 19, 1911), 1.; Frank Shuman, “Power from Sunshine: A Pioneer Solar Power Plant,” *Scientific American* 105 (September 30, 1911), 291-292.; “Harnessing the Sun-Rays for Pumping Water,” *Current Literature* 71, no. 5 (November 1911), 510.; and “A Commercial Sun Power Plant,” *Engineering Record* 64, no. 13 (September 23, 1911), 368-369.

increasing the economic productivity of Egyptian agriculture and for maintaining its strategic position in Africa.

Agriculture along the Nile had thrived for millennia, sustained by the annual floods which restored nutrient-rich sediment to the plains of Upper Egypt. Artificial irrigation involving water diversions and the construction of dikes and sluice gates began some 5,000 years ago.⁹³ Following its conquest of Egypt in 1517, the Ottoman Empire established a complex bureaucratic structure based on deference to local water users in day-to-day decisions about constructing, operating, and maintaining irrigation works. As historian Allan Mikhail explains, this led to the formation of “communities of water” which ensured the economic productivity of Egyptian agriculture according to imperial designs while at the same time allowing locals to maintain control over essential water resources.⁹⁴ This tradition of local control began to change with the advent of large-scale irrigated cotton production in the nineteenth century. In the 1860s, Khedive of Egypt Muhammad Ali hired British engineers to build earthen dams and canals as the basis for a perennial irrigation system. By reducing Egypt’s dependence on the annual floods of the Nile, Ali hoped to build an economic base sufficient to gain independence from the Ottoman Empire and to resist a British or French takeover. While Egyptian cotton production increased by 600 percent by the late 1870s – largely due to the interruption in global supply caused by the American Civil War – this was not enough to repay debts, and the nation was unable to resist British intervention in 1882.⁹⁵

⁹³ For an overview of the early history of irrigation on the Nile refer to P.M. Chesworth, “The History of Water use in the Sudan and Egypt,” in *The Nile: Sharing a Scarce Resource: An Historical and Technical Review of Water Management and of Economical and Legal Issues*, ed. P.P. Howell and J.A. Allan (Cambridge: Cambridge University Press, 1994), 66-71.

⁹⁴ Alan Mikhail, *Nature and Empire in Ottoman Egypt: An Environmental History* (New York: Cambridge University Press, 2011), Chapter 1.

⁹⁵ J.R. McNeill, *Something New Under the Sun: An Environmental History of the Twentieth Century World* (New York: W.W. Norton & Company, 2000), 168-169.

From the beginning of its occupation of Egypt, the British regime recognized the economic and strategic importance of maintaining the largest share of Nile water as possible. While Britain sought to defend its access to the Nile through conventional methods of diplomacy and military force, it also deployed hydraulic engineers, many with previous experience in India, to devise methods of retaining more of the great river's water for agricultural use. During the 1890s, India-born engineer William Willcocks surveyed the Nile in Egypt, concluding that a storage dam across the granite gorge at Aswan, 520 miles south of Cairo, would allow for two or even three yields of cotton each year, increasing Upper Egypt's productive capacity by at least twenty five percent.⁹⁶ Such returns were also dependent on establishing control over upstream waters. In 1898, following the Anglo-Egyptian Army's defeat of the Mahdist forces in the southern Sudan, Consul-General of Egypt Lord Cromer sent engineer William Garstin to the region to report on the navigability of the vast, vegetation-choked swampland known as the Sudd – meaning barrier in Arabic – on the upper reaches of the White Nile. During three subsequent reconnaissance missions, Garstin became convinced that the future of the British regime depended on retaining more of the water that entered the Sudd, as much as 60 percent of which, he discovered, was lost to evaporation. In 1904, Garstin proposed a 225-mile canal bypassing the Sudd, which he estimated would irrigate an additional two millions acres of land, bringing Egypt's total acreage under cultivation to eight million.

Initial work on what became known as the Jonglei Canal halted following Lord Cromer's and Garstin's retirements in 1907 and 1908 respectively. The emergence of a strong nationalist rebellion against the British regime further delayed the project. Other factors preventing its resumption included its immense scale and cost, as well as the physical and logistical challenges

⁹⁶ Frederic Courtland Penfield, "Harnessing the Nile," *The Century Magazine* 57, no. 4 (February 1899): 483-492.

of transporting a labor force and equipment through the dense mats of vegetation that each year clogged the shallow meandering waterways of the Sudd.⁹⁷ Despite these obstacles, the idea of engineering the entire Nile for the purpose of agricultural development remained a British priority. In 1908, Winston Churchill, at that time a major in the British Army, declared that “exact scientific control of the whole vast system of Central African waters, of the levels of every lake, of the flow of every channel, from month to month and from day to day throughout the year, is a need so obvious an undisputed as to leave argument unemployed.”⁹⁸

What Churchill saw as a natural course for the development of the Nile’s water in fact reflected a particular colonial imagining of the river that had emerged from the commingling of recent developments in science and technology and intensifying imperial rivalry over Africa’s finite natural resources. Envisioned in London and Cairo as a means to bring material prosperity to both Britain and Egypt, the project of “Nile control” also functioned as a physical expression of British imperial power over the Egyptian landscape and its inhabitants. As historian Jennifer Derr notes, when it was built in 1902, the Aswan Dam “transformed water from a local resource into one that could be controlled and allocated at the level of the central state,” often to the detriment of water users, especially those upstream from Aswan where agricultural development remained minimal.⁹⁹ The dam and subsequent plans for the Jonglei canal reflected a “downstream perspective” which envisioned the full length of the Nile and its tributaries as an

⁹⁷ The difficulties posed by the environmental conditions of the Sudd are vividly described in Robert O. Collins, *The Waters of the Nile: Hydropolitics and the Jonglei Canal, 1900-1988* (Oxford: Clarendon Press, 1990), 66-89.

⁹⁸ Quoted in Terje Tvedt, *The River Nile in the Age of the British: Political Ecology and the Quest for Economic Power* (New York: I.B. Tauris & Co., 2004), 82.

⁹⁹ Jennifer L. Derr, “Drafting a Map of Colonial Egypt: The 1902 Aswan Dam, Historical Imagination, and the Production of Agricultural Geography,” in *Environmental Imaginaries of the Middle East and North Africa*, 146.

ecologically coherent watershed that could be engineered to maximize the productivity of agriculture in Upper Egypt.¹⁰⁰

By 1911, British officials welcomed Shuman's proposal as an intriguing possibility for overcoming the various political, environmental, and economic impediments to Nile control. His tour of London also coincided with the appointment of General Horatio Herbert Kitchner, former commander of the Anglo-Egyptian Army, as Consul-General in Egypt.¹⁰¹ Shuman's plan had great appeal for Kitchner who had already declared his intent to retract the concessions his predecessor Sir Eldon Gorst had made to the Egyptian nationalists and to revitalize and expand on the irrigation projects that had been put on hold with Lord Cromer's and Garstin's retirements. Inspector-General of Antiquities Arthur E.P. Brome Weigall explained the rationale: "Not only does our control of Egyptian affairs...insure all the comforts of peace and justice both for the native and the European population, but it also procures that sense of general security which enables the commerce of the country to expand and prosper."¹⁰²

Kitchner recognized two primary applications for solar energy that accorded with these goals. First, as Shuman proposed, solar plants could supply essentially free and unlimited power for pumping water onto the parched desert lands above the natural flood plain of the Nile, replacing the time- and labor-intensive manually operated devices then used for that purpose. Kitchner also saw the possibility of sun machines as simpler, more elegant alternatives to Garstin's brute force solution to the problem of retaining the water lost to evaporation in the Sudd. If positioned at the outlet of the swampland, a massive solar-powered water pump could function to drain the Sudd, recharging the river channel downstream during the dry season.

¹⁰⁰ Tvedt, *The River Nile in the Age of the British*, 72.

¹⁰¹ Quoted in Arthur E.P. Brome Weigall, *A History of Events in Egypt from 1798 to 1914* (Edinburgh: William Blackwood and Sons, 1915), 238.

¹⁰² *Ibid.*, 241.

Kitchener believed that the greater volume would allow him to build additional dams upstream from Aswan without appearing to be “stealing” water from agricultural interests downstream. Such a system would allow cotton production to expand further south into southern Egypt and northern Sudan while imposing order to the region’s frequently hostile and unpredictable resident indigenous population. As one Kitchner attaché put it, the reengineering of the upper Nile basin would transform “the old hotbed of Mahdist barbarism into elysian fields of produce.”¹⁰³

Before such applications could be implemented, the British regime required a demonstration to ensure the functionality and reliability of the technology. Originally, Shuman proposed to cover four acres of desert near the farming village of al Meadi on the outskirts of Cairo with hot box collectors such as those he had put on display in Tacony. He estimated that the installation could produce a remarkable 1,000 horsepower, far more than any previous solar motor. A single motor of this kind, he claimed, could do the work of thousands of fellahin laborers using traditional methods.¹⁰⁴

Shuman’s investors, while enthused with the concept, remained skeptical of his design. Before approving the plan, they brought in physicist Charles Vernon Boys, author of the popular 1890 book, *Soap Bubbles: their Colours and the Forces that Mold them*, to review the plans. Though respected in Britain as a public face of science, Boys had limited practical knowledge of solar energy and energy economics generally. In his work, he also favored an aesthetic approach to design that may have been appropriate for public display but not necessarily for the vagaries of a competitive marketplace. “His space had three dimensions only,” his biographer wrote, “and

¹⁰³ Sydney Alexander Moseley, *With Kitchener in Cairo* (New York: Cassell and Company, 1917), 228.

¹⁰⁴ Shuman, “Solar Power.”

he was impatient with more.”¹⁰⁵ For Boys, Shuman’s simple hot box design seemed like a crude workshop prototype rather than a bold demonstration of British engineering prowess. Whereas Shuman hoped to launch a new industry by demonstrating a functional machine capable of generating power and profits immediately, Boys saw the project as primarily a political statement, as an opportunity to display an intriguing new technology with the potential to eventually contribute to British economic and political ambitions in the region. To make for a more effective display, he recommended that Shuman replace his hot boxes with mirror-lined parabolic trough collectors modeled after John Ericsson’s more elegant prototype. Parabolic collectors were more efficient and visually impressive, as Shuman understood, but they were also far more expensive. Under pressure from his investors and even his most ardent supporter Ackermann, Shuman ultimately agreed to honor Boys’s request.¹⁰⁶

To keep within his \$40,000 budget, Shuman had to dramatically scale back the plant’s size and power output. Fewer collectors meant that the plant could produce at most 65 horsepower. This was significantly more than any solar motor built to date, but still paltry compared to the 1,000 horsepower he had expected from his original design (and far less than the 3,000 horsepower possible with a coal plant of comparable construction cost). Shuman also encountered a number of difficulties during construction. He had originally planned to ship the pre-built hot boxes and other components from Philadelphia directly, but the new design requirements meant he would have to acquire materials and fabricate many of the components locally. He and Ackerman hoped that zinc pipes, the cheapest pipes available locally on short notice, would be a sufficient housing in which to vaporize the water and transmit the steam to the

¹⁰⁵ Rayleigh G. Strutt, “Charles Vernon Boys, 1855-1944,” *Obituary Notices of Fellows of the Royal Society* 4, no. 13 (November 1944): 771.

¹⁰⁶ Shuman’s frustration recounted in Jeremy Shere, *Renewable: The World-Changing Power of Alternative Energy* (New York: St. Martin’s Press, 2013), 115-116.

pump motor. In the initial tests, however, the zinc pipes softened under the intense heat until they “hung down limply like wet rags,” as one observer noted.¹⁰⁷ As costs mounted, Shuman also abandoned his plan for a large, insulated storage tank which he believed would have allowed the pump to run at night and on cloudy days. Under pressure from investors, colonial administrators, and the media, Shuman and Ackerman did their best to work through these setbacks; and on a 100 degree day in June 1913, they demonstrated the diminished but still impressive pump to a crowd of astonished businessmen, journalists, and dignitaries including Lord Kitchner.¹⁰⁸

The demonstration seemed to have been a success at first. A report in the *Egyptian Gazette* described it as “the modern substitute for sun worship” and “one of the most ingenious and interesting devices ever seen in Egypt.” The report also included a statement by Shuman’s underwriters touting the machine’s vast potential:

Sunlight abounds in the tropics and costs nothing. The sun power plant at Meadi shows plainly that it can be used to the greatest advantage. Any number of plants, like the one at Meadi, or larger, can be constructed, and mechanical power for all purposes without limit can be obtained. By means of this power all our irrigation can be done, artificial fertilizers manufactured to any extent from the nitrogen of the air, artificial ice made, electricity generated, and in fact, all work now done by the steam and petrol engines, can be done directly by the sun.¹⁰⁹

This vision of solar’s economic potential also had political implications, suggesting the possibility of a future geographic shift in industrial production toward Egypt and other colonies in the arid and tropical regions of the world. “Eventually,” Shuman’s underwriters proclaimed,

¹⁰⁷ “An Egyptian Solar Plant,” *The Washington Post*, February 2, 1913.

¹⁰⁸ A.S.E. Ackerman, “The Utilization of Solar Energy,” *Smithsonian Institution Annual Report* (Washington D.C.: Government Printing Office, 1915), 163-165.

¹⁰⁹ “Harnessing Phoebus: Sun Works Machinery,” 3, 6.

“the tropics will become the power station of the world through the development of sun power and because of the gradual exhaustion of the coal fields.”¹¹⁰

British engineers William Willcocks and James Ireland Craig also took note of the demonstration in their 1913 *Egyptian Irrigation*, observing that “the climates of Middle and Upper Egypt and the North Sudan should very suitable for the utilization of the power of the sun.” Just as important, they stressed that while coal was relatively cheap at Alexandria and Cairo, it became progressively more expensive further upriver. Their estimates of the cost of coal beyond Aswan and especially in the Sudan were much higher than the minimum amount Shuman estimated would make solar energy cost effective.¹¹¹

Shuman also stepped up his marketing campaign following the demonstration. In statements to the press, he described vast arrays of collectors in the desert regions of the world. These installations, he predicted, could one day satisfy all of the world’s energy needs. He calculated that the approximately 270 million horsepower then being produced worldwide by traditional means could be equaled by a 20,250 square-mile field of hot box collectors in Arizona or the Sahara Desert. While enormous, such an installation would still only occupy a fraction of the world’s desert lands. The total cost of such a complex, which he estimated at \$98 million, “would not be made for or by the individual, but for and by the entire human race.”¹¹² His Egypt machine, he argued in a 1913 letter to the editor of *Scientific American*, demonstrated that such ideas were feasible. “Sun power is now a fact,” he urged, “and is no longer in the ‘beautiful possibility stage.’” For industrial society to survive and progress beyond the inevitable exhaustion of the world’s coal fields, such projects had to move from the imagination into practice. “One

¹¹⁰ *Ibid.*, 6.

¹¹¹ William Willcocks and James Ireland Craig, *Egyptian Irrigation*, vol. II (London: E. & F. N. Spon, 1913), 758, 759.

¹¹² Frank Shuman, “The Most Rational Source of Power: Tapping the Sun’s Radiant Energy Directly,” *Scientific American* 109 (November 1, 1913): 334, 350.

thing I feel sure of,” he concluded, “is that the human race must finally utilize direct sun power or revert to barbarism.”¹¹³

Shuman’s demonstration also attracted interest beyond Britain including in France, Chile, and especially Germany which was also seeking ways to extend industrial capabilities to its African colonies. In 1913, the Reichstag held a special session to hear his proposal. The meeting resulted in an offer of 200,000 marks to install sun machines in German colonies in eastern Africa.¹¹⁴ Not to be outdone by a rival power, Lord Kitchener offered to provide Shuman with a 30,000 acre cotton plantation in the Sudan near the outlet of the Sudd for the construction of a much larger plant.

Several factors prevented Shuman from following through on these offers. Most importantly, the outbreak of World War I in 1914 halted all irrigation development in Egypt, and Shuman’s project, as he put it, was “put on the shelf.” Soon after, British troops dismantled the al Meadi plant for salvage materials. The increasing importance of oil as a fuel for transportation during the war also diverted industry and government attention away from other alternatives to coal.¹¹⁵

The war and the ascendance of oil, however, were not the only factors deferring Shuman’s dream. Seduced by the prospect of transforming Egypt into a modern irrigated paradise, Kitchener, Shuman, and others failed to appreciate the complex, interconnected ecological and social ramifications of environmental modification on such a scale. Interestingly, some of the harshest critiques came from William Willcocks, one of the principal architects of Egyptian irrigation. While he recognized that simply relying on the river’s natural cycle would

¹¹³ Frank Shuman, “Feasibility of Utilizing Power from the Sun,” *Scientific American* 111, no. 9 (February 28, 1914): 179.

¹¹⁴ “American Inventor uses Egypt’s Sun for Power,” *New York Times*, July 2, 1916.; Shuman also said that he was exploring opportunities in Chile.

¹¹⁵ *Ibid.*

not sustain the level of production necessary to meet modern demands, Willcocks also maintained that engineers would not be able to simply bend the river to their will. He argued that maximizing the river's potential would involve improvements to the existing social-environmental system rather than a wholesale reinvention of it. He was also critical of the scale of Kitchner's plans, pointing out that increased productivity had led to rapid population growth and a commitment to mono-crop agriculture. He suggested that the resulting reliance on imports exposed the Egyptian peasantry to the risk of calamity in the event of flood or drought, both common occurrences in the Nile region. He also argued that the more complicated, centralized infrastructure ended up exacerbating abuses of power that already existed, encouraging the use of forced fellahin labor and further concentrating political and economic power in the hands of British administrators and local elites.¹¹⁶

By the time Shuman demonstrated his solar plant, a number of other problems had become apparent. Dams and canals invariably required frequent costly repairs, and British officials often failed to address the critical issue of drainage in favor of building more dams to provide more water. This resulted in frequent insect infestations, disease outbreaks, soil depletion and salinization, an increasing dependence on artificial fertilizers, and mounting local resistance to British rule. Even before World War I, Egyptian cotton production had declined markedly as a result of these problems, and British engineers turned their attention to improving aspects of the existing system rather than committing to novel new methods of securing additional water.¹¹⁷

¹¹⁶ For Willcocks's critique of perennial irrigation see Beinart and Hughes, *Environment and Empire*, 138, 142-144.; For additional details on Willcocks's objections see Moseley, *With Kitchener in Cairo*, chapter 3.

¹¹⁷ Marlowe, *Anglo-Egyptian Relations*, 207-208.; Alan Richards, "Technical and Social Change in Egyptian Agriculture, 1890-1914," *Economic Development and Cultural Change* 26, no. 4 (July 1978): 728-731.

Shuman continued his marketing campaign despite signs that his invention would not generate the windfall he had expected. In 1916, he told the *New York Times* that while his plant at al Meadi showed impressive results, the location outside of Cairo was not ideal for solar energy generation. “Cairo is 30 degrees north, and it by no means the best place to put up a solar plant,” he explained, “but it is easily accessible and as we wanted to exhibit to the world our ability to operate it, we erected it there rather than in (we will say) the Sudan, where few people would go to see it.” The machine still provided an effective demonstration that the sun’s rays, though appearing intangible and impossible to manipulate, could in fact be “caught on mirrors, thrown in any desired direction, absorbed and turned into useful heat if proper contrivances are put up to effect this process.”¹¹⁸

Shuman maintained great confidence in solar’s potential up until his death in April 1918, seven months before the armistice. His work and the work of his predecessors in colonial solar development also became sources of inspiration and lessons learned for scientists and engineers still imagining a future that would eventually demand more energy than the world’s coal and oil reserves could provide over the long term. Specifically, his work hinted at the possibility of integrating the tropical and temperate regions of the world into a global industrial system that would continue to expand long after the depletion of the world’s fossil fuel reserves. In a speech at the Nobel Institute in Stockholm, Sweden in 1920, Swiss electrochemist Svante Arrhenius (often considered the father of climate change science), suggested that improvements to Shuman’s prototype would likely “play an important role in the opening up for cultivation of great arid districts in tropical countries.” Solar technologies could also potentially reverse what he described as “the decay of these regions” resulting from “the destruction of their aqueducts and irrigation plants” that had existed in ancient times but that “the present wandering population

¹¹⁸ “American Inventor Uses Egypt’s Sun for Power.”

is unable to restore.” Solar machines would not only serve to “re-establish the old agriculture and horticulture of these districts” but would allow for a transition from agriculture to industrial manufacturing over the long term as Western Europe burned through its coal supplies. This geographic shift would occur concurrently with a transformation in the global environment caused by industrial activities. Eventually, Arrhenius predicted, the greater amount of carbonic acid in the soil and atmosphere resulting from the burning of coal in northern latitudes would stimulate rapid growth of vegetation in these regions. “The total consumption of the available coal by the industries will, in a high degree, favor agriculture and the growing of forests in the temperate regions now the chief seat of culture,” he concluded, while the development of more efficient means of harnessing energy from sunlight would transform the deserts of the world into hubs of manufacturing and centers of industrial civilization.¹¹⁹

Such comments allowed the dream of solar energy utilization to persist even as commercial opportunities dwindled during the interwar years. They reflected continuing anxiety about future energy supply as demand continued to rise and as the extent of the world’s oil supplies remained uncertain. They also reflected a deep-rooted optimism that engineers and scientists would eventually discover a technological solution to the problem of fossil fuel scarcity. The work of John Ericsson, William Adams, Augustin Mouchot, and Frank Shuman, though ultimately unsuccessful economically, provided convincing demonstrations that solar technologies could function as alternatives to conventional energy technologies given certain environmental and economic conditions. Their work and writings also provided a justification for empire, both drawing on and sustaining a colonial mindset that envisioned the entire globe as a field for industrial expansion. Colonialism provided a forum for inventors, engineers, and

¹¹⁹ Svante August Arrhenius, “The Problem of the World’s Supply of Energy,” *Journal of the Franklin Institute* 190, no. 1 (July 1920): 120-121.

scientists to pursue an approach to energy which they thought would not be practical in northern latitudes – at least in the short term – but which they believed would allow for more effective utilization of previously unproductive regions on the geographic peripheries of empire.

According to the logic of solar development, these regions would continue to increase in importance as coal supplies dwindled in northern regions and as the colonial powers were forced to turn to other means of producing energy.

Chapter 2

Solar Energy and the California Dream

By the start of the twentieth century, California also emerged as a hub for solar technology development. There, as in South Asia and Africa, scarcity of coal prompted various schemes for tapping the free energy of abundant sunshine to stimulate the expansion of commercial enterprise and settlement into arid lands. But while from a European standpoint these efforts were meant to contribute to a larger project of maintaining control over distant colonial possessions by rationalizing and centralizing the technologies of production, in California, solar technologies offered the possibility of greater freedom of economic opportunity without resorting to centralized allocation of resources. By enabling anyone to become an energy producer, solar-powered irrigation pumps and home water heating systems symbolized what Stanford President David Starr Jordan considered one of the “charms” of California: personal freedom. “Man is man in California,” Jordan wrote. “He exists for his own sake, not as part of a social organism. He is, in a sense, superior to society.”¹²⁰

Californians’ vaunted “freedom to live,” as Jordan put it, was always more dream than reality. Historians have described it as a myth which obscured and justified a legacy of racial exclusion, monopolization, and environmental destruction.¹²¹ Much of California’s past, Mike Davis observes, reflects a “master dialectic of sunshine and *noir*,” a friction between the dream of a sun-blessed promised land and the nightmare of a society that replicated and even amplified

¹²⁰ David Starr Jordan, *California and the Californians* (San Francisco: A.M. Robertson, 1907), 17.

¹²¹ Richard B. Rice, William A. Bullough, and Richard J. Orsi, *The Elusive Eden: A New History of California* (Boston: McGraw Hill, 2002), 311.; William Deverell, *Whitewashed Adobe: The Rise of Los Angeles and the Remaking of its Mexican Past* (Berkeley: University of California Press, 2005).; For an environmental focus see Gray Brechin and Robert Dawson, *Farewell Promised Land: Waking from the California Dream* (Berkeley: University of California Press, 1999).; and Stephanie S. Pincetl, *Transforming California: A Political History of Land Use and Development* (Baltimore: Johns Hopkins University Press, 1999).

the patterns of economic exploitation present in the nation at large.¹²² The myth nevertheless persisted as a powerful shaping force in the state's history. While California increasingly resembled the rest of the nation socially and economically from the 1870s through the 1930s, the notion of independent citizens acting as autonomous agents of commercial expansion remained as a basis for political and economic activities, especially in southern California where it inspired a variety of creative if often far-fetched entrepreneurial pursuits and technological solutions to constraints on economic development. Some of these activities including citrus cultivation, oil drilling, and motion pictures ended up profoundly shaping the region's political economy, culture, and environment. Others such as the silkworm industry, health resorts, chemical rainmaking, and the importation of Australian Eucalyptus trees as a fuel supply foundered commercially but nevertheless reflected an openness to self-invention and experimentation that was always more than simply a myth.¹²³

This chapter examines solar technology development and promotion in California from the 1870s to the 1930s as an expression of this particular imaginary of the state. While most of the inventors profiled in this chapter were aware of solar demonstrations in the colonial world, and often incorporated information gleaned from accounts of this work in science and trade journals into their own work, they also adapted their designs and sales pitches to fit a specifically California context. Most came to California from other parts of the country and the world hoping to capitalize on rising demand for affordable energy supplies, especially in the less developed south where coal was expensive and hydroelectric sources were limited. They touted their

¹²² Mike Davis, *City of Quartz: Excavating the Future in Los Angeles* (New York: Verso, 1990), 23.

¹²³ William Alexander McClung, *Landscapes of Desire: Anglo Mythologies of Los Angeles* (Berkeley: University of California press, 2000), 16.; Catherine Gudis, "I Thought California would be Different: Defining California through Visual Culture," in *A Companion to California History*, ed. William Deverell and David Iglar (Malden, MA: Wiley-Blackwell, 2008), 40-74.; and Ian Tyrell, *True Gardens of the Gods: Californian-Australian Environmental Reform, 1860-1930* (Berkeley: University of California Press, 1999), ch. 3.

inventions as enabling technologies which by taking advantage of a free and abundant indigenous energy source, would promote economic independence for individuals and communities, freeing them from reliance on centralized irrigation systems and from the corporate monopolies then controlling the supply of imported coal. Solar technology, in this context, represented a different kind of colonial project, one that reconciled a general imperative to bring undeveloped arid lands into the fold of the industrial global market with a populist regard for economic freedom.

The chapter concludes with a brief profile of Smithsonian Institute secretary Charles Greeley Abbot whose efforts to establish a government-funded research agenda for improving the efficiency and lowering the cost of solar energy utilization became an important foundation for later solar advocacy. In compiling a technical record of past solar demonstrations and conducting experiments of his own, primarily at the Mount Wilson Observatory outside Los Angeles, Abbot synthesized ideas about solar energy that had formed in California and the colonial world since the 1870s into an argument for increased government funding for his astrophysical research. By identifying the range of potential social and economic benefits of establishing a scientific basis for solar technology development, Abbot contributed to sustaining public and professional interest in solar technology as a tool for developing arid lands, even as the expansion and consolidation of fossil fuel systems limited immediate commercial opportunities for alternatives.

The Land of Sunshine

As historian James Williams observes, the exploitation of indigenous energy resources played a critical role in California's transformation from a resource periphery into an independent industrial center by the early twentieth century.¹²⁴ The history of the search for coal, the development of long distance hydropower transmission systems, and the tapping of oil and natural gas reserves in California beginning in the late nineteenth century is well documented.¹²⁵ But while historians have usually focused primarily on the ascendance of dominant energy regimes, the growing power of corporations, changes in state and federal law, and the influence of progressive movements for greater public control of energy systems in the state, Californians also continued to experiment with smaller scale, locally accessible energy sources through the early twentieth century. Windmills, which first appeared on California farms in the 1850s, proliferated through the early twentieth century in rural areas where aquifers remained a source of irrigation and where hydropower and natural gas lines took longer to reach.¹²⁶ The possibility of harnessing energy from waves, the tide, and geothermal sources also stimulated entrepreneurial activity and investment.¹²⁷

The conversion of sunlight into useable energy constituted the most consistently attractive alternative to fossil fuels and hydropower in California from the late nineteenth

¹²⁴ James C. Williams, *Energy and the Making of Modern California* (Akron: University of Akron Press, 1997), 10.

¹²⁵ In addition to Williams see Paul Sabin, *Crude Politics: The California Oil Market, 1900-1940* (Berkeley: University of California Press, 2005).; and Thomas P. Hughes, *Networks of Power: Electrification in Western Society, 1880-1930* (Baltimore: Johns Hopkins Press, 1983), chapter 10.

¹²⁶ Williams, *Energy and the Making of Modern California*, 71-73.; For an early description of windmills see Horace Greeley, *An Overland Journey from New York to San Francisco in the Summer of 1859*, chapter 30. Accessed February 6, 2014 at <http://www.yosemite.ca.us/library/greeley/california1.html>.; For a broad treatment of the development of wind power technology in the late nineteenth and early twentieth centuries refer to Robert W. Righter, *Wind Energy in America: A History* (Norman: University of Oklahoma Press, 1996), chap. 2-4.

¹²⁷ For descriptions of the various early wave power experiments in California see Christine Miller, "Wave and Tidal Energy Experiments in San Francisco and Santa Cruz," 2004. Accessed February 6, 2014 at <http://www.outsidelands.org/wave-tidal.php>.; Also see John W. Lund, "100 Years of Geothermal Production," *Geo-Heat Center Bulletin* (September 2004): 11, 14.; and S.F. Hodgson, "A History of the Geysers Geothermal Field through 1960, an Annotated Bibliography," *Transactions – Geothermal Resources Council* 34, no. 2 (December 1, 2010): 1127-1130.

through the early twentieth century. While commercial applications had not yet proven feasible, by the turn of the century, solar technologies had a track record of functionality in Europe and in the colonies, and had attracted the interest of several prominent scientists and engineers, many of whom specifically identified California as ideally suited environmentally and economically for solar power.

As early as the 1870s, growing interest in solar technologies inspired a number of California inventors to pursue commercial applications. The first US patent for a solar device went to John S. Hittell and George W. Deitzler of San Francisco in 1877.¹²⁸ Hittell was well-known in California as the author of the 1863 booster publication *The Resources of California*.¹²⁹ He also filed patents for several other inventions in this period. In addition to his and Deitzler's "new appliance for storing and utilizing solar heat," he invented a "Poor Woman's Washing Machine" and the "Frisco Rein Holder," a clip for holding wagon reins in place.¹³⁰ A committed social Darwinist and *laissez faire* capitalist, Hittell regarded California as a hotbed of invention and a bellwether of male Anglo-Saxon progress. "The inventive fertility of California," he wrote in 1882, "is one of her chief claims to the respect of mankind."¹³¹

This image of California as a place naturally conducive to inventiveness and individual enterprise structured solar technology invention and promotion into the twentieth century. However, as in Egypt and Algeria, interest in solar energy also derived from underlying concerns about economic stability and the existence of environmental limits to industrial development.¹³²

¹²⁸ Charles Henry Pope, *Solar Heat: Its Practical Applications* (Boston: C.H. Pope, 1903), 38.

¹²⁹ John S. Hittell, *The Resources of California, comprising agriculture, mining, geography, climate, commerce, etc. and the Past and Future Development of the State* (San Francisco: A. Roman & Co., 1863).

¹³⁰ Claude Petty, "John S. Hittell and the Gospel of California," *Pacific Historical Review* 24, no. 1 (February 1955): 14.

¹³¹ John S. Hittell, *The Commerce and Industries of the Pacific Coast of North America* (San Francisco: A.L. Bancroft & Company, 1882), 415-416.

¹³² Richard J. Orsi, "Selling the Golden State: A Study of Boosterism in Nineteenth Century California," Ph.D. diss., University of Wisconsin, 1973: chapter 9.

The region's lack of coal provided the main incentive for exploration into alternative energy supplies. But other factors contributed to Californians' willingness to embrace new, untested technologies. As historian Kevin Starr observes, a view of the sun as the source of California's desirability as a living space co-existed with a fear of aridity and a compulsion to counteract it through technology. This ambivalence reached its fullest expression in water law and in battles over ambitious plans for agricultural and urban water diversions. By the 1880s, reclamation planning became a form of prophesy in the state as land speculators and engineers embarked on various schemes for redirecting California's watercourses.¹³³

Meanwhile, some inventors sought to capitalize on the situation by developing new methods of accessing sources of water not covered under irrigation districts or allocations. While windmills had served this purpose for decades, pumping groundwater by solar-powered steam engine represented a potentially more effective solution, especially in the vast, mostly unsettled areas of southern and southeastern California where the sun shined consistently for 300 or more days a year. Rising populist antagonism against the state's powerful corporate interests also created a context for solar to serve a different social function in California than in the colonies. Whereas Mouchot's, Tellier's, and Shuman's proposals for solar-powered irrigation in North Africa were meant to contribute to extending European industry and the authority of colonial governments into previously unproductive desert landscapes, in California, solar irrigation offered individuals the opportunity to cultivate cheap, available land without access to surface water while remaining free from bureaucratic management and corporate monopolization of scarce resources.

¹³³ Kevin Starr, *Material Dreams: Southern California through the 1920s* (New York: Oxford University Press, 1990), chapter 1.; Norris Hundley, Jr., *The Great Thirst: Californians and Water: A History*, revised edition (Berkeley: University of California Press, 2001), 94-112.; Donald J. Pisani, *From the Family Farm to Agribusiness: The Irrigation Crusade in California and the West, 1850-1931* (Berkeley: University of California Press, 1984), chapters 8 and 9.

In 1901, British inventor Aubrey Eneas moved to Southern California from Boston with the intent to market solar-powered irrigation pumps as simpler, more economical alternatives to coal-powered pumps and large-scale diversion and storage projects. A solar powered water pump, he reasoned, would be “of practical value to our great arid west, in affording this district an irrigation engine that requires but little care and no fuel.”¹³⁴ He claimed that a prototype he had tested earlier in Colorado could pump some 250,000 gallons of water per day from a height of twenty-five to thirty-five feet.¹³⁵ To attract publicity, he arranged with fellow Englishman Edwin Cawston to erect an even larger solar water pump on Cawston’s Pasadena ostrich farm, a popular attraction for wealthy Eastern tourists staying in nearby health resorts. Essentially a greatly enlarged version of Mouchot’s cone-shaped solar motor (although with the less efficient bottom portion of the cone cut off), Eneas’s machine consisted of a thirty-foot diameter, mirror-lined dish mounted on an equatorial steel frame. A mechanically-timed counterweight allowed the huge mirror to follow the sun throughout the day.

The Pasadena solar motor quickly became a public relations success. Tourists, journalists, and engineers from around the country marveled at the apparatus. The minimal labor required to operate the machine astonished journalist Frank Miller who observed that the operator had plenty of time to “hoe his garden, or read his novel, or eat oranges, or go to sleep.”¹³⁶ When in full sunlight, the boiler at the center glowed white hot, producing some ten to fifteen horsepower, enough to bring up a steady gush of groundwater. Irrigation engineer Charles Holder described the extreme temperatures the machine could produce: “should a man climb upon the disk and

¹³⁴ Quote from correspondence between Eneas and Samuel Langley who he turned to for advice in refining his initial designs. Quoted in Butti and Perlin, *A Golden Thread*, 82, 263.

¹³⁵ “A Solar Device,” *Los Angeles Times*, January 21, 1900.

¹³⁶ Frank B. Miller, “Harnessing the Sun,” *World’s Work* 1 (April 1903): 600.

cross it he would literally be burned to a crisp in a few seconds. Copper is melted in a short time here, and a pole of wood thrust into the magic circle flames up like a match.”¹³⁷

Observers were especially impressed with the machine’s functionality and labor saving capabilities. The device provided ample water to irrigate Cawston’s property, giving rise to lush gardens and vibrant, flowering camellia shrubs. For Holder, the solar engine held significant promise in water-scarce southern California:

No invention of modern times has given such an impetus to the development of arid lands as the solar motor, and it has been visited by many interested in the question. The development of Lower California has been seriously impeded by the lack of fuel; the country being dry and barren in localities where rich mines are known to exist. The country is cloudless for months – in every sense the land for the solar motor, as water underlies the surface almost everywhere, and when pumped up and sent out upon the soil the region, which was formerly a desert, can be made fertile and literally to blossom as the rose.¹³⁸

Here was the California dream manifest: a labor-saving technology, attuned to the region’s climatic endowments, requiring no fuel, easily installed and operated by the independent farmer or manufacturer, yet capable of performing the same work as an expensive, polluting, high-maintenance coal-powered pump.

William E. Smythe, one of the most vocal advocates for large-scale reclamation projects on western lands in this period, also commented on the solar motor’s suitability to California and the desert southwest. The device was not only well-adapted to the environment, Smythe observed, it also appealed to public sentiment, offering an alternative to cooperative water companies which, he observed, often became sources of “trouble, disappointment and demoralizing divisions...where it was necessary to invoke corporate enterprise or public enterprises.” The solar motor, in contrast, “supplies a method of irrigation well within the reach

¹³⁷ Charles F. Holder, “Solar Motors,” *Scientific American* 84, no. 11 (March 16, 1901): 169.

¹³⁸ *Ibid.*

of individual and small cooperative enterprises. It does not require great capital, either public or private. It will therefore contribute powerfully to the economic independence of men and communities.”¹³⁹

Eneas’s demonstration showed that it was technically, if not yet commercially, feasible to take advantage of the perpetual sunshine falling on the vast areas of the state which due to their remoteness and lack of water had previously appeared unsuitable for agriculture, mining, or manufacturing. “On these stretches of country, where now the coyote and gopher and jack-rabbit roam,” predicted California solar promoter Charles Pope in 1903, “the middle of this twentieth century may see a farming and manufacturing population of many millions, gathered from all parts of the world, enriched and made happy and contented by the very agency that has heretofore rendered the land desolate.”¹⁴⁰ Because they could operate wherever the sun shined, solar devices offered the added promise of freedom from expensive imported coal, corporate monopolies, and restrictive water allocation laws which discouraged small-scale independent enterprise. As Pope put it, “The use of sun-motors in pumping water for each farmer and manufacturer to use will be a...boon to the country, being more economical and less capable of monopoly and tyrannical management.”¹⁴¹

Beginning in 1903, Eneas sought to transition the good publicity into commercial success. He made his first sale to Arizona rancher Dr. Alexander J. Chandler, one of the largest landholders in the Salt River Valley near Phoenix. Chandler thought solar-powered irrigation would help him realize his vision of creating a “new Hohokam,” an agricultural Eden in the desert. All that was needed to transform the Salt River Valley into a modern desert civilization to match biblical Canaan or Egypt’s Nile River Valley was the application of engineering expertise,

¹³⁹ Smythe quoted in “Harnessing the Sun: The Solar Motor,” *Los Angeles Times*, January 13, 1901.

¹⁴⁰ Pope, *Solar Heat*, 138.

¹⁴¹ *Ibid.*, 139.

capital, and labor toward the development of a reliable water supply. The Arizona Canal, completed in 1885, represented the first step toward the reclamation of “lands which have been an unproductive desert of no value for any purpose,” as one journalist commented.¹⁴² Chandler also recognized the value of being able to tap groundwater in times of drought. A solar pump could also serve as an auxiliary in the event of technical failures in the canal system or legal disputes over water rights.

Eneas’s device also appealed as a promotional tool to attract settlers and land investment. With Chandler’s solar motor stimulating local interest, Eneas established an office in Tempe, where, on the advice of the Santa Fe Railroad, he staged another demonstration in 1904. The display impressed onlookers, including a Department of Agriculture official who observed: “The principle has now been established. All that is now necessary to make it a machine of practical use is to overcome a few mechanical imperfections which will undoubtedly be taken care of very soon.”¹⁴³ Eneas sold another solar motor to John May, a rancher in the desolate Sulphur Springs Valley near Willcox, Arizona. Once assembled, May’s machine provided a reliable flow of water throughout the summer. That fall, according to one journalist, “corn that would do Iowa credit grew like weeds, watermelons that were so full of water they would burst open and could have taken a prize at any man’s fair were grown.”¹⁴⁴

Eneas’s commercial success turned out to be fleeting. The following summer, with May’s first crop of pink beans beginning to ripen in the fields, the unpredictable weather of the Arizona

¹⁴² Quoted in Bradford Luckingham, *Phoenix: The History of a Southwestern Metropolis* (Tucson: University of Arizona Press, 1989), 27, 28-29.; For early reclamation efforts in the area refer to Philip VanderMeer, *Desert Visions and the Making of Phoenix, 1860-2009* (Albuquerque: University of New Mexico Press, 2010), 10.; Patrick Hamilton, *Salt River Valley: Its Attractions for the Immigrant, the Capitalist, the Invalid* (Phoenix: Maricopa Country Immigration Union, 1894), 5-8, 10.; Robert Conway Stevens, “A History of Chandler, Arizona,” *University of Arizona Bulletin* 25, no. 4 (October 1954): 16.; and Mark Reisner, *Cadillac Desert: The American West and its Disappearing Water* (New York: Viking, 1986), 108-109.

¹⁴³ Quoted in Aden B. Meinel and Majorie Petit Meinel, *Applied Solar Energy: An Introduction* (Reading MA: Addison-Wesley Publishing Co., 1976), 22.

¹⁴⁴ Ruth Mellenbruch, “Solar Motor was Great Invention,” *Arizona Range News* (September 12, 1941).

desert proved too much for the delicate apparatus. A hailstorm, “one of the worst storms that ever visited this part of the country,” swept over the valley, beating the bean crop into the ground and shattering “every glass in the reflector.”¹⁴⁵ This disaster, which was followed closely by the destruction of Chandler’s machine in a windstorm, fueled rising skepticism about the machine’s ability to survive the extreme desert weather for long. These events, coupled with the significant cost of the device (two to five times the cost of a conventional coal-powered pump), spelled the end of Eneas’s solar venture. With his company in the red by some \$125,000, Eneas lost the support of his investors and was forced to dissolve the business and move back to Boston in 1905.¹⁴⁶

The demise of Eneas’s business was not only the product of imperfect design. The rise of federally subsidized irrigation during this period also limited the possibilities for solar-powered irrigation in the Southwest. The passage of the Reclamation Act of 1902 marked a major shift in the federal government’s role in the development of arid lands. According to historian Donald Worster, the act reflected the government’s willingness to take a more central role in western economic development.¹⁴⁷ But government sponsored reclamation was more than a money-making venture. In fact, few federal reclamation projects proved profitable. It also represented an admission that traditional American problem-solving through private investment and individual initiative was no match for the harsh environment of the Western deserts. In the context of rapidly increasing population growth, direct government involvement in the construction of

¹⁴⁵ Ibid.; Vernon B. Schultz, *Southwestern Town: The Story of Willcox, Arizona* (Tucson: University of Arizona Press, 1964), 90.

¹⁴⁶ Kryza, *The Power of Light*, 226.

¹⁴⁷ Donald Worster, *Rivers of Empire: Water, Aridity, and the Growth of the American West* (New York: Pantheon Books, 1985), 165.

irrigation works was seen as necessary to accommodate an inevitable influx of people into the arid West.¹⁴⁸

Large landholders like Chandler and May were initially ambivalent about federal irrigation projects, fearing they would involve government seizures of land and water claims. In 1901, as Congress's passage of federal reclamation legislation appeared imminent, many southern Arizona water users began to reconsider their long-standing proposal to secure federal bonds to build a dam on the Salt River. An editorial in the *Arizona Republic* asked area residents to bind together "to build the dam ourselves and own it and control it."¹⁴⁹ These fears were justified in part. One of the principle requirements of the Reclamation Act was to provide water to individual farmers, not to speculators or corporate owners of existing canals and other irrigation works. The act, though, was flawed from the start. Its backers vastly underestimated the complexity of desert ecologies, refusing to accept that most places in the arid west were simply unsuitable for agriculture, with or without irrigation systems. Moreover, the new bureau created to choose projects and enforce compliance remained too weak to counter efforts by local elites and speculators to use federal reclamation for their own ends.¹⁵⁰

With the passage of the act, southern Arizona landowners quickly recognized the folly of trying to secure private investment for irrigation works while other regions in the West capitalized on government largesse. In order to maintain the land and water claims that were the source of their wealth and influence, Phoenix area landholders banded together in 1903 to form the Salt River Valley Water Users Association (SRVWUA). Their purpose was to secure a federal project on their terms. Fortunately for them, the Salt River Valley had many of the

¹⁴⁸ Reisner, *Cadillac Desert*, 111.

¹⁴⁹ Quoted in Smith, *The Magnificent Experiment*, 20.

¹⁵⁰ Donald J. Pisani, *Water and the American Government: The Reclamation Bureau, National Water Policy, and the West, 1902-1935* (Berkeley: University of California Press, 2002), chapter 2.

characteristics government officials were looking for to demonstrate the benefits of federal reclamation, including fertile soils, a year-round growing season, a relatively reliable water supply in the Salt River, good dam sites upriver, an established canal system, and a well-organized community of landholders seemingly willing to make agriculture work in the region. For Frederick Newell, the first director of the Reclamation Service, these factors outweighed the fact that every one of the members of the SRVWUA owned far more than the maximum of 160 acres the act permitted an individual to irrigate. His expectation was that the existing landholders would subdivide their holdings once federal irrigation works were established. Following the construction of the Granite Reef Diversion Dam in 1908 and the Roosevelt Dam in 1911, Chandler and many of his fellow SRVWUA members did exactly that, securing immense profits in the process.¹⁵¹

In addition to lining the pockets of local landholders, federal reclamation eliminated the principal reasons for pursuing solar as a local solution to the challenges of irrigating the desert. When the possibility of a large dam on the Salt River was uncertain, Chandler, other landholders, and railroad companies saw solar irrigation as an intriguing alternative. Solar fit with their broader vision to develop the valley for agriculture and reap the profits which would follow from increased land sales. Chandler anticipated that publicity generated from solar demonstrations would highlight the region's environmental attributes as well as the community's self-reliance, creativity, and commitment to reclamation, thus providing an attractive incentive for individuals seeking to invest in western land. Ultimately, though, the passage of the Reclamation Act and the approval of the Salt River Valley Project soon after removed any incentive for individual farmers

¹⁵¹ Smith, *The Magnificent Experiment*, chapters 1 and 2.; VanderMeer, *Desert Visions*, 30-31.; Reisner, *Cadillac Desert*, 117.; Reisner notes that the Salt River Project "was notable for having been all but taken over by speculators."

to purchase novel, expensive, and yet still not particularly reliable machines to pump groundwater.

Additionally, as Eneas later admitted, his devices were actually far less efficient in terms of cost-per-horsepower than traditional coal powered pumps, despite the high price tag. He further noted that while low heat solar motors which did not require costly reflectors might prove more practical than his design, “the actual obtaining of any great power from solar rays is still a great unsolved problem.”¹⁵²

While his company eventually failed, the initial success of Eneas’s devices in Pasadena and Arizona attracted worldwide attention. In 1904, a representative of the British administration in Egypt visited Tempe to view the solar pump in operation. Eneas regarded California and Arizona as entry markets to prepare the devices for application in other coal-poor regions in the colonial world. Seven years before Frank Shuman travelled to London to pitch his vision of a solar future for the Nile Valley, Eneas sold one of his devices to the Egyptian government under Lord Cromer to be installed in the Sudan. He also took orders for two more devices intended for South Africa. Though his company went bankrupt before he could ship the orders, Eneas contributed to rising interest in solar powered irrigation as a means for developing arid lands not just in California and the American Southwest but worldwide. In 1906, William Jevons even referenced Eneas’s machine in the third edition of *The Coal Question*, noting that recent demonstrations in California had changed his mind regarding the possibility of solar energy as a substitute for coal, at least in “favourable climates.”¹⁵³

California continued to be a hub for solar experimentation in the years that followed. Between 1901 and 1909, Henry E. Willsie and John S. Boyle from Olney, Illinois hoped to

¹⁵² Quoted in Charles Greeley Abbot, *The Sun* (New York: D. Appleton and Company, 1911), 372.

¹⁵³ William Stanley Jevons, *The Coal Question: An Inquiry Concerning the Progress of the Nation, and the Probably Exhaustion of Our Coal Mines*, 3rd ed., ed. A.W. Flux (London: MacMillan & Co., 1906), 190.

capitalize on rising demand for more affordable and accessible energy supplies in the region. Their idea was to adapt Charles Tellier's earlier flat plate, low temperature, ammonia-based design into a solar motor to supply water and electricity to remote mines in the desert southwest. Tellier's design, they reasoned, while less spectacular than Eneas's stately dish, was cheaper to build and less susceptible to the elements. The machine's efficiency, affordability, and transportability would enable the development of the mineral reserves of California and the southwest without requiring the establishment of a centralized coal, gas, or electricity generation network.

They also adapted the design to the conditions they encountered at their construction site, a vacant plot of desert near the remote settlement of Needles, California in the central Mojave Desert. First, they recognized that the plant had to be robust enough to withstand high winds. The collectors also had to be situated in a way that they could be easily cleared of accumulations of dust and debris. After a series of experiments, they also determined to use sulphur dioxide as the volatile liquid (as opposed to the more common ammonia) because it created less pressure on the pipes and could be manufactured as a by-product of the sulphurous ores commonly found in southwestern mines. Also, after finding that the local desert sand held "a sort of capillary circulation of water" which limited its usefulness as an insulator, they added a pane of glass with an insulating air space behind the black asphalt lining the heat collectors. Finally, the small shed where the boiler was located became deathly hot during operation. They mitigated this by storing some of the water pumped from the well to cool the apparatus. They also decided to build the shed in a thicket of arrowweed, the only substantial vegetation in the area, to provide some shade.¹⁵⁴

¹⁵⁴ "Power from the Sun's Heat," *Engineering News* 61, no. 9 (May 13, 1909): 509.

Whereas Eneas had staked the success of his company on the curious appeal of his machine, Willsie and Boyle erred towards economic practicality, quantifying every stage of the design and construction process in terms of cost compared to a coal- or coal gas-powered machine with a similar horsepower output. The resulting machine had none of the elegance that characterized Eneas's stately dish reflector. It sat squat to the ground, the only protruding features being the cooling water tank and the condenser, a circular enclosure overflowing with insulating straw. The 1,000 square feet of collectors could generate about the same fifteen horsepower as Eneas's machine, but the device was cheaper to build, less prone to damage by the elements, and could (they claimed) run at night.

In a 1909 article in *Engineering News*, Willsie evaluated the commercial prospects through a complex matrix of environmental conditions, fuel and labor costs, maintenance requirements, and power output needs. He calculated that even if built on a large scale, a solar power plant would still cost about three to four times more than the forty dollars-per-horsepower for a comparable coal powered plant. The solar plant, though, would require no imported fuel, it would need less maintenance, and it would not require the services of a fireman. Willsie initially concluded that solar power could be economical in regions of consistent sunshine where coal cost sixty-six cents per ton or more. This was not considerably higher than the cost of coal in many industrial areas. However, changes in the regional energy market made his calculations irrelevant almost immediately. By 1909, more efficient coal gas engines were becoming the technology of choice in southwestern mines. His revised calculations which took this into account suggested that for solar to compete with coal gas, the cost of coal would have to be two dollars per ton or more.

Although he recognized the limited applicability of solar in terms of its cost compared to traditional fuels, Willsie still believed solar would be economical in certain locales. One mine in Mojave County, he noted, had to import coal twenty miles across the desert and five miles over a mountain range at a cost of about \$72,000 a year. He ended his article on a positive note: “For many years this desert country must be sparsely populated for much of it cannot be irrigated; the geological reports do not indicate any probable finds of fuel, and the freight hauls are long. Here to my mind is the field for sun power. Here each experiment leading to something tangible will receive encouragement and support.”¹⁵⁵ This confidence belied his cost evaluations which seemed to indicate that innovations in traditional fuel systems might rapidly erase any limited cost advantage for solar, even in isolated, arid regions. Although they demonstrated that solar engines could be viable in some situations, Willsie and Boyle ceased their project in 1909 and never pursued a commercial application for their device.

Solar Water Heating in California

While demonstrations of solar irrigation pumps became a topic of interest in the national and international scientific and engineering press, solar water heaters, the most profitable and lasting commercial application of solar technology prior to World War II, attracted comparatively little attention and were embraced with less hyperbole by residential consumers. For the thousands of Californians who purchased solar water heating systems for their homes beginning in the 1890s, water heated by sunlight was an everyday convenience. “We didn’t think it was anything revolutionary,” recalled Pasadena resident Walter Van Rossem in an interview with historians Ken Butti and Joseph Perlin: “Everybody had one. It was a thing of the time

¹⁵⁵ Ibid.

because it made sound economic sense.”¹⁵⁶ However, even if residents saw their choice of solar as a rationale economic decision, it still had political implications, aligning with a general frustration with dependence on large, out-of-state coal suppliers that became a central theme in California politics at that time. Solar water heating also accorded with a particularly middle-class Anglo California aesthetic, reflecting what historian Kevin Starr describes as residents’ desire “to achieve something better in the manner of American living: to design their cities and homes...in harmony with the land and the smiling sun.”¹⁵⁷

Californians employed a variety of methods for heating water in the late nineteenth century. In rural areas without plumbing or gas lines, people heated water in pots on their cook stove, laboriously transferring water to a tub for bathing or washing clothes. In small cities and towns where homes were connected to a water main, most people attached water tanks to their stove. Heating water by this method took time; and in the heat of summer, a fire burning in the stove could be “torture,” as one resident recalled. In larger cities, many residents had separate water heating systems powered by coal gas. While these systems were more convenient and reliable (though dangerous if left on), coal gas remained a luxury for most Californians, costing approximately \$1.60 per thousand cubic feet, equivalent to about ten times the cost of natural gas in the late 1970s, according to Butti and Perlin.¹⁵⁸

At first, some residents attempted to counter high energy costs and the inconvenience of conventional methods by simply placing metal water tanks outside in direct sunlight. This

¹⁵⁶ Quoted in Ken Butti and John Perlin, “Solar Water Heaters in California, 1891-1930,” *Soft-Tech*, ed. J. Baldwin and Stewart Brand (New York: Penguin, 1978), 55.

¹⁵⁷ Kevin Starr, *Americans and the California Dream, 1850-1915* (New York: Oxford University Press, 1973), 413.; William Alexander McClung’s develops this further, describing the middle class Anglo myth of Los Angeles as simultaneously an Arcadia, “a found paradise” and a Utopia, a built paradise. Californians, he suggests, turned to technology and architecture to transform the state into a more livable version of itself by accentuating its intrinsic qualities. William Alexander McClung, *Landscapes of Desire: Anglo Mythologies of Los Angeles* (Berkeley: University of California Press, 2000), 4-6.

¹⁵⁸ Butti and Perlin, “Solar Water Heaters in California,” 53-54.

provided enough water for a quick shower by late afternoon on sunny days, but the water lost heat quickly when the sun went down. In 1891, Clarence Kemp, an inventor and businessman from Baltimore, Maryland patented an iron tank painted black and fitted to a frame that could be mounted on a roof or outside wall where it could absorb sunlight throughout the day. He called his device the Climax and put it on the market in Baltimore. His advertisements from the time featured either his patented cellar drainage system or his home coal gas machine, suggesting that the solar water heater was not his best-selling product. Although Kemp was more an opportunistic entrepreneur than a solar idealist, he recognized the appeal of devices that would free consumers from energy monopolies. “Why not be independent of gas and electric companies?” implored an ad for his home coal gas machine.¹⁵⁹

Pasadena businessmen E.F. Brooks and W.F. Congers recognized the potential appeal of Kemp’s solar water heater in the cloudless and coal scarce west. In 1895, they convinced Kemp to sell them the rights to the Climax for \$250. This proved to be a bargain. After an initial cost to the consumer of about twenty five dollars, the Climax could pay for itself in three or four years, making it an appealing and practical option for many southern California homeowners. In 1898, Brooks and Congers sold the brand rights for \$2,500. By 1900, according to advertisements for the Climax, some 1,600 solar water heaters had been installed in southern California alone.¹⁶⁰

By the turn of the century, several solar systems were on the market in southern California. In 1898, Los Angeles realtor Frank Walker introduced one of the more effective designs. Walker’s system protruded less from the rooftop and was more aesthetically pleasing. It was also integrated with the existing heat system, making it more convenient for homeowners. In 1905, Charles Haskell, who had previously managed Aubrey Eneas’s Los Angeles office,

¹⁵⁹ Advertisement for Kemp’s Climax Gas Machine in Edward Bellamy’s *The New Nation* 3, no. 1 (January 7, 1893): 29.

¹⁶⁰ Advertisement in *The Land of Sunshine* 13, no. 5 (November 1900).

acquired the rights to sell and manufacture the Climax heater. Haskell refined the design, swapping out the cylindrical tanks with a flat rectangular tank which warmed up quicker. Haskell's "Improved Climax" quickly outsold the standard Climax despite the higher price tag. J.J. Backus, the superintendent of buildings in Los Angeles, sang its praises in a letter to the *The Architect and Engineer of California*, writing: "I am ready to admit that we were unreasonably prejudiced against the heater, and feel that refusing to let you install one in my house for so long a time after you first approached me upon the subject, we lost a great deal of comfort and convenience." Backus was also certain that Haskell's company could become a great success with "a little judicious advertising." In addition to newspaper and periodical ads, word of mouth would also be effective. "Of this we are sure," Backus concluded: "every person having a heater will in a way become and advertising agent for your company, for so great will be his satisfaction that he cannot help talking about it."¹⁶¹

By this time, Haskell had already mounted an advertising campaign. His ads in popular periodicals were tailored to the individual consumer, especially women. Haskell appealed to consumers' desire for cost effectiveness, convenience, and simplicity. "Why let the sunshine go to waste, and your money too," one advertisement asked, when the Improved Climax could "furnish hot water from sunshine alone?" Solar water heating was especially useful for domestic chores. It could provide hot water "for your bath, laundry, and all domestic purposes, without cost, damage or delay."¹⁶²

While effective on warmer sunny days, the Climax and Improved Climax were susceptible to changes in the weather. Pasadena resident Walter Van Rossen noted that water

¹⁶¹ Butti and Perlin, "Solar Water Heaters in California," 59.; J.J. Backus, "Praise for Solar Heater," *The Architect and Engineer of California* 8 (March 1907): 98.

¹⁶² Ad reprinted in Ken Butti and John Perlin, *A Golden Thread: 2500 Years of Solar Architecture and Technology* (Palo Alto: Chesire Books, 1980), 124.

from his family's Climax was noticeably colder in winter.¹⁶³ Protected by nothing more than a glass coating, even the tank on the Improved Climax lost heat quickly, especially at night and in cloudy weather. One visiting journalist expressed confusion at southern Californians' affinity for a device that only worked when the sun was out. During his visit, clouds predominated and the ubiquitous rooftop collectors remained inert. The author assumed that, considering the lack of anything "ornamental about them," the collectors must have functioned exceptionally well in sunny weather for so many residents to buy them.¹⁶⁴ What he did not recognize was the freedom from reliance on centralized, out-of-state coal suppliers the devices afforded. The ability to maintain control over one's household energy supply became as important as cost in driving the popularity of solar water heaters in California, despite inconsistencies in their function.

The popularity of solar heaters spurred a number of inventors to improve on the design. In 1909 former Carnegie Steel engineer William J. Bailey patented his Day and Night system. Bailey's invention was an improvement on the Climax in two respects. First, instead of a conventional water tank, he used a coil of small-diameter copper pipes which heated up much faster. He also separated the heating system from the storage tank, connecting the roof-top heater to an insulated storage tank inside the home. This allowed for the availability of hot water at night and on overcast days (as long as they were preceded by a sunny day). The system operated on the thermosyphon principle. Because the lighter hot water would rise to the top of the storage tank, Bailey simply placed the tank in the attic of the house, above the level of the outside collector. The cold water at the base of the tank would then automatically cycle through the copper coils without requiring a pump.¹⁶⁵

¹⁶³ Butti and Perlin, "Solar Water Heaters in California," 56.

¹⁶⁴ "The Spectator," *Outlook* 85 (March 1907): 499-500.

¹⁶⁵ Patent 966,070, Solar Heater. William J. Bailey, Monrovia, Cal., *Official Gazette of the U.S. Patent Office* 157 (August 1910): 79.

Despite its higher cost of \$180 (more than triple the cost of Frank Walker's system), the Day and Night quickly became the "*ne plus ultra* of solar heaters," according to one newspaper report.¹⁶⁶ Homeowners especially appreciated the availability of hot water in the early morning, a period of peak demand.¹⁶⁷ The higher initial cost was also offset by savings in gas consumption. Most solar water heater users also had a gas furnace to heat water when solar heated water was unavailable. Advertisements claimed that the Day and Night could cut gas consumption as much as seventy-five percent while the Climax could reduce it about forty percent. For some builders, solar water heating systems typified a particularly southern California aesthetic, combining innovative, functional engineering with a classic style appropriate for the region's environmental attributes. One Spanish-style home in the exclusive Santa Barbara hills included a Day and Night system integrated with electric heating. "The whole scheme," wrote one architect, "has been worked out with a sympathetic appreciation of the early local Spanish work, augmented naturally with modern mechanical equipment."¹⁶⁸ Bailey also organized a series of publicity stunts at local fairs where retailers challenged skeptical observers to hold their foot in a tub of scalding water heated by a Day and Night collector. The resulting public interest allowed Bailey to move out of his backyard workshop and into a larger facility by 1911.¹⁶⁹

A cold spell in January of 1913 prompted another round of innovations. Temperatures as low as nineteen degrees in the Los Angeles area caused water in Day and Night collectors to freeze solid. One employee recalled that when the cold set in, copper pipes "popped like popcorn

¹⁶⁶ "Solar Heater – A Monrovia Perfects and New and Improved Heater," *Monrovia Daily News*, July 17, 1909: 1.

¹⁶⁷ "Sun Hitched to the Bathtub," *Technical World Magazine* 21 (March 1914): 74-75.

¹⁶⁸ Carleton Monroe Winslow, "Southern California Home of H.L. Hitchcock, Built of Double Wall Concrete," *Concrete* 18 (August 1921): 57.

¹⁶⁹ "Solar Heaters," *The Spatula* 20, no. 6 (March 1914): 285.; Butti and Perlin, *A Golden Thread*, 132.; For a good description of the sun coil system see "Putting the Sun at Work in the House," *Popular Science Monthly* 90, no. 1 (January 1917): 4.

all over the county.”¹⁷⁰ Bailey responded by replacing the water in the coils with an antifreeze solution consisting of ammonia and water. The coils in the new model ran from the collector into the storage tank where they transferred heat to the water for use. He also began using galvanized steel for the coils, which was cheaper and more widely available than copper. Sales rebounded as a result. The company even expanded to other parts of the southwest including Arizona and New Mexico. In 1913, *Arizona Magazine* reported that “the sight of the Sun Coil is becoming as familiar on Salt River Valley homes as in California, where they have been in general use for years.”¹⁷¹ Some local governments also went solar. In 1914, the Counties of Los Angeles and San Diego purchased several Day and Night systems for public playgrounds. Public schools in Monrovia, Pasadena, San Gabriel, and Placentia also installed solar heating systems. “This affords the children a refreshing shower of warm water” noted one journalist.¹⁷² By the end of World War I, Bailey had sold more than 4,000 units. The high cost of coal remained an important factor. “In this section of the country where soft coal sells for \$13 a ton,” wrote one journalist in 1916: “a builder cannot afford to waste his sun-rays. California is in peculiar need of its solar heaters.”¹⁷³ Business peaked in 1920 when more than 1,000 Day and Night systems were installed.¹⁷⁴

As with prior efforts at solar commercialization, the California solar water heating industry proved short-lived. Sales of solar hot water systems dropped off markedly during the 1920s as natural gas lines extended across the region, providing a cheaper locally-produced alternative to coal for household uses. As new gas reserves were discovered, oil companies took

¹⁷⁰ Quoted in Butti and Perlin, *A Golden Thread*, 132.

¹⁷¹ “Let the Sun do the Work,” *Arizona Magazine* (October 1913): 9.

¹⁷² C.L. Edholm, “Old Sol will Heat your Water – Free,” *American Builder* 16 (March 1914): 44.

¹⁷³ Lee McCrae, “Utilizing Sun-rays in a Home,” *Countryside Magazine* 23, no. 4 (October 1916): 203.

¹⁷⁴ Day and Night advertisement in *The Associated Grower* 1, no. 4 (June 1920): 18.; Butti and Perlin, *A Golden Thread*, 139.

advantage of property and tax codes to ensure that production facilities and gas lines would remain part of their pre-existing network. Conservation policies intended to eliminate waste and benefit the greatest number of people also further encouraged the consolidation of disparate oil and gas production systems into larger, centralized public and private utility networks which could offer rates, incentives, and a level of convenience that local manufacturers of household solar heating systems could not match. During the 1920s, oil and gas companies also began offering discounts on natural gas appliances to consumers, further undercutting the solar water heating market.¹⁷⁵

Solar water heaters did not disappear entirely. In the 1930s, the industry experienced a rebirth in Florida where natural gas was not readily available. The industry later became established in rapidly industrializing but fuel-scarce Japan.¹⁷⁶ In California, Bailey also continued to sell a few Day and Night units through the 1930s. As late as 1941, he sold a “big lot of them” to Pan American Airlines to be installed at their stopover point on Canton Island in the South Pacific. According to his son William J. Bailey Jr., the order was on the dock awaiting shipment at the time of the invasion of Pearl Harbor. They were never shipped, and Bailey ceased production soon after.¹⁷⁷

Because solar water heating systems were relatively simple to assemble, some homeowners and independent builders continued to install them in rural parts of California and the southwest where they continued to represent symbols of economic self-reliance and independent technical initiative. In 1930, *Popular Mechanics* published a description of a home-

¹⁷⁵ James Williams, *Energy and the Making of Modern California* (Akron: University of Akron Press, 1997), 131-132, 138-140.; Paul Sabin, *Crude Politics: The California Oil Market, 1900-1940* (Berkeley: University of California Press, 2005), 121-122.; Butti and Perlin, *A Golden Thread*, 140.

¹⁷⁶ Aden B. Meinel and Majorie Petit Meinel, *Applied Solar Energy: An Introduction* (Reading MA: Addison-Wesley Publishing Co., 1976), 13.

¹⁷⁷ Butti and Perlin, *A Golden Thread*.

built system incorporating many of the design concepts that had made Bailey's system a success. The unit consisted of a coil of galvanized iron pipes installed in a glass covered, wood-frame box. The storage tank was positioned outside the house adjacent to and slightly raised above the collector. The tank was insulated with asbestos paste, and could provide 36 gallons of water heated to approximately 115 degrees daily. With an estimated installation cost of only \$32, such a system would soon pay for itself. If assembled and installed properly, the solar heater could provide most of the hot water needed for bathing. The homeowner would still require a gas heater, but only as "an auxiliary" during cloudy weather or for washing clothes or dishes when extremely hot water was required.¹⁷⁸

Science and the Politics of a Solar Future

As immediate commercial opportunities for solar irrigation pumps and hot water heaters dwindled in California in the interwar years, industrial engineers and scientists replaced independent inventors as the primary agents keeping the solar dream alive. Scientific interest in solar technology peaked in the decade following World War I when a series of coal strikes in the US and Great Britain slowed coal production, and when the extent of oil and natural gas supplies was still uncertain.¹⁷⁹

As in previous decades, engineering interest in solar was not simply technical. It also included a powerful social and political dimension which incorporated the various rationales for solar development that had taken shape over the previous half-century. At stake was nothing less than the long term survival and continuing progress of industrial civilization. American electrical

¹⁷⁸ Ernest E. Oertel, "Water Heater for Sunny Climes," *Popular Mechanics* (May 1930): 875-877.

¹⁷⁹ Lamont Charles Hempel, "The Politics of Sunshine: An Inquiry into the Origin, Growth and Ideological Character of the Solar Energy Movement in America," Ph.D. diss., Claremont Graduate School, 1983: 57-58.

engineer Charles P. Steinmetz captured this blending of fear and optimism in a 1923 statement on the prospects of solar energy. “Sometime in the future,” he wrote, “when the coal supply will be exhausted and all the water powers developed, when the babbling brook and the roaring cataract will be gone and the sluggish pools extend from powerhouse to powerhouse to feed the power demand of an ever increasing population – will our civilization come to a standstill for lack of further energy supply and then begin to decay because there is no standstill in nature?” Like coal, Steinmetz warned, the earth’s oil and natural gas supplies would also eventually be exhausted. The total energy that could be harnessed from the flow of rivers, the wind, and the waves and tides would make up only a small portion of the deficit. Only direct sunlight, “the greatest of all energies,” existed in sufficient abundance to carry industrial civilization beyond the age of coal. “The amount of energy of the sunlight falling on the uninhabited and uninhabitable deserts is over two hundred thousand millions of horsepower, thousands of times larger than all the water power and the power we now get from coal. So this is the problem for the engineers of the future – to harness the energy of sunlight; this accomplished, there will never be any more lack of energy.”¹⁸⁰

Charles Greeley Abbot, secretary of the Smithsonian Institute, was especially active in pursuing this aim. Abbot developed his interest in solar technologies while working under Samuel Langley as an assistant at the Smithsonian Astrophysical Observatory beginning in 1895. Langley had been an early pioneer in solar invention, building and testing a “hot box,” a wood frame box with a layered glass covering, during his 1881 expedition to Mount Whitney.¹⁸¹ Abbot

¹⁸⁰ Charles P. Steinmetz, “Solar Energy: A Problem for the Future,” *The Times of India*, July 20, 1923, 16.

¹⁸¹ Samuel Pierpont Langley, *Researches on Solar Heat and its Absorption by the Earth’s Atmosphere: A Report of the Mount Whitney Expedition* (Washington D.C.: Government Printing Office, 1884), 166.; Langley’s hot box experiments were later described by Swiss electrochemist Svante Arrhenius, one of the first scientists to explore the role of atmospheric gasses in contributing to climatic change, as a useful miniature model of the atmosphere. Svante Arrhenius, *Worlds in the Making: The Evolution of the Universe*, trans. Dr. H. Borns (New York: Harper, 1908), 51-52.

also made improvements to Langley's bolometer, a highly sensitive recording instrument for measuring the heat content of solar radiation.¹⁸² Also under Langley, Abbot followed in the footsteps of earlier solar inventors, setting up solar observation posts in various sunny regions of the world including the Mojave Desert, the summit of Mount Whitney, Arizona, the nitrate deserts of Chile, Algeria, and Egypt. Through these experiences, Abbot became increasingly aware of the potential practical benefits of his work, particularly in the area of energy production. Over his long career, until just before his death in 1973 at the age of 101, Abbot published dozens of articles and several books touting solar radiation as a promising future energy source. His career arc allowed him to bridge the time gap between the first period of solar development in the late nineteenth and early twentieth centuries and the better known solar energy revival of the 1970s.¹⁸³

Abbot's solar advocacy emerged from his immediate goal of securing additional government funding for the Smithsonian's astrophysical research. His hope was "that the astrophysical observatory might justify its support" by offering suggestions for practical applications of its science programs. A scientific understanding of the nature of solar radiation, he urged, could accrue benefits in a variety of fields including meteorology, agriculture, and health. Abbot maintained, for example, that sun exposure for children in smoky urban centers could be the key to curing rickets. He also suggested that studying the sun might help scientists determine the habitability of other planets in the solar system.¹⁸⁴

¹⁸² Donald H. Menzel, "Charles Greeley Abbot," *Q. Jl R. astr. Soc.* (1977), 138.

¹⁸³ "Charles G. Abbot, Pioneer in Solar Energy Use, Dies at 101," *Los Angeles Times*, December 17, 1973: 2.

¹⁸⁴ Charles Greeley Abbot, *The Sun and the Welfare of Man* (New York: Smithsonian Institution Series, Inc., 1929), 234-239.; For a good overview of Abbot's career with a focus on his role in promoting the activities of the astrophysical observatory, refer to David H. Devorkin, "Defending a Dream: Charles Greeley Abbot's Years at the Smithsonian," *Journal for the History of Astronomy* 21 (1990): 121-136.

Abbot's primary interest, however, was to apply his solar research to the problem of "obtaining heat and power from solar rays without the intervention of plant chemistry."¹⁸⁵ During the 1920s and 1930s, he collected and reviewed available information on past solar experiments for the purpose of providing a scientific assessment of the existing state of the technology. In the process, he identified many of the technical impediments to its greater dissemination, established the relative effectiveness of different reflective materials and volatile liquids, and proposed some new directions in solar and atmospheric research. At the Smithsonian observatory on Mount Wilson outside of Los Angeles, Abbott also built and experimented with a variety of solar devices to test his theories. These included a solar cooker which the research team used to prepare many of their meals, and a half-horsepower "solar boiler" which, in a 1936 demonstration for the National Broadcasting Corporation (NBC), supplied electrical power for a radio broadcast on Abbot's solar experiments across the United States and Canada.¹⁸⁶

While Abbot's inventions attracted public and professional interest, he was less concerned with their immediate commercial prospects than their value as examples of the long term benefits of greater scientific attention to the problem of solar energy utilization. This view of solar as a future technology was demonstrated in September 1936 when his plan to display his solar boiler for an audience at the Third World Power Conference in Washington D.C. was derailed when the volatile liquid became too hot and melted the soldering holding the pipes together. Undeterred, Abbot turned the "flop" into a positive statement about the need for more research. *The Washington Post* reported: "The scientist took the disappointment in his stride, with the casual disregard of setbacks that men of the test-tube and microscope have. To him it was a

¹⁸⁵ Abbot, *The Sun and the Welfare of Man*, 9.

¹⁸⁶ His early experiments in solar cooking are described in Charles Greeley Abbot, "The Sun – Our Star and Power Source: How Solar Heat may be used to Replace the Earth's Vanishing Energy," *McClure's Monthly Magazine* 54, no. 12 (February 1923): 89-95. For the NBC broadcast see *Power* 80 (1936): 546.

small thing, merely another obstacle to be overcome by patient experiment, by repeated trial-and-error.” Abbot told the assembled engineers, scientists, and reporters that while he was sorry the device did not work as expected, he recognized that like himself, “they too were chiefly interested in the principle, rather than the practice, of such a distant development as power from the sun.” That principle, if further developed through professional scientific research, nevertheless had tremendous practical potential. He estimated that if built over a single square mile of desert, a bank of collectors based on his prototype would be capable of producing some 40,000 horsepower a day.¹⁸⁷

Abbot’s calls for public funding for solar research also represented warnings about an over-reliance on fossil fuels and hydropower, which while presently abundant and cheap, were also finite and impractical as power sources in many parts of the world. He also saw his solar work as a demonstration of an especially promising application of government-supported scientific research that could not be achieved in the foreseeable future through market activities alone. While he admired the work of Eneas, Shuman, and other independent inventors, Abbot also recognized that their incomplete scientific understanding of the nature of sunlight and their dependence on short term profits had limited their ability to refine their inventions to match the cost, reliability, and energy output of the fossil fuel and hydropower systems that were then beginning to dominate the energy market. As the age of the independent inventor gave way to an era characterized by the professionalization and institutionalization of new technology development, he believed, government-funded research would be essential to transforming solar

¹⁸⁷ Sidney Olson, “Invention Fails to Shine; Solar Engine Balks,” *The Washington Post*, September 9, 1936.; Also see C.G. Abbot, “Utilizing Heat from the Sun,” *Electrical Engineering* (July 1939): 294-298.; “Power from the Sun,” *Los Angeles Times*, January 6, 1936:7.; “Sun’s Power Use Predicted,” *Los Angeles Times*, October 25, 1939: 9.

into a commercially viable supplement and eventual alternative to these increasingly entrenched but ultimately unsustainable systems.¹⁸⁸

Between the 1870s and late 1930s, the idea of harnessing the energy of sunlight for practical use appealed to a number of inventors, engineers, scientists, and government officials in Europe and the US who saw it as a promising basis for perpetuating the future expansion of industrial civilization by reducing its dependence on fossil fuels. While solar failed to become established on a large scale by the 1920s, the increasingly active role of government in energy resource development and technological change in the US created an opportunity for the social and political meanings produced in California and the colonial world to potentially outweigh doubts about solar's short term commercial competitiveness. These meanings appealed across a wide spectrum of modern aspirations and desires. Solar offered the possibility of continuing industrial progress beyond the age of coal and oil. The prospect of turning on the sunshine also both reflected and sustained an enduring optimism in the potential for technology to create a more prosperous, orderly, and secure world. Finally, solar technology development aligned with a general shift toward more informal forms of imperial expansion after World War I. The experience of solar development in California, in particular, hinted at the potential for individuals, equipped with specialized technology, to become agents of commercial expansion in arid regions, while the imperial state retreated into the background as an enabler of technological change rather than the primary agent of conquest. Despite the market failure of solar technologies in the early twentieth century, the promise of solar energy as an accessible, inexhaustible substitute for fossil fuels became firmly established as a political rationale for its continued development.

¹⁸⁸ Carroll Pursell, *The Machine in America: A Social History of Technology*, 2nd ed. (Baltimore: The Johns Hopkins University Press, 2007), 203-204.

Chapter 3

Energy Anxieties in an Age of Abundance

In the United States by the mid-1930s, while some engineers and scientists continued to maintain that solar energy would one day comprise a significant part of the nation's and the world's energy budget, even the most optimistic advocates acknowledged that near term commercial possibilities were limited. The amount of solar radiation striking the earth was clearly impressive, amounting to some 4,840 horsepower per acre according to some estimates. Yet its diffuse nature, periodicity, and susceptibility to changes in the weather were seen as major disadvantages in a nation mired in depression and seeking dependability, affordability, and stability of energy supply. Despite decades of experimentation and the investment of "a great deal of money" into the problem of harnessing energy from direct sunlight, one futurist wrote in 1935, the few solar energy systems still in operation were "maintained by cranks or by freaks of local patriotism," and "could all be replaced economically by ordinary heat engines."¹⁸⁹

Such assessments formed in a period of dramatic change in the US during which the expansion and consolidation of fossil fuel and hydropower systems allowed for an unprecedented surge in energy consumption. Beginning in the 1930s, measurable energy use in the US doubled every decade until the early 1970s. The advent and expansion of what historian David Nye calls "the high energy economy" was the product of the convergence of several factors including the development of new oil and electricity production and distribution technologies, the mechanization of farming, rural electrification, rapid growth of manufacturing, suburbanization,

¹⁸⁹ Jonathan Norton Leonard, *Tools of Tomorrow* (New York: Viking Press, 1935), 50.

and the greater availability and affordability of energy-intensive consumer products including automobiles and home appliances.¹⁹⁰

The federal government played a key role in all of these changes. To stimulate economic recovery during the Great Depression, President Franklin D. Roosevelt initiated public works projects and created new institutions to stimulate electricity generation and consumption. These included the establishment of the Rural Electrification Administration (REA) and the creation of large-scale regional hydroelectric projects including the Tennessee Valley Authority and later the Columbia Basin Project. New Deal programs to encourage road building, housing construction, and to provide more affordable home loans created additional demand for electricity and oil in particular. While the New Deal provided the foundations for the high energy economy, World War II allowed for its realization. The urgent demand for large amounts of electricity for wartime manufacturing and oil for military transport prompted the government to shift its focus from managed growth and public power to collaboration with oil and gas companies and electric utilities toward maximizing production. To ensure a continuing supply of low cost oil during and after the war, the federal government incentivized increased domestic production while also pursuing diplomatic measures to allow US companies access to new oil discoveries in Venezuela, Canada, and the Middle East. These efforts smoothed the nation's transition from a wartime economy into a consumer economy characterized by unprecedented prosperity, high levels of demand for energy intensive goods and services, and renewed confidence in technology and the capitalist system.¹⁹¹

¹⁹⁰ David E. Nye, *Consuming Power: A Social History of American Energies* (Cambridge, MA: MIT Press, 1998), 187.

¹⁹¹ *Ibid.*, ch. 7.; Martin Melosi, *Coping With Abundance: Energy and Environment in Industrial America* (Philadelphia: Temple University Press, 1985), 181-182, 194, 199, 207.; Craufurd D. Goodwin, "Truman Administration Policies toward Particular Energy Sources," in *Energy Policy in Perspective: Today's Problems, Yesterday's Solutions*, ed. Craufurd D. Goodwin (Washington D.C.: The Brookings Institution, 1981), 69-127.

For the most part, a positive outlook on the nation's and world's energy future prevailed during this period. But as Americans committed to a high energy way of life predicated on the availability of abundant, low-cost fossil fuels, they also accepted that in order to maintain a continuous supply of energy and increasing economic growth into perpetuity, they would eventually have to devise ways to take advantage of more permanent energy sources. The risks of dependence on oil became apparent before and especially during World War II when concerns about fuel and materials shortages led to gas rationing and a general sense of insecurity that carried over into the immediate postwar years. By the 1950s, the glut of Middle Eastern oil eased but did not entirely eliminate these concerns. And while nuclear energy emerged during this period as the favored energy panacea of the long term future, serious questions about its cost and technical feasibility persisted through the 1950s and into the early 1960s. By the time the first commercial reactors went online in the mid-1960s rising public concerns about their safety and environmental risks were beginning to present another significant obstacle to a nuclear future.

This chapter examines continuing interest in solar energy technology from the late 1930s through the 1960s as a response to these underlying insecurities about the limitations and risks of fossil fuel, hydropower, and nuclear development schemes during an era of general optimism in technology's potential to ensure the continuing availability of cheap, abundant energy. I discuss three primary avenues of solar technology development during this period: the emergence of the "solar house" as a response to fuel shortages during and immediately after World War II; the formation of the Association for Applied Solar Energy (AFASE) in Phoenix, Arizona in 1954 and its evolution as a nexus for regional, national, and international cooperation in solar technology development and promotion; and the cooperative efforts of solar inventors and scientists in the US and worldwide to introduce simple solar devices as tools for economic

development in arid regions of what became known as the “Third World” from the 1950s through the 1960s.

These activities were not simply money-making ventures. Though predicated on confidence in the eventual feasibility of commercial solar, they also represented political statements about America’s and the world’s energy priorities in an era of increasing material abundance counterbalanced by mounting geopolitical tensions between the US and the Soviet Union, the looming threat of nuclear annihilation, and growing socio-economic disparities between “industrialized” and “non-industrialized” nations. And yet, while solar technologies took shape within the framework of a Cold War developmental mindset, solar advocates also raised questions about the basic philosophies and strategies of that mindset. Through efforts to introduce solar technologies in the rural regions of the Third World in particular, solar advocates laid the groundwork for an alternative approach to development which emphasized not direct technology transfer from core to periphery, but technological adaptation to local social and ecological conditions. And while solar energy technologies had by the late 1960s evolved mostly in isolation from the early environmental movement, they reflected and contributed to a rising cultural awareness of the temporality and environmental risks of fossil fuel- and nuclear energy-based development schemes.

The Solar House

By the start of World War II, uncertainties about oil companies’ ability to meet rapidly rising demand prompted a resurgence of public interest in energy conservation. Chicago architect Fred Keck responded by working to improve the energy efficiency of the mainstay of the rising

American middle-class: the single-family suburban home.¹⁹² Incorporating new materials and new technologies including, most importantly, double-pane glass, introduced by the Libbey-Owens-Ford Glass Company in 1935, Keck experimented with a variety of designs to cut home oil and gas use by taking advantage of direct solar rays. In 1940, he designed and built a long ranch-style home with expansive south-facing windows and overhanging eaves for Chicago real-estate developer Howard Sloan. A local newspaper termed the model home a “solar house.” Soon after, the national media took notice. In 1941, *Business Week* deemed solar home construction “the newest threat to domestic fuels.” Seeking to capitalize on the publicity, Sloan built a thirty-home development based on Keck’s design in the Chicago suburb of Glenview, calling it “Solar Park.”¹⁹³

As concerns over energy shortages mounted during the war, Keck and a number of other architects branched out, earning contracts to design solar heated homes, schools, hospitals, and offices across the country. In 1944, *Popular Mechanics* reported that Keck’s design concepts could reduce home heating costs by one third.¹⁹⁴ In a promotional pamphlet released that same year, the Libbey-Owens-Ford glass company described the solar house as “a modern approach to house planning geared to today’s rather than yesterday’s standard of living.”¹⁹⁵ *Reader’s Digest* similarly touted the solar home as “at once the most provocative and practical conception of modern living.”¹⁹⁶ In 1945, Tucson, Arizona architect Arthur T. Brown built a solar home incorporating an eight-inch-thick black painted masonry wall which absorbed solar heat during

¹⁹² For a discussion of the postwar solar house as emblematic of a distinctly American architectural modernism see Daniel A. Barber, “The Modern Solar House: Architecture, Energy, and the Emergence of Environmentalism, 1938-1959,” Ph.D. diss., Columbia University, 2010: 39-60.

¹⁹³ Butti and Perlin, *A Golden Thread*, chapter 15.; “Solar Houses,” *Business Week* (December 27, 1941), 42.

¹⁹⁴ “Solar House Reduces Fuel Bills by One-Third,” *Popular Mechanics* (February 1944), 61.

¹⁹⁵ Libbey-Owens-Ford, *Solar Houses: An Architectural Lift in Living* (Toledo: Libbey-Owens-Ford, 1944), 3, 5.

¹⁹⁶ Ralph Wallace, “The Proven Merits of a Solar Home,” *Reader’s Digest* 44 (January 1944): 104.

the day and radiated it out gradually to keep the home warm even at night. Brown also designed and built the first solar-heated public building, an elementary school in Tucson in 1948.¹⁹⁷

Keck's and Brown's "passive" solar designs involved no mechanical heat collection or transfer technologies. Although incorporating some non-traditional building materials, passive solar houses were simply elaborations on an existing modernist aesthetic, designed and oriented to best take advantage of sun exposure.¹⁹⁸ Mechanical or "active" solar house heating also attracted interest during this period. In 1938, wealthy Boston industrialist Godfrey Cabot Lodge pledged \$650,000 to the Massachusetts Institute of Technology (MIT) for research into the use of roof mounted solar collectors. Professor of chemical engineering Hoyt Hottel directed the program with assistance from graduate student Byron Woertz. The team based their design on the solar hot water heating systems used previously in Southern California and, by then, in Florida and Japan. The idea was to expand the size of the system to provide heat for an entire house. The first MIT solar house was built in 1939 and included 408 square feet of shallow glass box collectors connected to an electric heat pump. The entire basement of the house was taken up by a 17,400 gallon water tank encased in two feet of insulation for storing hot water during the night. While the model house remained at a comfortable 72 degrees through the winter, the team's cost analysis suggested that a commercial solar-heated house was not economically feasible.¹⁹⁹

¹⁹⁷ For Arthur Brown see Helen J. Kessler, "In the Solar Vanguard: In 1946, Architect Arthur Brown used Industrial Components and a Simple Solar Mass Design to Temper the Desert Climate," *Fine Homebuilding* 11 (October-November 1982): 29-33.; Arthur T. Brown, Kathryn M. Wayne, Harriett Silverman Nevins, *Arthur T. Brown, FAIA: Architect, Artist, Inventor* (Tucson: College of Architecture Library, University of Arizona, 1985), 19, 20, 60.; For an evaluation of different solar house designs from this period see Francis William Hutchinson, "The Solar House: Analysis and Research," *Progressive Architecture* 28 (May 1947): 90-94.

¹⁹⁸ The variety of passive solar home designs that appeared in the immediate postwar years are also described in Marion J. Simon, ed., *Your Solar House: A Book of Practical Homes for all Parts of the Country* (New York: Simon and Schuster, 1947).

¹⁹⁹ H.C. Hottel and B.B. Woertz, "The Performance of Flat-Plate Solar Heat Collectors," *American Society of Mechanical Engineers Transactions* (February 1943): 91-104.; James J. Bohning, "Hoyt C. Hottel: MIT's

World War II interrupted the solar research program at MIT as all of the principal researchers were reassigned to war-related research. However, the wartime infusion of federal spending on science and technology also provided opportunities to continue work on solar heating elsewhere. In 1943, the War Production Board (WPB) funded a solar heating study headed by professor of chemical engineering George Löf at the University of Colorado, Boulder. The purpose was to develop and test a solar-heated air system and evaluate its potential as a safeguard against possible fuel shortages. Kenneth Miller, consultant for the Consumer Products Branch of the WPB's Office of Production Research and Development, proposed a design involving the layering of interlocking, blackened glass sheets as a collector for a home solar hot air heating system. Between 1943 and 1946, the research team built and maintained a prototype collector on the roof of the chemical engineering building on the University of Colorado campus. They also mounted 460 square feet of collectors on the roof of Löf's 1,000 square foot bungalow in Boulder.²⁰⁰

The results were encouraging. Löf found that a typical suburban home could be retrofitted with a solar hot air system relatively easily. He proposed that such a system could be economical in regions south of the fortieth parallel (roughly the location of Boulder). North of that, infrequent winter sun and extreme cold would require continued use of a conventional heat system. For about \$500, he concluded, a resident in a favorable region could install a solar heating apparatus which would save about 20 to 30 percent of the annual heating costs. The team also predicted that savings would increase to 50 to 60 percent in new home construction which included a basement "storage bed" consisting of about six tons of crushed rock.

Combustion and Solar Energy Pioneer," *Chemical Engineering Progress* 84, no. 3 (March 1988): 73-77.; August L. Hesselschwerdt, "Performance of the MIT Solar House," in *Space Heating with Solar Energy*, ed. Richard W. Hamilton (Cambridge: MIT Press, 1954), 99.

²⁰⁰ Butti and Perlin, *A Golden Thread*, 117-154.; Daniel Behrman, *Solar Energy: The Awakening Science* (Boston: Little, Brown and Company, 1976), 89-112.

A number of obstacles stood in the way of immediate commercialization. The durability of the apparatus was a cause for concern. Thermal stresses tended to cause the glass plates to crack; and although the team proposed several methods for alleviating this problem, they had insufficient funds for further testing. And although the casing for the home retrofit withstood the cold, snow, and wind of the Boulder winter, the prototype collector on the roof of the laboratory was demolished in a wind storm. While such challenges were not insurmountable, Löff worried that a potential homebuyer would be wary of purchasing a heat system which most heating and ventilation contractors would not know how to repair.²⁰¹

Ultimately, the sponsors of the study were less concerned with producing a marketable product than with demonstrating the technical feasibility of Miller's design concept. Unlike the inventors and entrepreneurs in the late nineteenth and early twentieth centuries who had much at stake professionally and financially in the immediate profitability of their inventions, in the larger scheme of federal support for science and technology during World War II, the University of Colorado project represented a miniscule expenditure involving no market risk. Even though it did not result in a commercial product, this work built on prior technologies and represented a partial fulfillment of Charles Abbot's earlier calls for greater government support for research into solar utilization.

In the decade following World War II, skyrocketing demand for oil and natural gas threatened to plunge the nation into an energy crisis. The problem was not that oil reserves were depleted. By the end of the war, the development of new extraction, refining, and distribution technologies, in combination with discoveries of reserves in South America and the Middle East, eased earlier concerns that the earth's supply of fossil fuels might run out in the near future. The

²⁰¹ George Löff, Office of Production Research and Development, War Production Board, "Solar Energy -- Utilization for House Heating," research report (May 1946), 57-60.; Butti and Perlin, *A Golden Thread*, 206.

problem, rather, was a shortage in the immediate availability of supply. Oil companies were not prepared to supply a vastly expanded industrial sector and a public anxious to get back into their cars, move out to distant suburbs, and take advantage of new opportunities for consumption. Americans' experience with gas rationing during the war, combined with their anxiety about the possibility of another depression, generated interest in energy conservation measures.²⁰²

Citing these concerns, Hoyt Hottel was able to secure a combination of private and public funds for the revival of the MIT solar house project. By 1951, Hottel's team had built three solar houses, each one incorporating lessons learned from the previous house. The first included a "water wall," a row of water-filled barrels lined up along a bank of south-facing double-pane windows. The barrels would, in principle, accumulate heat and then radiate it gradually into the house at night. However, they also radiated heat back through the windows, resulting in the loss of some 70 to 85 percent of the heat collected. The second and third MIT solar houses were fitted with rooftop collectors which cycled hot water to an insulated water tank stored in the attic of the house. The third house also incorporated passive design features, and was outfitted with a conventional electric heater as a supplement. From 1949 to 1950, a graduate student and his family lived in the house to test if the design could be adapted in a practical way for residential use. The most surprising result was the effectiveness of the south-facing windows, which supplied an estimated 30 percent of the total heat for the house, almost matching the amount provided by the costly rooftop collector and heat storage system. The experiment continued until

²⁰² For wartime and postwar fuel shortages see John G. Clark, *Energy and the Federal Government: Fossil Fuel Policies, 1900-1946* (Urbana: University of Illinois Press, 1987), 316-380.; Richard H.K. Vietor, *Energy Policy in America since 1945: A Study of Business Government Relations* (Cambridge, NY: Cambridge University Press, 1984), 50, 95.; and Goodwin, "The Truman Administration," 1-63.

1953 when faulty wiring in the electric heater caused a short. In their response to the alarm, the fire department hacked the delicate rooftop collectors to pieces.²⁰³

Also at MIT, Hungarian-American Professor of Biophysics Maria Telkes became interested in solar when she received a navy contract to design a solar desalination still for use in life rafts. After the war, Telkes worked with Hottel briefly to test heat absorbing materials for use in active solar home heating. They disagreed over the economic feasibility of solar homes supplemented with conventional heat systems, however, and Telkes eventually sought funding for her own project from outside the university. In 1948, Boston philanthropist Amelia Peabody provided Telkes with funds for the construction of a solar house using Glauber's salts (sodium sulfate decahydrate), a low cost manufacturing compound used in the production of glass, detergent, and paper products. The resulting house, an "exclusively feminine project" as the *Saturday Evening Post* described it, consisted of 18 collectors spanning the entire 75 feet of the home's south wall. The heat collected was then passed over a 480 square foot container of salts. The idea was that the salt would melt, and the heat would then be released gradually as the salt recrystallized. With relatively consistent winter sunshine, the house could be heated comfortably without use of an auxiliary generator.²⁰⁴

Encouraged by these results, Telkes became confident in the possibilities for solar utilization in a variety of other applications in specific regions. In the San Francisco bay area, she pointed out, some 700,000 tons of "solar salt" was already being produced each year through the

²⁰³ Butti and Perlin, *A Golden Thread*, 197-214. For a profile of the family that lived in the MIT house see John Kobler, "Like Living in a Macy's Window," *Saturday Evening Post* 222 (September 24, 1949): 42-43.; Also see Eric Hodgins, "Power from the Sun," *Fortune* 48 (September 1953): 134-135.

²⁰⁴ Maria Telkes, "Space Heating with Solar Energy," *The Scientific Monthly* 69, no. 6 (December 1949): 394-396.; Maria Telkes, "A Review of Solar House Heating," *Heating and Ventilation* 46, no. 9 (September 1949): 68-75.; Maria Telkes, "Storing Solar Heat in Chemicals," *Heating and Ventilation* 46, no. 10 (November 1949): 79-86.; Butti and Perlin, *A Golden Thread*, 213.; Butti and Perlin note that although results suggested that the salts stored heat reasonable well, Telkes never demonstrated clearly that this occurred because of "heat fusion." It is possible that the huge mass of salt did not really melt, but simply retained heat much like the water or rock used in previous MIT experiments.

use of open air evaporators. She also observed that “tropical and arid islands could receive sufficient potable water, by distilling sea water, using the overabundance of sunshine.” Telkes, like other solar engineers of this era, also sought to demonstrate solar energy’s potential as a complement, and possible competitor, to nuclear power as a primary energy source, especially in arid and tropical regions. She calculated that the Btu’s contained in one pound of Uranium 235 was equivalent to the amount of solar energy falling on a half-square-mile on a clear day in summer, without considering the process of conversion to useable energy. Through the 1950s, Telkes remained at the forefront of a push among some scientists and engineers to earn public and private funding for solar research towards these aims. “The total research and development expenditures made thus far in solar energy utilization are infinitesimal when compared with the expenditures made in the development of other natural resources,” she wrote in 1951. “Sunlight will be used as a source of energy sooner or later anyway. Why wait?”²⁰⁵

The Association for Applied Solar Energy

Through the 1950s, solar house designs never achieved the up-front cost advantages necessary to compete in a postwar housing market increasingly driven by cheap standardized construction and declining heating oil and electricity prices. Yet the basic premise of solar energy utilization continued to gain momentum, bringing together independent inventors, scientists in public and private research institutions, and entrepreneurs toward the goal of building the technical foundations for a future industry. University of Wisconsin Professor of Chemistry Farrington Daniels was an especially vocal proponent. Daniels’s interest in solar

²⁰⁵ Quotes from Maria Telkes, “Future Uses of Solar Energy,” *Bulletin of the Atomic Scientists* (August 1951): 217-219.

energy emerged from his experience as director of the Metallurgical Laboratory for the Manhattan Project during World War II. Like many of his peers, his role in the creation of the atomic bomb left him with a conflicted sense of technology's potential to both destroy and create. After the war, he determined to use his knowledge and experience to ensure peaceful applications of advances in science and technology during the war. In 1947, he filed one of the first patents for a commercial nuclear reactor. That same year, he joined the Board of the *Bulletin of Atomic Scientists* through which he advocated against the proliferation of nuclear weapons. While he continued to support nuclear energy development, Daniels also recognized the potential for solar energy to serve as a supplement to nuclear for certain applications. The research, development, and promotion of solar energy technologies became the focus of both his professional work and public advocacy.²⁰⁶

Daniels's solar advocacy blended a conservationist critique of increasing fossil fuel consumption with optimism that a focused, government-supported solar energy research and development agenda would allow for continuing prosperity and material abundance in the US and worldwide, even as fuel supplies became scarce. In 1949, Daniels told the American Association for the Advancement of Science that research into solar energy was a necessary endeavor "in these times of profligate spending of the world's natural resources and uncontrolled increase in population." "When we have used up our coal and oil, exploited our available land with intensive farming, and trebled our population," he asked, "can we then call on the sun to give us still more means to satisfy our ever increasing demands for food, fuel, and power?" He believed so. However, echoing Charles Abbot, he also called for a strong commitment from scientists, government, and the private sector:

²⁰⁶ Behrens, *Solar Energy*, 187-190.

There is a long challenging road of research and development which must be followed first – and we must not get the idea that we are about to step into a new era of physical and economic abundance. We can't eat sunshine, we can't carry it where we want to use it, and, because it cannot easily be used to produce high temperatures, we find it is difficult to apply directly in our heat engines.²⁰⁷

A number of prominent scientists in the US and Europe echoed Daniels's assessment. In his 1950 Presidential Address to the British Association, prominent chemist Sir Harold Hartley described research in the fields of both solar and nuclear energy as “a duty to posterity... while we are living on reserves.” For Hartley, a diversified energy basis for society was essential to meet contemporary challenges stemming from “the destruction and disruption of war, the economic unbalance of the older countries, and the claims of the less-developed countries with their ill-nourished millions for a better share in the worlds dividends.”²⁰⁸ Two years later, Harvard University President James D. Conant told an audience at a meeting of the American Chemical Society in New York City that by the 1970s, nuclear energy would prove to be “a disappointment” and that solar energy would emerge “as an inexhaustible source of new power.” Conant also predicted that by committing to a course for the development of solar technologies in the present, by 1985 “the world will have at last realized its age-old dream of lifting most of its labor from the backs of man.”²⁰⁹

Charles Abbot also continued to push for greater government support for solar energy research. In 1951, he helped draft a proposal for \$100,000 federal grant for the construction of a Smithsonian solar energy research facility on the summit of the 7,500 foot Clark Mountain in the

²⁰⁷ Farrington Daniels, “Solar Energy,” *Science* 109 (January 1949): 51.

²⁰⁸ Sir Harold Hartley, “Man's Use of Energy,” *The Bulletin of the Atomic Scientists* (November 1950): 322-324.; R.V. Jones, F.R.S., “Address at the Memorial Service for Sir Harold Hartley, F.R.S., at Westminster Abbey on 17 October 1971,” *Notes and Records of the Royal Society of London* 27, no. 2 (February 1973): 182.

²⁰⁹ Quoted in Mark Novak, “The World will be Wonderful in the Year 2000!” *Smithsonian Magazine*, Paleofuture blog, February 29, 2012. <http://blogs.smithsonianmag.com/paleofuture/2012/02/the-world-will-be-wonderful-in-the-year-2000/>; Also see Eric Hodgins, “Power from the Sun,” *Fortune* 43, no. 9 (September 1952): 130.

Mojave Desert near the California-Nevada border. “This test,” reported the *Los Angeles Times*, “might well be the forerunner of hundreds of solar power plants throughout the West which could harness the now-wasted heat of the sun to generate trillions of kilowatt-hours of electricity every year.”²¹⁰

Some analysts saw solar energy as more promising than nuclear in the long term. In a 1950 article for *Popular Mechanics* titled “Miracles you’ll see in the next Fifty Years,” *New York Times* science editor Waldemar Kaempffert predicted that in the tropical and desert areas of the world where land was cheap and fossil fuels were scarce, solar energy would be more profitable than nuclear energy.²¹¹ In another article, Kaempffert described the sun as “the mightiest of power plants.” He also noted the extreme imbalance in federal government support for nuclear versus solar energy. Despite “several billions” of dollars dedicated to nuclear science, he wrote, “atomic energy for industrial use is not just around the corner; it is not even in sight.” He also asked whether a “practical money-making sunpower plant” could be built through a ten-year, \$200,000,000 federal government program. His answer: “Probably. The problems that must still be solved before the sun irrigates deserts, milks cows and vacuum-cleans rugs are no more difficult than those that confront the designers of an atomic power plant.”²¹²

Interest in solar energy was not the exclusive province of scientists, engineers, and futurists. Labor leader Walter P. Reuther, president of the Congress of Industrial Organizations (CIO), also advocated for greater government support of solar energy research. In a critique of President Dwight D. Eisenhower’s Economic Report for 1955, Reuther charged the administration with failing to promote “the productive ability of the American economy.” An

²¹⁰ “Plant to Harness Solar Energy may be built,” *Los Angeles Times* 1 July 1951: 2.

²¹¹ Waldemar Kaempffert, “Miracles you’ll see in the next Fifty Years,” *Popular Mechanics* (February 1950): 114.

²¹² Waldemar Kaempffert, “Tapping the Mightiest of Power Plants,” *New York Times*, April 2, 1950: 39.

active search for new sources of energy, including “the development of atomic power and the possible practical use of solar energy,” he said, would provide a necessary foundation for both a growing labor force and increasing automation, and would make possible “the creation of abundance in terms undreamed of before.” The economic report, Reuther concluded, offered “no preparation of the Congress and of the people to meeting the new technology and to use it for the benefit of the Nation.”²¹³

The federal government had not entirely ignored solar energy. As early as 1949, Department of Interior officials began discussing solar energy technologies as part of a broader national conservation strategy.²¹⁴ In 1951, President Harry Truman created the Materials Policy Commission (known as the Paley Commission after its chairman) to examine possible responses to anticipated materials shortages associated with the Korean War. In order to offset the risks of dependence on foreign oil, the commission argued for direct government funding for solar technology research. The 1952 report described the utilization of solar energy as “perhaps the most important contribution technology can make to the solution of the materials shortage.” In addition to pursuing nuclear energy and the development of synthetic fuels, the report urged “aggressive research in the whole field of solar energy.”²¹⁵ Later that year, the National Security Resources Board echoed these recommendations, advising the government to take “an aggressive investigative approach to the possibilities of utilizing presently unconventional energy sources such as atomic energy, radiant energy, solar energy, tidal energy, and wind energy.”²¹⁶ Although the Eisenhower administration later “torpedoed” legislation to increase direct federal government

²¹³ “Statement by Walter P. Reuther, President, Congress of Industrial Organizations” in Committee on Economic Report, “January 1955 Economic Report of the President,” Hearing ID: HRG-1955-ERJ-0001 (January 24, 26-28, 31 – February 3, 8-10, 16, 1955), 1200-1201.

²¹⁴ Harvey Strum, “Eisenhower’s Solar Energy Policy,” *The Public Historian* 6, no. 2 (Spring 1984): 37.

²¹⁵ President’s Materials Policy Commission, *Resources for Freedom* (Washington D.C.: Government Printing Office, 1952), vol. 1, 132, 170.; vol. 4, 220.

²¹⁶ National Security Resources Board, *The Objectives of United States Materials Resources Policy and Suggested Initial Steps in their Accomplishment* (Washington D.C.: Government Printing Office, 1952), 4.

funding for solar energy research and development, and while the Paley commission's projections of material shortages later proved to be vastly overstated, those interested in pursuing the Commission's recommendations found ways to benefit indirectly from government spending on science, technology, and energy.²¹⁷

The increased interest in solar energy research also created an impetus for greater organization and communication between researchers, businesses, and investors. In 1953, Farrington Daniels met with Harry Sargent, President of the Arizona Public Service Corporation, to discuss the need for an organization to bring together individuals and companies in the US and around the world working in the solar field. While Daniels saw such an organization as crucial for spreading information about solar energy, Sargent and the other founders saw a potentially lucrative business opportunity. With no company making commercial solar devices at the time, the field was "wide open," declared the *Wall Street Journal* in 1954.²¹⁸

In March 1954, Sargent assembled a group of businessmen, lawyers, bankers, and scientists, mainly from Arizona and California, to form the Association for Applied Solar Energy (AFASE). One of the founding members was Walter Bimson, president of the Valley National Bank of Phoenix and a key member of the "old boys network" responsible for bankrolling much of Phoenix's postwar development. As head of the largest bank in town, Bimson had signed off on loans to suburban home developer Del Webb, who subsequently transformed Phoenix into the retirement capitol of America. Bimson also smoothed the way for Chicago-based communications giant Motorola to move to Phoenix in 1955. He was also deeply involved in local politics, helping to create a municipal tax code friendly to big business, and assisting local

²¹⁷ Strum, "Eisenhower's Solar Energy Policy," 37.

²¹⁸ Ellis Haller, "Making Solar Power Devices is Wide Open Field, Scientist Says," *Wall Street Journal*, October 14, 1954: 1.; For Sargent's and Daniels's meeting see Harvey Strum, "The Association for Applied Solar Energy/Solar Energy Society, 1954-1970," *Technology and Culture* 26, 3 (July 1985): 571-572.

political upstart Barry Goldwater in his unlikely rise to Republican presidential candidate in 1964. And while Bimson himself was never directly implicated with the mafia, his Valley National Bank contributed to the construction of several early Las Vegas hotels including the Desert Inn and Bugsy Seigal's Flamingo. He hoped that transforming Phoenix into a global center into commercial solar energy would attract both federal and private investment and would further boost the city's ascendance as a "desert empire" and a real estate developer's paradise in the thriving Sun Belt.²¹⁹

Also among the AFASE organizers was Jesse Hobson, director of the Stanford Research Institute (SRI). Hobson's involvement was critical to the early growth of the organization. The association with SRI provided professional credibility, access to some of the most advanced scientific research facilities in the world, and most importantly a source of funding for projects, publications, demonstrations, and conferences.²²⁰

As had been the case prior to World War II, California and the desert southwest became a locus of activity in solar technology development and promotion after the war. In 1954, Hobson gave a talk on solar energy at a conference in Los Angeles on the topic "The Future of the West." "The West is rich in many natural resources," he said, "but it is particularly favored because of its sunlight conditions." He added that desert areas with little apparent value for "conventional economic development" were particularly suitable for solar energy applications. "The amount of sunlight available throughout the year is high and the cost of land is low, so commercial plants may find these areas attractive for their operations."²²¹

²¹⁹ The role of Bimson's Valley National Bank in the rise of postwar Phoenix is covered in Peter Wiley and Robert Gottlieb, *Empires in the Sun: The Rise of the New American West* New York: G.P. Putnam's Sons, 1982), chapter 7.

²²⁰ Strum, "The Association for Applied Solar Energy/Solar Energy Society," 571-572.

²²¹ "Desert Seen as Center in Solar Energy Quest," *Los Angeles Times* 1 September 1954, 5.

While the region's favorable climate and relative political and economic autonomy continued to spur interest in solar energy, other factors also came into play. Most notably, the war had generated major demographic and economic growth for California and the surrounding region. Between 1940 and 1946 the federal government pumped some \$35 billion into the state's manufacturing industries and high-tech research institutions. The state received twelve percent of all the federal government's war contracts during this period, far more than any other state. In addition to enormous ship and aircraft manufacturing plants, military bases proliferated along the west coast, bringing in huge numbers of workers and service personnel. The state's population swelled from 6.9 million in 1940 to nearly 11 million by the end of the decade. Annual income also more than doubled during this period from \$835 in 1940 to \$1,752 by 1948. Defense-related industrial and residential development also spilled over into the surrounding region. Phoenix, Las Vegas, and Albuquerque, as well as other smaller towns and cities, were transformed from remote backwaters to booming suburban-industrial-post-industrial centers by the end of the war.²²²

Taking a different view than Daniels, Bimson and the other business-minded organizers of the AFASE shared President Eisenhower's vision of a free enterprise approach to meeting the nation's energy requirements. Their activities followed from "the conviction that freedom of enterprise and action can successfully develop the inexhaustible potential of solar energy for the benefit of all mankind."²²³ And yet, the organization was also deeply linked to Big Science, receiving government grants from the National Science Foundation, the National Academy of

²²² Gerald Nash, *The American West Transformed: The Impact of the Second World War* (Bloomington: Indiana University Press, 1985), ch. 4.; James Williams, *Energy and the Making of Modern California* (Akron: University of Akron Press, 1997), 270-271.

²²³ AFASE board of directors to the Ford Foundation, March 13, 1961. International Solar Energy Society Collection (hereafter ISES papers), Arizona State University, Architecture and Environmental Design Library Archives, Box 2, Folder 17.; This letter was a request for a grant of \$228,000 from the Ford Foundation for expanding the activities of the Solar Energy Research Service Center of the AFASE

Sciences, the Office of Naval Research, the Air Force, and the Department of Commerce.

Initially, primary support came from SRI which, though established by a private trust, worked almost exclusively on government contracts by the late 1940s.²²⁴ Other funds came from membership dues from several California high-tech firms operating primarily under government contracts. Grants from the United Nations Educational Scientific and Cultural Organization (UNESCO) and private foundations including the Rockefeller and Ford Foundations comprised the remainder of the AFASE's funding.²²⁵

In 1955, the AFASE held its first annual international conference on solar energy applications. Held in Phoenix and sponsored by the SRI, the conference attracted some 1,000 attendees to listen to presentations and view demonstrations of a variety of solar projects from around the globe. While the large aerospace corporations were interested primarily in potential military and space-based applications, a number of inventors and entrepreneurs were pursuing the commercialization of simple products that would appeal to the typical suburban American consumer. Maria Telkes predicted that "small household appliances like toasters, beaters or mixers using the sun's energy might be in fairly widespread use within the next five years."²²⁶ The AFASE's newsletter *The Sun at Work* also featured advertisements promoting novelty devices such as solar powered record players, radios, swimming pool covers, and hot dog roasters.

As part of its effort to increase the visibility and accessibility of solar energy research, the AFASE assembled a library collection, funded by SRI and held at Arizona State University. In

²²⁴ Rebecca S. Lowen, *Creating the Cold War University: The Transformation of Stanford* (Berkeley: University of California Press, 1997), 115-118.

²²⁵ Ashton J. O'Donnell, manager of Program Development to Mr. E. Lee MacLean, executive vice president of AFASE, 2 April 1959. ISES papers, box 2, folder 11.; Strum, "The Association for Applied Solar Energy/Solar Energy Society," 572.

²²⁶ Quoted in Haller, "Making Solar Power Devices is Wide Open Field."

addition to *The Sun at Work*, which focused on solar energy applications, SRI funds also supported the publication of a technical journal, *Solar Energy*. The organization also published a bibliography of world solar research in 1955 and again in 1959. The second edition included more than 3,000 articles on a variety of subjects ranging from “the fuel situation” to the history of solar technology to atmospheric data collection to the various technologies being proposed for solar energy utilization. The purpose of the bibliography, AFASE President and retired Shell Oil Executive Jan Oostermeyer explained, was to address the general lack of awareness of worldwide research among the many individuals working on solar energy, and on the nature of the research itself. “Because the sun is the common property of all mankind,” Oostermeyer wrote, “solar energy research has long been carried out in an isolated and uncoordinated fashion in almost all geographic areas.” The publication was meant to serve as a “foundation stone in the future development of solar energy,” providing general and specific information on all aspects of solar research, development, and applications.²²⁷

Among the organization’s more visible endeavors was its sponsorship of a 1957 international competition to design a solar house. The project, titled *Living with the Sun*, attracted architects interested in passive solar design, builders of active thermal heat systems, and photovoltaic researchers. The winning house, designed by a firm in Minneapolis, was a simple, rectangular concrete and glass structure surrounded by a shell of mechanically-controlled solar collection louvers. The panel appreciated the “logic of its solar equipment.” In contrast to other

²²⁷ Jan Oostermeyer, “Forward,” in *Applied Solar Energy Research: A Directory of World Activities and Bibliography of Significant Literature*, ed. Jean Smith Jenson (Phoenix: The Association for Applied Solar Energy, 1959), vii.

proposals which included some purely aesthetic features, the entirety of the design promoted efficient use of solar heat.²²⁸

When it was built in a Phoenix suburb in 1958, the house attracted a stream of curious observers. It also became the last gasp of the solar house movement, however, which by that time had already largely been abandoned in favor of electric air conditioning and heating.²²⁹ The AFASE board's excitement over the house's popularity quickly turned to frustration at the community's response. Neighbors complained about the increased traffic. A local newspaper also raised questions about "whether the design met zoning requirements for 'conventional southwestern architecture'."²³⁰ These concerns persisted even though the house had been designed with the desert environment in mind, and despite the best efforts of the designers to also "bring the desert into the house" by using a color scheme inspired by the surrounding landscape. Within months of its completion, the house was sold for far less than its construction cost and with its active solar space heating system never having even been fully connected.

Living with the Sun, as one architectural historian has observed, represented a significant early effort to "allow innovation in design to produce a new relationship to technology, and...to the material, and political issues that accompanied the slow depletion of fossil fuels."²³¹ Yet the disappointing result also highlighted the challenges of domestic commercial solar energy development stemming from the larger cultural, economic, and institutional forces animating postwar housing construction. It also hinted to the more business-oriented members of the

²²⁸ The "Living with the Sun" competition is described in detail in Barber, "The Modern Solar House: 389-440.

²²⁹ Adam Rome, *The Bulldozer in the Countryside: Suburban Sprawl and the Rise of American Environmentalism* (New York: Cambridge University Press, 2001), 64.

²³⁰ Quoted in John A. Ruffie and Harry Z. Tabor, "The International Solar Energy Society: The First 25 Years, 1955-1980," in *The Fifty Year History of the International Solar Energy Society and its National Sections*, vol. 1, Karl Bier, ed. (Boulder: American Solar Energy Society, Inc., 2005), 21.

²³¹ Daniel Barber, "Living with the Sun: Architecture and the Association for Applied Solar Energy," conference paper, accessed November 18, 2014 at <http://epress.lib.uts.edu.au/ocs/index.php/AASA/2007/paper/view/72>.

AFASE that widespread domestic commercialization of solar energy was perhaps not on the immediate horizon as they had originally expected.

Still, for those involved in solar energy research and invention in the late 1950s, commercial prospects were not as bleak as they appeared in retrospect. The troubles faced by the Living with the Sun committee seemed at the time to be growing pains. These were viewed as typical problems faced by small businesses when introducing an unfamiliar technology within a conservative political economy that favored stability, reliability, low up front cost, and convenience. Breaking into the suburban consumer market in particular would require patience and creativity in tackling the basic technical problems of solar energy utilization. As late as 1959, an analyst for the trade journal *Heating, Piping, and Air Conditioning* made the case that the obstacles to widespread use of solar energy for space heating were no less surmountable than those facing nuclear energy.²³²

AFASE board member Henry Sargent, President of the American & Foreign Power Company, argued that the industry which first solved the problems of high initial cost, limited efficiency, and storage of solar heat would also “be the first to realize substantial profits from solar energy.”²³³ Success in changing consumer habits and influencing local, state, and federal government institutions to accommodate alternative energy technologies and home designs, Sargent and others believed, would follow from a gradual process of research, public education, and small-scale commercialization. Their optimism reflected a revival of cultural interest in small business enterprise in the US in the context of the Cold War. Even as large corporations dominated the postwar economy, historian Mansel Blackwell writes, Americans came to see small businesses as “bastions of individualism and democracy against the threats of

²³² George W. Rusler, “Nuclear or Solar Energy: Which is more Practical for Space Heating?” *Heating, Piping, and Air Conditioning* 37, no. 2 (February 1958): 106-109.

²³³ Henry Sargent, “Commercial Applications – 1959,” in *Applied Solar Energy Research*, xx.

totalitarianism and communism.”²³⁴ Solar advocates also proposed a formula of small business-based innovation common for the time. The idea was to adapt existing solar technologies to a few specialized applications for which more conventional or larger-scale energy sources were ill-suited.²³⁵

They had valid reasons to be confident. In the context of the rapidly expanding consumer economy of the late 1950s, a number of avenues for alternative energy-based development had either already taken shape or seemed just on the cusp of becoming lucrative market opportunities. As people flocked to the growing suburbs of southern California, Arizona, and the larger “sunbelt” following World War II, millions more consumers came to be living in a climate conducive to solar water heating, passive solar architecture, active solar home heating, and solar air conditioning and refrigeration systems. Solar inventors and businesses also found ways to capitalize on government grants and contracts. By 1959, several companies including Arthur D. Little, Inc. and the American Searchlight Company were manufacturing commercial solar furnaces under government contracts. These were being used at military installations in San Diego, California and Natick, Massachusetts to simulate the heat of a nuclear blast for the purpose of testing materials to protect troops. One of the largest direct government investments in solar energy at this time came in the field of solar distillation. By 1959, the Office of Saline Water was conducting tests of experimental stills ranging in size from 500 to 2,500 square feet at the Battelle Memorial Institute in Port Orange, Florida.²³⁶

²³⁴ Mansell G. Blackford, *A History of Small Business in America*, second edition (Chapel Hill: University of North Carolina Press, 2003), 131.

²³⁵ *Ibid.*, 119.

²³⁶ Sargent, “Commercial Applications,” xx-xxi.; In France, Felix Trombe of the National Solar Energy Laboratory drew on the early high temperature solar collector designs of Augustin Mouchot, Aubrey Eneas, and Charles Abbott to design and build the world’s first commercially viable solar furnace, which was used to produce commercial-grade zirconia as well as number of specialty steels and alloys for industrial applications.

Additionally, even as nuclear emerged as the favored energy source for the long term future, solar technology research ended up being carried along in its wake. At a hearing on “frontiers in atomic research” in 1959, George Löf told the Joint Committee on Atomic Energy that “solar energy has sort of been riding along on the coat-tails of a number of...atomic energy developments.” Specifically, he noted the applicability of recent research into nuclear thermal electric generation to solar energy research. He also observed that the Manhattan Project and the establishment of the Atomic Energy Commission (AEC) had firmly established the federal government as an active contributor to the development of nation’s energy infrastructure. Ensuring reliable increases in the availability of energy became more than simply a business matter, he argued. In the context of a postwar order characterized by a standoff between two global superpowers over the ideological, political, economic, and technological future of the world, energy resource development became a matter of national security and prestige as well as means to ensure the continuation of the American way of life. The increasingly active role of the federal government in shaping the course of the nation’s energy future provided a rationale for also using government to stimulate research into solar energy as a future supplement to nuclear and as an alternative energy source for specific applications beneficial to the development and security of the nation.²³⁷

*Energy for the “Solar Belt”*²³⁸

²³⁷ Testimony of George Löf, *Frontiers of Atomic Energy Research: Hearings before the Subcommittee on Research and Development of the Joint Committee on Atomic Energy, March 22, 23, 24, and 25, 1960* (Washington D.C.: Government Printing Office, 1960), 358.

²³⁸ William H. Stead, “The Sun and Foreign Policy,” *Bulletin of Atomic Scientists* 8, no. 3 (March 1957): 86-87.

Among the AFASE's early goals was to define which solar applications would be feasible both from a commercial and a technical standpoint. The obstacles to domestic commercialization became apparent early on, and many US solar advocates turned their attention to potential international markets. At the inaugural 1955 meeting in Phoenix, SRI President and AFASE cofounder Jesse Hobson expressed what he and many other prominent solar advocates were already beginning to see as the most promising path for solar energy technology.

Visions of the sun's magic become more meaningful when examined together with our knowledge of conditions in undeveloped or undeveloped geographic areas. There is probably nothing so exorbitantly expensive as the lack of power or the lack of energy. It is difficult for many areas of meager energy resources to maintain much above the subsistence level, even with continual, backbreaking toil. In these areas, using the sun's energy can literally change the face of the land and bring to its people new hopes and satisfactions which should be denied no man.²³⁹

Hobson's call to adapt solar technologies for use in fuel-poor regions of the world was not simply a business consideration. It was also political, aligning with national diplomatic objectives in the context of the Cold War and decolonization. In his 1949 inaugural address, President Harry S. Truman articulated the goal of "making the benefits of our scientific advances and industrial processes available for the improvement and growth of undeveloped areas." Truman's "Point IV" as it was known since it was the fourth point in his outline of foreign policy objectives called on academic institutions and the private sector to share the nation's "imponderable resources in technical knowledge" with regions of the world where "economic life is primitive and stagnant" and where people suffered from chronic poverty, food shortages, and disease. This was not a policy of economic aid in the mold of the Truman Doctrine and the

²³⁹ Quoted in "Phoenix Host to Symposium," *Sun at Work* 1, no. 1 (March 1956): 4.

Marshall Plan, but a program aimed at building modern capitalist democracies in the image of the contemporary United States.

While the intent from a national security standpoint was to export technology in order to forestall communist takeovers in the decolonizing world, Point IV also involved US businesses and technical organizations in a global project of humanitarian assistance predicated on cooperation between governments, private industry, and scientific institutions worldwide.²⁴⁰ Solar technology offered an attractive basis for technical assistance in what US Employment Service administrator William H. Stead referred to as the “solar belt,” the region encircling the earth’s mid-section between approximately the fortieth latitudes north and south where the sun shined consistently for most of the year. Within this region lived more than half of the world’s population, many of whom were living in what Stead described as pre-industrial, even pre-agricultural, conditions.²⁴¹

Many of these activities were organized under the auspices of UNESCO, established in 1946 “to contribute to peace and security by promoting collaboration among the nations through education, science, and culture.”²⁴² Under its first chairman, Julian Huxley, UNESCO adopted a philosophy of “World Citizenship” which, historian Glenda Sluga explains, held that global unity would be “a necessary step in the evolution of mankind from tribes to nations, from national consciousness to ‘One World.’”²⁴³ The specific aim was to “root out the underlying causes of

²⁴⁰ Jacob Darwin Hamblin, *Oceanographers and the Cold War: Disciples of Marine Science* (Seattle: University of Washington Press, 2005), 15-16.

²⁴¹ Stead, “The Sun and Foreign Policy,” 87.

²⁴² Quoted in Malcolm S. Adiseshiah, “The Intellectual Centre,” in *Forty Years of the United Nations*, ed. U.S. Bajpai (New Delhi: Lancer International, 1987), 189.

²⁴³ Glenda Sluga, “UNESCO and the (One) World of Julian Huxley,” *Journal of World History* 21, no. 3 (2010): 393.

war” by working toward economic and political development, education, public health, and universal observance of human rights.²⁴⁴

The inclusion of science in the organization’s purpose was key. Maheshwar Dayal, India’s representative in UNESCO, later recalled that during the early years “there was an understanding that, whether one was in one ideological camp or the other, the basic facts of science were not different. Water was water everywhere, consisting of molecules of hydrogen and oxygen.... There was no such thing as communist water or capitalist water, black or white water, Christian or Hindu or Muslim water.”²⁴⁵ Science, Dayal added, served as “a cementing force for understanding between peoples, apart from furthering the understanding of science itself and of its role in society and social development.”²⁴⁶ Following a familiar Enlightenment premise, UNESCO’s early leaders conceived of the modern world as primarily a “scientific culture.” By grounding programs for social and economic development on scientific principles, Huxley and others believed, the organization would not only promote peace, general welfare, and global unity, it would also contribute to furthering the natural sciences and improving on technology.

The early mission of UNESCO exemplified the ways in which nineteenth century colonial notions of science and technology as indicators of racial and cultural superiority and means of controlling nature continued to inform global politics in an age of decolonization.²⁴⁷ Also like in earlier eras, however, the ideology that informed the early activities of UNESCO

²⁴⁴ Stanley Meisner, *United Nations: The First Fifty Years* (New York: Atlantic Press, 1995), 223-224.

²⁴⁵ Maheshwar Dayal, “Promotion of Science,” in *Forty Years of the United Nations*, 209-210.

²⁴⁶ *Ibid.*, 210.

²⁴⁷ Michael Adas, “Modernization Theory and the American Revival of the Scientific and Technological Standards of Social Achievement and Human Worth,” in *Staging Growth: Modernization, Development, and the Cold War*, eds. David C. Engerman, Nils Gliman, Mark H. Haefele, and Michael E. Latham (Amherst: University of Massachusetts Press, 2003), 25-45.; Also see Anthony Q. Hazard, *Postwar Anti-Racism: The United States, UNESCO, and “race,” 1945-1968* (New York: Palgrave Macmillan, 2012). While Adas and Hazard see this revival of colonial thinking as primarily an American innovation, other historians recognize it in international organizations. See especially Sluga, “UNESCO and the (One) World of Julian Huxley,” 395.

and other organizations involved in the larger project of Third World development did not always manifest as intended in practice. Postwar development programs, historian David Biggs writes, instead often served “as a real and imagined possibility space that, regardless of intention, allowed new flows of people, technology, and ideas” to move back and forth between the US and Europe and nations and communities on the rural peripheries.²⁴⁸ While predicated on the universalizing potential of technology, development schemes often became subject to the demands of local elites. In many cases, development workers found themselves adapting their priorities and activities according to local preferences and environmental conditions. The resulting tension between ideology, the priorities of the various parties involved, and on-the-ground practice interfered with American and European geopolitical ambitions, while also allowing alternative development visions to come under consideration. Solar technology became the basis of one such alternative vision.

Solar advocates in the US and worldwide in the 1950s and 1960s pursued a development philosophy based on the idea that local environmental conditions determined the technological means by which different societies could progress. In this respect, their views were closer to an older, more conservative, and somewhat less instrumental “reformist” model of development which recognized that while the end goal was to extend the benefits of modern science and technology around the world, doing so required responsiveness to local conditions.²⁴⁹ Development projects could not simply replicate the same plans everywhere in the world, solar advocates argued. Customary indigenous practices, the preferences of local leaders, and local environmental particularities would have to be taken into account. Many undeveloped nations,

²⁴⁸ David Biggs, *Quagmire: Nation-Building and Nature in the Mekong Delta* (Seattle: University of Washington Press, 2010), 156.

²⁴⁹ Nils Gilman, *Mandarins of the Future: Modernization Theory in Cold War America* (Baltimore: Johns Hopkins Press, 2003), 9-10.

William Stead argued, “do not need and probably do not wish to try to duplicate our Western industrial structure and gadgets.”²⁵⁰

Identifying available energy resources was critical to this transformation. In Europe and the United States, solar advocates argued, vast coal and oil reserves provided an easily transportable, high output store of energy, capable of powering everything from trains, ships, and cars to steel mills to air conditioning units and vacuum cleaners. Lacking these concentrated sources, much of the rest of the world was unable to match the rapid pace of economic growth of the West. “The unfairness of nature in distributing fossil fuels and water power over the globe,” wrote biophysicist and editor of *The Bulletin of Atomic Scientists* Eugene Rabinowitch in 1951, “is a very serious handicap to the plans of industrialization of South-East Asia and South America – plans on which all hopes of ultimate stabilization of the population of these areas and rise of their living standards are commonly based.”²⁵¹

Without a commitment to find and make use of other sources of energy, solar advocates saw two outcomes of this growing disparity, neither being desirable. In the first scenario, large-scale, state-sponsored development projects in “non-industrialized” nations would require vast amounts of fossil fuels to be shipped long distances at high cost. This would accelerate the already imminent depletion of the world’s fossil fuel reserves, leading to major global crisis at some point in the late twentieth century. In the second scenario, if the US and other developed nations chose not to invest in energy in these places or decided to wait until nuclear became feasible, the results would be a humanitarian nightmare. Pursuing simple, task-specific solar energy technologies, remarked Shri Keshava Deva Malaviya, Deputy Minister for Natural

²⁵⁰ Stead, “The Sun and Foreign Policy,” 87.

²⁵¹ Eugene Rabinowitch, “World’s Energy Supplies and their Utilization, *Proceedings of the American Academy of Arts and Sciences* 79, no. 4 (July 1951): 307.

Resources and Scientific Research in India, would be a step “towards peace, happiness and universal equity and brotherhood.”²⁵²

Solar advocates also made the case that, in terms of its energy infrastructure, the United States was not at the end point of the development spectrum. The nation’s remarkable prosperity had a finite material basis. “None of the experts denies that there will be *some* time when mankind will have to do without fossil fuels,” remarked Dutch Professor D. Dresden at a 1954 UNESCO conference on wind and solar energy applications in arid zones held in India. While confident that nuclear would eventually replace fossil fuels as the primary energy source for most urban, industrial applications, Dresden and others recognized that nuclear energy was also dependent on a finite source: uranium, which, while perhaps more plentiful than coal and oil, would also eventually be used up. Dresden described the situation in familiar economic terms, arguing that “in using these fuels we are living on *capital* and not on *income*. This capital may be bigger or smaller than we believe it to be; we may adapt our spending to its size, but one day it will have been exhausted.”²⁵³

Farrington Daniels further argued that while nuclear had great potential to provide electrical power to dense urban areas, it was not practical everywhere.²⁵⁴ Its greatest strength, immense output, also made it cost-effective only in regions of the world requiring high levels of concentrated energy. The extremely high costs of building, operating, and maintaining a nuclear

²⁵² Shri Keshava Deva Malaviya, Deputy Minister for Natural Resources and Scientific Research, “Inaugural Address,” *Arid Zone Research – VII: Wind and Solar Energy: Proceedings of the New Delhi Symposium* (Paris: United Nations Educational, Scientific and Cultural Organization (UNESCO), 1956): 20.

²⁵³ Professor D. Dresden (Netherlands), “General Review Paper,” *Wind and Solar Energy*, 27.; Economists were employing this metaphor as early as the 1880s. See for example, Edward P. Jackson, “Will Our Coal Supply ever be Exhausted?” *The North American Review* 149, no. 395 (October 1889): 511-512.; Daniels employed the same metaphor, see Farrington Daniels, “Utilization of Solar Energy,” *Wind and Solar Energy*, 129.

²⁵⁴ For discussions of the complementary function of solar and nuclear during this period see Farrington Daniels, “Atomic and Solar Energy,” *American Scientist* 38 (October 1950): 521-548.; Eugene Ayers and Charles A. Scarlott, *Energy Sources: The Wealth of the World* (New York: McGraw-Hill, 1952), 168-176, 186-218, 279-283.; and Harrison Brown, *The Challenge of Man’s Future* (New York: Viking Press, 1956), 172-182.

power plant could only be recouped through correspondingly high rates of energy consumption. In much of the world, for much of the immediate future, Daniels believed, nuclear energy would be overkill. Residents of rural regions of Africa, South Asia, and South America required only small amounts of energy for specific purposes. These included pumping and distilling water, cooking, heating water, and accessing media. “In competition with atomic energy,” he wrote, “solar energy has the advantage of safety and the ability to operate in small uses.”²⁵⁵ Nuclear critic Waldemar Kaempffert extended this, arguing that solar energy might even be more cost effective for large-scale power generation in much of the world. “It would be cheaper to build a solar power plant along the Equator than a big uranium reactor,” he claimed. “It is true that solar power plants sprawl over much territory; but land is cheap in most tropical regions.”²⁵⁶

These places would also serve as proving grounds for technologies which might eventually be adapted for use in the United States and other developed nations. Whereas many American modernizers in government and academia saw development as a linear process of technology transfer from core to periphery, Daniels revived the nineteenth century notion of peripheral zones as laboratories, or incubation zones, for scientific and technical research which would benefit the core.²⁵⁷ As George Löf noted, “the utilization of solar radiation to satisfy some of man’s energy needs may well be the unique example of a technology applied in an unindustrialized or undeveloped economy before substantial use is made in countries having a high degree of technical development.”²⁵⁸ Solar advocates’ vision of development aimed not at the re-creation of a static contemporary America across the globe, but at a process of

²⁵⁵ Farrington Daniels, “The Future of Solar Energy,” *Sun at Work* 4, no. 1 (March 1959): 16.; Farrington Daniels, “A Limitless Resource: Solar Energy,” *New York Times*, March 18, 1956: 40.; also see Jean Smith Jensen, “Harnessing the Sun Around the World,” *Sun at Work* 4, no. 1 (March 1959): 3.

²⁵⁶ Waldemar Kaempffert, “Atomic-Power Development through Private Enterprise faces many Obstacles,” *New York Times*, April 12, 1953: E11.

²⁵⁷ Farrington Daniels, “Utilization of Solar Energy,” 129-130.

²⁵⁸ George O.G. Löf, “The Future of Solar Energy,” *Sun at Work* 4, no. 1 (March 1959): 17.

technological co-creation between core and periphery in which the end point receded into the future as energy needs changed.

This long-term view hinted at a potentially lucrative pay-off for those willing to invest in solar energy technology at its current early stage. It also provided a rationale for governments and private foundations to support solar energy research and development despite its limited short term commercial prospects in developed nations and its lack of military function. “If a new development is socially useful as well as technically feasible,” Daniels argued, “it may be politically wise to proceed with it at once, even if it is not economically self-supporting at first.”²⁵⁹ Some US government agencies acted on this premise. In 1957, the Department of Commerce (DOC) sponsored solar exhibits at the International Fair in Athens, Greece, which attracted nearly one million visitors. A year later, the DOC supported a similar display in Casablanca.²⁶⁰ Such efforts, William Stead argued, would contribute to Cold War aims by making energy available to “the ‘uncommitted nations’ struggling for freedom and economic advancement.”²⁶¹

Short term goals were modest. Daniels recognized that for large-scale applications, existing solar devices could not compete with conventional methods of converting and transmitting energy. “There is no era of solar prosperity just ahead,” he acknowledged, “only, for later, hopes through research. But they are intriguing, challenging hopes.” The AFASE, as he saw it, had two roles: the first was to provide a forum for making recommendations and encouraging scientists, engineers, and economists to study the various environmental, technical, and economic aspects of solar energy conversion and utilization; the second was to actively take

²⁵⁹ Daniels, “Utilization of Solar Energy,” 130.

²⁶⁰ Harvey Strum, “The Association for Applied Solar Energy/ Solar Energy Society, 1954-1870,” *Technology and Culture* 26, no. 3 (July 1985): 575.

²⁶¹ Stead, “The Sun and Foreign Policy,” 87.

part in the development, testing, and promotion of task-specific technologies for immediate use “in those areas which greatly need mechanical and electrical power in small isolated units.”²⁶²

AFASE members contributed to this work mainly through participation in international conferences on energy and development. The largest of these was held by invitation of the Italian government in Rome in August of 1961. Sponsored by UNESCO and attended by scientists, engineers, inventors, and entrepreneurs from around the world, the UN Conference on New Sources of Energy aimed at “bringing together experts in the fields of solar energy, wind power and geothermal energy, as well as people interested in energy development in general, to provide...up-to-date information...and to facilitate an exchange of views and experience relating to practical problems, potentialities and limitations in utilizing these three sources of energy, especially in areas lacking conventional energy sources or facing high energy costs.”²⁶³

The organizers described the program as a non-political gathering of scientists. Participants were instructed to “attend as individuals and not as representatives of governments, organizations or societies.”²⁶⁴ The intent was to separate “humanitarian” aims from Cold War geopolitics, and to define “economic development” as a function of values-free applications of scientific and engineering research. Even Pope St. John XXIII got behind the idea of energy as the universal root of humanity’s “true welfare,” telling the conference attendees that “The Creator distributed energy in abundance throughout the world, and the genius of man applies itself, from age to age, in capturing it and utilizing it for his needs.” In “the technical age of humanity,” the Pope added, it had become evident that the Creator had placed at the disposal of

²⁶² Daniels, “Utilization of Solar Energy,” 130.; Daniels had expressed these ideas for a much wider audience at the World Population Conference held in Rome in 1954. “World Told to Develop Solar Power,” *Los Angeles Times*, September 8, 1954: 18.; “Solar, Not Atomic Energy will Prove Boon to Poor Lands, Population Parley is told,” *New York Times*, September 8, 1954: 13.

²⁶³ “Rome World Power Conference and Agenda Announced,” *Sun at Work* 5, no. 4 (1960): 13.

²⁶⁴ *Ibid.*

humanity other energy supplies beyond “the classic type.” These included “sources little or not yet utilized until now, like the sun, or the wind, or even the waters and vapors hidden in the entrails of the earth.” The Pope offered a blessing to the scientists and technicians committed to the ordained task of making these sources available to “the populations of the underdeveloped countries, whose immense needs today...make an incessant appeal to all men of gallant soul.”²⁶⁵

This humanitarian cast overlaid a distinctly political agenda based on belief in the universalizing potential of science and technology that had carried over from the colonial period to become a foundation of Cold War era development ideology. It was also a product of a trend towards greater international cooperation among scientists in a variety of fields from meteorology to geophysics. UNESCO served as a rallying point for academic and industrial scientists seeking to expand opportunities for both basic and applied research as a way to diffuse the aggressive nationalism that had precipitated the two world wars and the Cold War.²⁶⁶ However, although participants at the Rome conference held to a traditional belief in a correlation between increasing energy consumption and higher standards of living, the event also provided a forum for identifying the limitations and vulnerabilities of high cost, centralized, high output forms of energy production based on exhaustible or geographically fixed sources. While the conference organizers and attendees generally saw themselves as contributing to the project of development as defined in the context of the Cold War and decolonization, they were also offering a political critique of the technological underpinnings of that project, drawing attention to the widely varying energy requirements of different regions of the world, as well as the fundamentally transitory nature of fossil fuel- and nuclear-based development schemes.

²⁶⁵ “Pope John Addresses Rome Power Conference,” translated by Dr. Judith J. Radke, *Sun at Work* 6, no. 3 (1961): 15.

²⁶⁶ Spencer R. Weart, *The Discovery of Global Warming* (Cambridge, MA: Harvard University Press, 2003), 32.

The conference attracted some 500 scientists, engineers, entrepreneurs, and government administrators from more than seventy countries. The discussions were based on 250 scientific papers on specific subjects and 20 general papers summarizing the major developments and applications in the fields of solar, geothermal, and wind energy. The majority of the papers and discussions dealt with solar energy applications. Presenters covered a wide range of topics including atmospheric monitoring in arid regions; solar distillation experiments in Chile, France, India, the United Arab Republic, and the Soviet Union; the “vast number” of solar water heating systems being used around the world, including an estimated 350,000 in Japan; the possibilities for installing solar air conditioners and refrigeration systems in “more primitive communities in hot areas”; research into materials with high heat storage capacity; and experiments in the Soviet Union to convert thermal heat to electricity.²⁶⁷

The papers themselves mainly focused on technical questions and breakdowns of costs versus other energy options. The broader cultural and environmental implications were addressed in the discussions. AFASE journal editor Sidney Wilcox provided a summary of responses. A number of commenters stressed the need to employ other metrics besides price, efficiency, and output in determining the applicability of solar energy systems for certain applications. These included convenience, availability of materials for constructing solar machines, and adaptability to “the customs of the people in the area where they are to be used.” One of Farrington Daniels’s colleagues from the University of Wisconsin, for example, noted that “a solar cooker developed...for Mexican and American Indians was abandoned after extensive field trials because it did not successfully cook frijoles (beans), the principal food of the people.” Another presenter observed that while large “industrial units” might be appropriate in some locations,

²⁶⁷ United Nations, *Proceedings of the United Nations Conference on New Sources of Energy: Solar Energy, Wind Power, and Geothermal Energy* (New York: United Nations, 1963-1964).; “Specialists Summarize the Rome Papers,” *Sun at Work* 6, no. 3 (1961), 10-13.

private and public investment in solar should also be directed towards “smaller family and village level devices.” The quantity of available energy was not the only determinant of living standards, he added. “Man doesn’t live by kilowatts alone and a change in government doesn’t necessarily improve living standards.”²⁶⁸

Others predicted that solar energy installations could allow for dramatic, even “revolutionary” socio-economic and demographic transformations. Small-scale, task-specific solar devices could significantly “improve the living conditions at the village level” according to one researcher. In India, one presenter estimated, the purchase of a solar powered loom could enable a single woman to increase her cloth output from 15 cents worth to 75 cents worth per day, allowing her “an extra 60 cents to buy goods and services.” In rural Ghana, where the government had already instituted compulsory education, only a small capital outlay would be required to produce electricity “in the micro-kilo range so that children can study after dark,” according to another presenter. The larger goal was to prevent the depopulation of rural areas and to stem the tide of overpopulation in urban centers. Innovations in solar air conditioning and refrigeration might even encourage agricultural settlements in areas with “adverse climates,” such as Central Australia, which were believed to be too inhospitable for most economic enterprises.²⁶⁹

These topics continued to receive attention at conferences and trade exhibitions around the world. A number of presenters stressed the immediate contributions of small private firms. A 1961 seminar hosted by the Greek Atomic Energy Commission and the Hellenic Society for Solar and Aeolian Energy and held under the auspices of the NATO Scientific Council featured a presentation and discussion regarding the commercialization of solar water heaters in Israel.

²⁶⁸ Sidney W. Wilcox, “The Editor’s Notes on the Rome Power Conference,” *Sun at Work* 6, no. 3 (1961): 7-8.

²⁶⁹ *Ibid.*

According to Reiner Sobotka, managing director of Miromit Sun Heaters, Ltd., the company had produced and sold some 30,000 solar water heating units in the past decade for domestic use and for export to 25 countries. Sobotka stressed taking a practical rather than theoretical approach to solar energy development, arguing that “solar devices will not be used simply because they are solar, but only if they do a better and more economical job than competitive equipment.” This meant, for instance, putting less emphasis on measures of efficiency than on ease of cleaning and maintenance.²⁷⁰

Commercial viability was not simply a matter of good design. Solar businesses also depended on support from national governments, private foundations, and international organizations. The US government provided less direct support than the governments of Israel, France, and Japan where fossil fuels were more expensive and less abundant and where the political culture was more accommodating to direct government intervention in the economy. However, some US agencies were involved in solar demonstrations. The DOC, for example, sponsored a series of small business-oriented trade fairs in undeveloped nations through the 1950s and early 1960s. These exhibitions were designed to create niche markets for US products while also serving the broader national goal of capitalist development in the Third World. DOC officials encouraged demonstrations of solar devices at these fairs, “provided they have been developed for a particular country or geographical area.” Commerce Secretary Luther H. Hodges explained the basic aims in an announcement for a 1961 US trade exhibition in Ghana in West Africa: “Our exhibition will be practical, do-it-yourself demonstration of American techniques and equipment which other new countries have found helpful in achieving their goals of economic and social progress,” he said. The theme of the exhibition was “Small Industries are Big Business.” The idea was “to illustrate the real interest of the US Government in assisting the

²⁷⁰ John Yellot, “Solar and Wind Energy Seminar Held at Sounion,” *Sun at Work* 6, no. 3 (1961): 16-18.

Republic of Ghana to develop its industry by providing both visual and manual examples of what can be done by using basic tools and production techniques.” Solar technologies, Hodges noted, “have been popular in all of the instances where they have been exhibited.”²⁷¹

Conferences and exhibitions on solar energy applications in the Third World put forward a development vision which intersected with but differed from the more high profile development projects of this era. While rooted in a confidence in science and technology as the bases of socio-economic progress, solar energy proposals were less dependent on continuous expert oversight which accompanied large scale hydroelectric and nuclear energy schemes. And although reliant on state sponsorship, in the long run they would involve less direct, sustained control from large corporations and governments in developed nations. For American members of the AFASE, the intent was to use government and/or private foundation funding for the initial research, fabrication, and demonstration of solar technologies. The focus would be on simple, easily operated and maintained devices which could be manufactured with local materials using local labor. Third World governments, research institutions, and private companies could then build the market for solar technologies themselves on these foundations.

Encouraging local solar invention was part of the agenda. Between 1961 and 1963, the editors of *Sun at Work* posted frequent updates of the work of Shunam Li of Taipei, Taiwan. Li, a retired customs worker and a self-taught electrical engineer, designed, built, and tested a number of solar-powered mechanisms including a six by seven foot aluminum solar cooker which “surprised the elders, 80 years of age, in the surrounding area.” Using simple hand tools, he also fabricated several twelve-inch diameter concave mirrors. While the mirrors were

²⁷¹ “U.S. to Hold First Exhibit in West Africa,” *Sun at Work* 6, no. 3 (1961): 6.; The National Academy of Sciences was also active, sending American scientists to South America to advise university scientists about the potential uses of solar energy through its Committee on Inter-American Scientific Cooperation. See National Academy of Sciences, National Research Council, *Annual Report, Fiscal Year, 1960-61* (Washington D.C.: Government Printing Office, 1961), 108.

“marketable,” Li said, the foci were “not up to standard.” Grinding and polishing the mirrors by hand could not match the exactness of a machine-manufactured mirror, he admitted. While his neighbors saw his work as a “curiosity,” the “Chinese and foreign lands” where he had sent photos of his furnace showed no interest whatsoever: “A curiosity is remained to be solved until it becomes a reality,” he wrote: “This is the usual route a scientist has to get through.” Li’s tenacity and optimism compelled the editor of *Sun at Work* to send one hundred dollars plus shipping expenses to Taipei for one of Li’s handmade mirrors. The money was “to be used for purchasing a small solar workshop and equipping it with power tools.” The editors also encouraged other AFASE members to do the same so that “Shunam Li’s faith and courage will have its reward.”²⁷²

Research before Commercialization

The AFASE began to struggle financially in 1959 when the new leadership at the Stanford Research Institute decided to cut funding. The organization survived through a partnership with Arizona State University, but when it became evident that immediate profits were not going to be made in the solar field, many of the original members, especially local private firms, dropped out. Direct federal government support also failed to materialize. Between the late 1950s and 1960s, bills introduced by California Congressman Craig Hosmer, Minnesota Senator Hubert Humphrey, and Nevada Senator Alan Bible to increase federal funding for solar research stalled in committee. Very little of the \$100,000 spent by the National Science Foundation each year for solar research made it into to the AFASE coffers. Most of this money went to large corporations including General Electric, DuPont, Westinghouse, Goodyear,

²⁷² “West of the Bamboo Wall,” *Sun at Work* 6, no. 3 (1961): 3-7.

and others pursuing space-based or other high-tech solar applications. By 1963, the organization was operating at a deficit. With membership down 30 percent, dues and temporary grants were not providing sufficient funds to support the organization's library, conference activities, and two separate quarterly journals.

That year, the AFASE was reorganized as a professional scientific society and renamed the Solar Energy Society (SES). Farrington Daniels was elected as the first president. His notoriety and international connections helped the organization to survive the transition. The National Science Foundation also agreed to continue funding the publication of *Solar Energy*. In 1966, the Rockefeller Foundation granted \$20,000 to the SES to fund translations of journal articles and conference paper abstracts, to expand the library, and to support a world solar tour by Executive Secretary Frank Edlin. The survival of SES was also a result of its expansion beyond its Southwestern business roots. The organization's journals and conferences focused less on immediate commercial applications than on work being done at government and industrial research labs internationally. By 1967, the organization had approximately one thousand members in 85 different countries plus another thousand subscribers to the SES journals.²⁷³

For Daniels, international expansion and a greater focus on science were necessary steps. In his view, the problem of making solar technologies "economical," the overriding concern from a business standpoint, derived from the lack of sufficient basic research and a lack of knowledge of the most suitable markets. Although filling these gaps meant seeking funds from governments, universities, and private foundations which up until then had shown only lukewarm interest, it also encouraged a more future-oriented approach to solar technology

²⁷³ Farrington Daniels, "Words from the Retiring President," *Sun at Work* 12, no. 2 (1967): 4.; "Solar Power Bill Planned by Hosmer," *Los Angeles Times*, August 18, 1957: 40.

development. While some immediate commercial applications may have existed in the 1960s, the value of pursuing these was not to make a profit in the present but to establish a technological foundation for a more diversified future energy regime. In his 1964 treatise, *Direct Use of the Sun's Energy*, Daniels described how a future generation might look back on the age of fossil fuels:

We might imagine a conference in the distant future when the shortages of coal, oil, and gas are felt. Our descendants might well blame us for our wasteful extravagances in the use of these most important natural resources. They might say, 'You consumed gasoline in 200-hp engines simply to carry one person to his office and back. You talked about the folly of burning for fuel cow dung which should be used for fertilizer, yet you burned the limited supply of organic fossil fuel that should have been used as raw material for making petrochemicals. You used it not only for concentrated energy in engines at high temperatures but even for low-temperature operations such as cooking, heating and cooling of houses, and distillation of water that could often be as well done by the sun, thereby saving more of the coal, oil, and gas for us.'²⁷⁴

Continued shortsightedness in industry, government, and scientific institutions in the development of new energy sources, Daniels felt, would invite catastrophe. The source of the strength of the United States in the postwar world – its fossil fuel energy network – was also its greatest liability, he stressed. While maintaining a progressive view of science and technology, Daniels and other solar advocates also recognized limitations and vulnerabilities in large, fossil fuel-based technological systems.²⁷⁵

The Third World remained a primary field for exploring alternatives through the 1960s. The goals of international scientific cooperation and greater equality in worldwide standards of living grew increasingly central to discussions of the potential benefits of solar energy-based

²⁷⁴ Farrington Daniels, *Direct Use of the Sun's Energy* (New Haven: Yale University Press, 1964), 17-18.

²⁷⁵ In 1971, Daniels wrote, "it is a crime against nature and our descendants to use our irreplaceable fossil fuels for low-temperature heating. They should be reserved for high-temperature heating and for petrochemicals and the making of rubber, plastics, fertilizers, and many other products." Farrington Daniels, "Utilization of Solar Energy – Progress Report," *Proceedings of the American Philosophical Society* 115, no. 6 (December 1971): 490.

development. Business considerations became bound up with ideas about the relationship between technology, environment, and development. In 1966, the SES held a conference in Boston on the topic of “solar energy needs in developing countries.” Father de Breuvery, the director of the Resources and Transport branch of the UN explained the rationale: “Today it is an imperative dictate, commonly accepted throughout the world that international society should strive in every way to secure for all its members at least a minimum level of well-being and to give to each of its members an equal chance for progress. It is in this perspective that the promotion of new techniques of energy production need to be considered and the efforts of investigators supported.”²⁷⁶

In addition to technical papers, the Boston conference included several presentations on the social, political, environmental, and economic aspects of solar research and development. The discussions focused on the roles of both governmental and non-governmental organizations. John Wilkes of the US Agency of International Development described his agency’s efforts to promote solar technologies in various places around the world. Gerald Ward of the Brace Research Institute, a non-governmental engineering research organization established in Canada in 1957, discussed solar energy applications in arid rural areas. M. Saif-UI-Rehman, research officer of the Pakistan Council of Scientific and Industrial Research suggested that the use of solar energy as a low temperature heat source could help reduce inequalities in worldwide standards of living. Energy consumption, he wrote, was the root of “Man’s material welfare.” Energy in the form of thermal heat and electricity powered the machines that allowed societies to make greater use of natural resources for the production of quality goods and services. He also observed that if fuel consumption was equalized worldwide, population numbers would rise, and

²⁷⁶ Quoted in Frank E. Edlin, “Our Future and Our Work in Solar Energy,” *Sun at Work* 11, no. 1 (1966): 12.

demand for fossil fuels would increase exponentially, further accelerating the depletion of supply. Furthermore, he argued, socio-economic inequalities would likely persist under a fossil fuel-based development scenario, since the costs of importing fuels to different regions of the world varied tremendously.²⁷⁷

A better approach, Saif-Ul-Rehman argued, would be to adapt energy sources to the potentialities and constraints of particular environments and to local material needs and cultural preferences. This could be achieved through a collaborative research effort involving local and international scientific institutions, governments, and businesses. Countries with considerable surpluses of fossil fuels such as Norway, Yugoslavia, and Australia would require little change in the immediate future. Nuclear energy would eventually be beneficial in urbanized countries with high population densities where conventional energy resources were already scarce or threatened. Solar energy, and to a lesser degree wind energy, while perhaps eventually adaptable to industrialized nations, would be most suitable in the near future for “the scattered communities of the rural areas of the poor and developing countries of Asia, Africa, and South America.” Solar devices could be adapted relatively easily to individual tasks and small-scale household production. The use of solar energy involved no transportation costs and did not require construction and maintenance of costly high-tension electrical lines and distribution facilities. Solar devices could also be manufactured, sold, and operated by local people, reducing the necessity for extended intervention by already industrialized nations. “Now is the time,” he concluded, “for the governments, scientists, and engineers of the poor but sun-rich countries to

²⁷⁷ M. Saif-Ul-Rehman, “Prospects and Limitation of Solar Energy Utilization in Developing Countries,” *Solar Energy* 11, no. 2 (1967): 98-108.

increase their efforts in basic research and engineering to develop solar devices for different practical applications for the comfort and prosperity of their future generations.”²⁷⁸

In 1967, the SES elected Peter Glaser, former head of the Engineering Sciences Section of Arthur D. Little, Inc., a consulting firm with connections to MIT, to succeed Farrington Daniels as president. In his introductory address, Glaser reiterated the organization’s commitment to international cooperation in solar technology research and development as a means to resolving “our present disparity between the highly developed industrial countries and the non-industrialized countries in which a technology gap remains to be bridged.” He also stressed a long term future outlook. Although solar technologies had only seen a few limited applications, the impending depletion of the world’s fossil fuel stocks meant that “we cannot continue to mold the future in the cast of the past.”²⁷⁹

The experience of solar energy advocates over the past decade and half, Glaser observed, reflected a new era in which the criteria for selecting technology had expanded beyond considerations of short term profits and efficiency. With governments, private philanthropic foundations, scientific institutions, and local people playing an increasingly central role in science and technology research and development, a variety of social, political, and environmental factors had come into play. “Our choices have to be made in relation to the basic considerations now facing the world,” Glaser said. Questions about “population size, economic advancement, transportation, communications, and co-existence” increasingly determined which technologies received the support and attention of investors, consumers, scientific institutions, governments, foundations, and international organizations and which fell by the wayside. In addition, concerns were emerging out of the nascent environmental movement about the

²⁷⁸ Ibid., 101, 108.; Also see G.O.F. Löf D.J. Close, and J.A. Duffie, “A Philosophy for Solar Energy Development,” *Solar Energy* 12 (1968): 243-250.

²⁷⁹ Peter E. Glaser, “The New President Speaks to the Society,” *Sun at Work* 12, no. 2 (1967): 6-8.

potential for “certain new technologies” to “imperil the future welfare and safety of mankind.” The possibility of global warming caused by the accumulation of atmospheric carbon dioxide, and problems stemming from the disposal of radioactive waste, constituted additional “limitations on the tremendously increased requirements expected for electrical power over the next century.”²⁸⁰

For Glaser, humans were at a crossroads where the technological choices they made in the present would have enormous, potentially irreversible effects in the future: “The earlier depredations of our resources were usually made with a fair knowledge of the harmful consequences, for it is easy to see that erosion follows the deforestation of a hillside, or that the overgrazing of large land areas creates dusty desert. The hazards of modern pollutants, though, are generally not appreciated until after the technologies which produced them are well established in the economy.”²⁸¹ In anticipation of this, he advised SES members to move beyond “present uncommitted thinking or experimentation prompted by disinterested curiosity,” and to seek to contribute to a broader need “to conserve our natural resources and lessen the hazards to our species.”²⁸²

These comments echoed a critique of technology that underlay the broader environmental movement. But Glaser was also presenting these ideas in the framework of the SES’s past focus on socio-economic and technological development as it took shape in the context of the rise of international scientific organizations as means to resolve tensions stemming from the Cold War and decolonization. A future characterized by universally high standards of living, worldwide material prosperity, and a healthy environment could be achieved not by rejecting technology but by choosing the correct technology to accomplish these goals. These ideas set the tone for

²⁸⁰ Ibid., 6-8.

²⁸¹ Ibid., 7.

²⁸² Ibid., 8.

discussions about “appropriate technology” which took shape in response to the perceived failings of Third World development schemes by the late 1960s.

The introduction of the environment as a consideration in Third World development at the 1972 United Nations Conference on the Human Environment, held in Stockholm, Sweden provided an additional context for reconsidering solar’s potential as a developmental technology. While solar energy was not a significant topic of discussion, the Stockholm Conference defined an agenda for which solar technologies appeared well suited. Balancing a continuing commitment to technology and economic development with environmental protection involved establishing “a partnership between science and politics,” conference secretary Maurice Strong argued.²⁸³ The aim was to redirect humanity’s creative potential in science and technology toward preserving the ecological systems upon which human life and well-being depended. Though resulting in few specific policy recognitions, the Stockholm Conference challenged a prevailing tenet that economic growth and environmental preservation were inherently conflicting aims. It also identified technology as the key to this reconciliation. The conference declaration noted that while technology had been a major source of environmental problems, “if used wisely,” it could also contribute to “the capability of man to improve the environment.”²⁸⁴ This concept of technology’s potential to promote social justice and equality by restoring balance between human activities and the environment became an important underlying rationale for the revival of solar technology in the Third World and the First World following the 1973 oil embargo. It also anticipated the emergence of sustainability as the dominant paradigm for global environmentalism by the late 1980s.

²⁸³ Maurice F. Strong, “The Stockholm Conference: Where Science and Politics Meet,” *Ambio* 1, no. 3 (June 1972): 74.

²⁸⁴ United Nations, *Declaration on the Human Environment: Draft Declaration on the Human Environment* (New York: United Nations General Assembly, 1972).

Chapter 4

A Spin-off Technology: Semiconductors, Solar Cells, and the Space Race

This chapter traces the early development of photovoltaic solar cells alongside the growth of the US electronics industry and the space program from the 1950s to the early 1970s. The purpose is to further highlight the combination of geopolitical and environmental factors shaping solar technology development in the context of the Cold War. Solar cells did not simply emerge from the minds of brilliant scientists, engineers, and managers, but were situated in time and place. They were products of a combination of political, economic, environmental, and cultural changes associated with the Cold War which together provided a context for new directions in research, technology innovation, and commercial enterprise.

Greater government involvement in technology development during the postwar years became a primary factor shaping the development of solar cells. As historian Stewart Leslie argues, the military-industrial-university complex forged during the war years focused the combined power of government, business, and academia towards the design and production of large-scale, primarily defense-oriented technologies.²⁸⁵ This relationship continued through the Cold War years as Americans pursued what they saw as the interrelated goals of national defense, consumer abundance, and global technological supremacy.

However, while defense needs remained paramount, many scientists and research institutions also sought to maintain autonomy. Historian Paul Forman notes that while some physicists expressed opposition to military control of nuclear research on ethical grounds, “the smoldering resentment of collectivization and compartmentalization in scientific work,” most

²⁸⁵ Stewart W. Leslie, *The Cold War and American Science: The Military-Industrial-Academic Complex at MIT and Stanford* (New York: Columbia University Press, 1993).

closely associated with the army's Manhattan Project, became the primary motivating force.²⁸⁶ Some scientists, even working within the system, found ways to take advantage of government programs to pursue their own projects in both basic and applied research. Additionally, while historians have tended to focus on "the monuments of Big Science" such as rocket boosters, jet aircraft, particle accelerators, and nuclear power plants, the integration of government-sponsored scientific research and technology development with a vigorous, expanding consumer economy also allowed a range of companies, from large industrial research laboratories to small and medium-sized businesses to pursue "spin off" technologies including radar components, transistors, computers, and communications satellites which eventually had applications unrelated to their original intended purposes.²⁸⁷ Photovoltaic cells – first introduced at AT&T's Bell Laboratories in 1954 – became one such spin off, providing a power source for remote communications posts, a variety of novelty consumer gadgets, and for orbital satellites and other space vehicles by the late 1950s.

Photovoltaic cells also evolved as hybrids of nature, technology, and politics, developed through government-industry collaboration according to a combination of political, technical, environmental, and economic criteria. The intent was not to control nature, but to work within natural potentialities and constraints to achieve political goals. Both the silicon solar cell and its cousin the transistor operated by quantum processes which scientists and engineers could account for with some accuracy through experimentation and mathematical equations, but which they could not directly observe or manipulate. Most solar cells were also designed and

²⁸⁶ Paul Forman, "Behind Quantum Electronics: National Security as Basis for Physical Research in the United States, 1940-1960," *Historical Studies in the Physical and Biological Sciences* 18, no. 1 (1987): 182.; Also see Peter Galison, Bruce Hevly, and Rebecca Lowen, "Controlling the Monster: Stanford and the Growth of Physics Research, 1935-1962," in *Big Science: The Growth of Large-Scale Research*, ed. Peter Galison and Bruce Hevly (Stanford: Stanford University Press, 1992), 46-77.

²⁸⁷ David Reynolds, "Science, Technology, and the Cold War," *The Cambridge History of the Cold War: Volume III: Endings*, ed. Melvyn P. Leffler and Odd Arne Westad (New York: Cambridge University Press, 2010), 378-399.

manufactured to function for long periods of time in the rigors of space, a factor which while making them indispensable for the space program, drove up their costs to the point that they remained impractical for terrestrial commercial applications. Even though they remained too expensive for widespread use, solar cells became symbols of national technological achievement. They stirred the public imagination, allowing Americans to glimpse a future powered by clean, effectively unlimited energy.

Bell Labs and the First Solar Battery

Although the first with practical applications, the Bell Solar Battery was not the first working photovoltaic cell. In 1839, French physicist Edmond Becquerel observed the effect when he exposed a sample of silver-oxide bathed in an acidic solution to light. In 1860, William Gryllis Adams, the chief electrician overseeing the laying of the first trans-Atlantic telegraph cable, found that the conductivity of crystalline selenium seemed to change depending on the amount of light exposure. Adams and his student Richard Evans Day later demonstrated in the laboratory that exposure to light actually caused a current to flow through the selenium. They called this the “photoelectric effect.” In 1885, just three years after Thomas Edison had introduced the first coal-fired electric generator, New York inventor Charles Fritts created a solar cell by covering a thin layer of selenium with a semi-transparent gold leaf film. When exposed to light, the module produced a small electrical current. In response to Fritts’s work, pioneering electrical engineer Werner von Siemens deemed photoelectricity “scientifically of the most far-reaching importance.” Some saw photoelectric technology as a means to eliminate industrial

pollution. One scientist remarked that photoelectric cells might bring about “the total extinction of steam engines and the utter repression of smoke.”²⁸⁸

At the time, the science of quantum mechanics was in its infancy. No one knew how photoelectricity worked or why the effect occurred only in certain materials. Then in a seminal 1905 essay, Albert Einstein proposed that light was composed of packets of energy, or “quanta” (now known as photons), which varied in intensity depending on wavelength. From this, scientists reasoned that strong photons could dislodge weakly bonded electrons, causing them to “flow” towards a positive charge, creating an electrical current. By the 1910s, scientists began referring to this phenomenon as the “photovoltaic effect.” In 1931, German physicist Bruno Lange introduced a new selenium solar cell based on Fritts’s original design. Lange believed that “in the not too distant future,” vast arrays of solar cells could generate enough electricity “to compete with hydroelectric and steam-driven generators in running factories and lighting homes.” Still, his device hardly bettered Fritts’s earlier device in efficiency, converting far less than one percent of the light received into electricity. Light sensitive selenium cells were eventually incorporated into light meters in cameras; but the high cost of the material, the difficulties of manufacturing the cells, and the tendency of the selenium to degrade with exposure to strong sunlight convinced most scientists and engineers that the technology would have limited industrial applications in the short term.²⁸⁹

By the early 1950s, no research facility in the world was better prepared to explore the potential technological and commercial applications of the photovoltaic effect than Bell Laboratories. Between its establishment in 1911 and the start of World War II, AT&T’s

²⁸⁸ Quotes and information from John Perlin, *From Space to Earth: The Story of Solar Electricity* (Ann Arbor: aatec Publications, 1999), 15-24.

²⁸⁹ *Ibid.*; For Lange’s work see “Magic Plates tap Sun for Power,” *Popular Science Monthly* 118 (June 1931): 134.; and “Power Direct from Sunlight,” *Scientific American* 152, no. 1 (January 1935): 38-39.; For the limits of selenium cell power generation see Earl D. Wilson, “Power from the Sun,” *Power* 79 (October 1935): 517.

“research branch” was responsible for some of the most important developments in communication electronics including the vacuum tube amplifier, one of the first sound motion picture systems, long distance television transmission, radio astronomy, and the “vocoder,” the first voice synthesizer.²⁹⁰

Historian Thomas Hughes points to the ascendance of Bell Labs in the early twentieth century as epitomizing the transition from the independent inventor to the industrial research laboratory as the primary driver of American invention. By hiring inventors, physicists, and engineers to work in house, AT&T could avoid the legal battles over patents that the company had become embroiled in as it sought to fulfill its aim of “One Policy, One System, Universal Service.” According to Hughes, the advent of the industrial research laboratory directed invention towards the narrower goal of improving components of the existing system rather than exploring new kinds of systems. By maintaining the system, he argues, Bell Labs contributed to maintaining AT&T’s position at the hub of the nation’s telecommunications network.²⁹¹

Yet the rise of the industrial research lab also provided a work space somewhat insulated from the short term market risk the independent inventors of the earlier era had to contend with. The size of the parent company and the immense sums of grant, private investment, and government contract money flowing into Bell Labs and other similar facilities, especially during and after World War II, created opportunities for scientists and engineers to pursue research avenues which did not always have immediate, obvious profitable applications. Among the most notable of these inventions, the transistor, developed at Bell Labs in 1947, also eventually had

²⁹⁰ Leonard S. Reich, *The Making of American Industrial Research: Science and Business at G.E. and Bell, 1876-1926* (New York: Cambridge University Press, 1985), ch. 7 and 8.; Prescott C. Mabon, *Mission Communications: The Story of Bell Laboratories* (Murray Hill, NJ: Bell Telephone Laboratories, 1975), ch. 3, 170-179.

²⁹¹ Thomas Hughes, *American Genesis: A Century of Invention and Technological Enthusiasm, 1870-1970*, rev. ed. (Chicago: University of Chicago Press, 2004), 150-159.

applications far beyond what even the scientists who best understood the enigmatic physics at work in these tiny devices could imagine at the time. The photovoltaic solar cell, unveiled with much fanfare in 1954, was developed in close connection with the transistor. Both technologies grew out of materials research relating to the mysterious metals known as semiconductors which could be used to control electrical currents with a high degree of precision.²⁹²

The transformative, some deemed “magical,” creations that came out of Bell Labs in the 1940s and 1950s were at the time attributed to a handful of brilliant scientists working in collaboration towards the goal of revolutionizing communications.²⁹³ Mervin Kelly, the director of research at Bell, maintained that there was no magic involved. He attributed the development of the first marketable solid state amplifier, the point junction transistor, to a strategy of innovation which proceeded in a linear fashion from discovery to development to manufacture.²⁹⁴ William Shockley, the head of the Bell solid state group, later credited the first transistor to what he termed the “creative-failure methodology” of management. Kelly’s willingness to see repeated failure as a creative process, Shockley believed, created an “atmosphere of innovation” at Bell conducive to defining the fundamental problems of solid state amplification.²⁹⁵

The first transistor, though, was not simply the product of human intelligence and managerial acumen. The scientists at Bell Labs were also working within a fundamentally changed world. The marriage of government, science, and industry during World War II had stimulated rapid changes in both military and consumer technologies. Additionally, as historians

²⁹² See especially Michael Riordan and Lillian Hoddeson, *Crystal Fire: The Birth of the Information Age* (New York: Norton, 1997).; and Jon Gertner, *The Idea Factory: Bell Labs and the Great Age of American Innovation* (New York: Penguin, 2012). Ch. 5.

²⁹³ Milton Silverman, “Ma Bell’s House of Magic,” *Saturday Evening Post* 219, no. 46 (May 17, 1947): 26, 67, 69, 72, 74, 76.

²⁹⁴ Gertner, *The Idea Factory*, 152.

²⁹⁵ William Shockley, “Creative Failure Methodology,” *Electronics and Power* 22 (February 1973): 59.

Christophe Lécuyer and David Brock observe, the postwar microelectronics industry took shape from a material basis. The development and commercialization of transistors and solar cells could not have taken place without the push by Bell Labs and other research facilities to obtain supplies of raw semiconductor materials and to manufacture ultrapure crystals from those supplies.²⁹⁶ Moreover, the Bell Labs scientists were tinkering with a phenomenon that even their most elegant theorizing could only describe in metaphorical terms. The scientists themselves disagreed over whether they had “invented” a new technology or “discovered” a natural phenomenon.²⁹⁷ Semiconductor technologies were not applications of quantum theory but products of an experimental industrial engineering program to reveal and make use of the latent quantum potentialities of semiconductor materials.

Bell Labs researchers had recognized practical value in the properties of semiconductors early on, incorporating silicon crystals in vacuum tube diodes beginning in the late 1930s. In 1938, Mervin Kelly assigned a team of four scientists to the nebulous task of “fundamental research work on the solid state” with the purpose of discovering “new materials or methods of processing old materials which will be useful in the telephone business.”²⁹⁸ Much of the initial work focused on silicon. While abundant in nature, however, silicon was not readily available at the level of purity required for the applications being devised at Bell Labs. The team also quickly discovered that silicon’s conductive properties tended to vary widely from sample to sample.

Testing led to some unexpected discoveries. In 1940, Russell Ohl, an electro-chemist working on short wave radio communications, found that a rod of manufactured silicon he had been experimenting with produced nearly half a volt of current when exposed to light. When

²⁹⁶ Christophe Lécuyer and David C. Brock, “The Materiality of Microelectronics,” *History and Technology* 22, no. 3 (September 2006): 301-325.

²⁹⁷ William F. Brinkman, “A History of the Invention of the Transistor and where it will lead us,” *IEEE Journal of Solid-State Circuits* 32, no. 12 (December 1997): 1858.

²⁹⁸ Quoted in Riordan and Hoddeson, *Crystal Fire*, 84.

Kelly demonstrated the effect to the rest of the solid state team, they were “completely flabbergasted,” according to Walter Brattain. The voltage generated was more than ten times greater than had been achieved in the earlier selenium photovoltaic cells.²⁹⁹ Later, Brattain proposed an explanation for what was happening. He realized that through slight differences in molecular composition probably resulting from the fabrication process, the ingot was comprised of “pure” silicon on one end and “commercial” silicon on the other. One of the ends held an excess of electrons while the other held a deficit, creating what Ohl and metallurgist Jack Scarff later labeled a “p-n junction” or positive-negative junction between the two sides. When light photons jarred loose the excess electrons on the “n” side, the free electrons passed to the “p” side of the barrier while the “holes” where the electrons used to be passed over to the “n” side. This movement of electrons and holes constituted an electrical current.³⁰⁰

World War II interrupted these first forays into semiconductor research. But the war also fueled rapid growth at Bell Labs. The percentage of work under military contracts grew from 10 percent at the start of 1941 to 30 percent after the attack on Pearl Harbor in December of 1941 to 80 percent by the end of 1942.³⁰¹ The vast majority of this work contributed to the radar technology research and development program headquartered at MIT’s Radiation Laboratory. By the end of the war, the US government had spent approximately 3 billion dollars on radar research, a full billion more than it had spent on nuclear weapons development.³⁰² During this

²⁹⁹ Ibid., 88.

³⁰⁰ Scarff also suspected at the time that the different qualities of the silicon were the product of infinitesimal impurities in the silicon sample, a proposal which according Scarff, Walter Brattain initially dismissed. See Lillian Hoddeson, “Interview with Dr. Jack Scarff,” 6 August 1975. American Institute of Physics, accessed October 30, 2012 at <http://www.aip.org/history/ohilist/4857.html#8>.; Also see John Scarff, “The Role of Metallurgy in the Technology of Electronic Materials,” *Metallurgical and Materials Transactions* 1, no. 3 (1970): 561-573.

³⁰¹ James William Spurlock, “The Bell Telephone Laboratories and the Military-Industrial Complex: The Jewett-Buckley Years, 1925-1951,” Ph.D. diss. George Washington University, 2007: 213, 235-236.

³⁰² Gertner, *The Idea Factory*, 65-66.; A number of scientists and military strategists at the time argued that while the atomic bomb may have ended the war, radar had won it by enabling US forces to track enemy vessels and locate military targets with pinpoint accuracy.

time, Bell Labs “served the American public” both by conducting research to expand the nation’s telephone network and by providing for national defense. By 1945, Bell had undertaken more than a thousand “development projects” for the armed forces, “many with spectacular effect upon our enemies,” according to one advertisement.³⁰³ Bell’s value to the military also likely spared it from being dismembered through US Justice Department anti-trust actions.³⁰⁴

As Bell Labs grew into an arm of national defense, its public and private functions became increasingly conflated. It was apparent to President Frank Jewett that while advances in vacuum tube, radio, and radar technologies were vital to the war effort, this work was also laying the foundation for a revolution in how people would share information across the globe in the future. Both projects seemed to hinge on finding ways to take advantage of the inscrutable physics occurring within semiconductors. In 1942, flush with defense funds, the laboratory moved into a new, \$4.1 million facility in suburban Murray Heights, New Jersey. With its modular interior that could be rearranged to meet fast-changing lab space needs, and its staff of nearly 9,000 scientists and technical assistants by 1945, the facility provided a space conducive to the marriage of quantum theory and materials engineering for both public and commercial purposes.³⁰⁵

With the end of the war, the solid state team resumed their work with semiconductors, but in a new, larger, better-funded, and more flexible research facility. Mervin Kelly revised the team’s research agenda in 1945 to reflect a new era of industrial research in which federal spending on science and technology, coupled with a competitive commercial economy, had caused the line between basic and applied research to blur even further. Kelly’s aim was “to

³⁰³ “A Modern Syllogism,” advertisement in *Popular Science* (March 1945): 5.

³⁰⁴ Daniel J. Kevles, “Korea, Science, and the State,” in *Big Science: The Growth of Large-Scale Research*, ed. Peter Galison and Bruce Hevly (Stanford: Stanford University Press, 1992), 314.

³⁰⁵ Gertner, *The Idea Factory*, chapters 5 and 6

achieve the unified approach to the theoretical and experimental work of the solid state area.” This research, he urged, was “so basic and may well be of such far-reaching importance” that company expenditures for the program would be justified even without a clear identification of profitable applications.³⁰⁶ The goal was not simply to maintain ATT&T’s existing system, but to stay ahead of the rapidly changing electronics industry even if it meant taking short term financial risks on new technologies. Solid state amplification may have seemed an obscure pursuit to much of the public; but for the scientists, engineers, and managers on the front lines of semiconductor research at Bell and other industrial research labs, it was a game-changer with the potential to radically alter how people engaged with one another and with the environment through technology.

Like Jewett, Kelly moved easily between the worlds of government, academia, and private industry. He became a key figure in building the technological foundations of what historian Lizabeth Cohen labels the postwar “consumers’ republic,” the strength of which, both from a domestic and a geopolitical standpoint, lay in rising consumer spending and material abundance.³⁰⁷ For Kelly, Bell Labs played a crucial role in maintaining a “two-front defense” against the global spread of communism. Americans, he said, “are faced with maintaining a military strength adequate to deter the Russians from a general war, while at the same time maintaining a civilian economy that provides our people with an increasingly abundant life.”³⁰⁸ He saw semiconductor research at Bell Labs as vital both for maintaining American military superiority and building the consumer electronics industry of the future.

³⁰⁶ Ibid., 80.

³⁰⁷ Lizabeth Cohen, *A Consumers’ Republic: The Politics of Mass Consumption in Postwar America* (New York: Alfred A. Knopf, 2003).

³⁰⁸ Gertner, *The Idea Factory*, 162.

The significance of the work going on at Bell Labs remained opaque to most Americans in the late 1940s and early 1950s. When the company unveiled the first working transistor in June 1948, the press hardly knew what to make of the tiny sliver of metal with two wires sticking out of it. The *New York Times* relegated the news to the last few paragraphs of a column on “the News of Radio,” noting simply that the device “has several applications in radio where a vacuum tube ordinarily is employed.”³⁰⁹ Bell’s official press release offered only a few vague suggestions of possible applications. A letter submitted by Walter Brattain and Jack Bardeen to the *Physical Review* detailing the quantum processes at work in the device also did little to help the lay reader.³¹⁰

The device did, however, appeal to the military which ultimately provided the funding to develop a commercially viable transistor.³¹¹ The unveiling also piqued the interest of the electronics industry. RCA, Motorola, Westinghouse, as well as several smaller companies immediately requested samples. The director of MIT’s electrical engineering department also wrote to Bell Labs to suggest that the transistor might have applications in high speed digital computing. The basic significance of the device, they recognized, was that it could do more with less energy. The transistor was, at its core, an energy conserving device. A small electrical current pushed electrons from one side of the transistor to the other, amplifying the outgoing current. The device could be used to control telephone and radio signals with a high degree of precision. It required significantly less power than a vacuum tube, it was more rugged, it was smaller and thus more mobile, and it did not require a warm-up period to function. In short, the

³⁰⁹ “The News of Radio: Two New Shows on CBS will Replace ‘Radio Theatre’ during the Summer,” *The New York Times*, July 1, 1948: 46.

³¹⁰ J. Bardeen and W. Brattain, “The Transistor, a Semi-Conductor Triode,” *Physical Review* 74, no. 2 (1948): 230-231.

³¹¹ Thomas J. Misa, “Military Needs, Commercial Realities, and the Development of the Transistor,” in *Military Enterprise and Technological Change: Perspectives on the American Experience*, ed. Merritt Roe Smith (Cambridge, MA: MIT Press, 1985): 253-287.

transistor seemed capable of vastly expanding the capacity for transmitting information, both for military and civilian purposes.

As any scientist familiar with semiconductors in the early 1950s knew, manufactured silicon had another distinguishing quality. With the right combination of impurities, it became highly photosensitive. Bell Labs management never assigned a team specifically to the task of researching photovoltaic electricity; but because they were permitted to follow up on their own ideas without first requesting permission from upper management, members of the solid state team found opportunities to pursue the possibilities. In 1953, experimental physicist Gerald Pearson, Walter Brattain's lab mate since 1945 and the official witness of the demonstration of the first working transistor in 1947, joined with chemist Calvin Fuller on a project to develop a silicon rectifier, a device to convert Alternating Current (AC) to Direct Current (DC). In testing prototypes, they realized that some of the silicon ingots exhibited the same photovoltaic qualities that Russell Ohl had observed in 1940.³¹²

Thinking that silicon photovoltaic devices might have profitable applications in the communications industry, Pearson contacted fellow Bell scientist and college friend Daryl Chapin, an electrical engineer working on power sources for rural telephone systems. Chapin had already been considering selenium cells as a possible solution. At the time, diesel generators or dry cell batteries were the only available options for supplying electricity to remote locations. Both required frequent maintenance and replacement. The components in generators and batteries also tended to degrade rapidly in the tropical environments where Chapin was concentrating his efforts. A solar battery, in theory, would have few sensitive components and would require little or no maintenance; it could conceivably operate continuously without needing to be replaced or recharged; and it would actually generate electricity from the same

³¹² Gertner, *The Idea Factory*, 170-171.

climatic conditions which were so detrimental to conventional remote power supplies. Most importantly, because remote phone systems would operate with transistors rather than energy intensive vacuum tubes, the power requirements would be minimal. Even if the price per watt of solar electricity proved high, the overall cost might still be low enough to justify production.³¹³

Work proceeded rapidly. “The solar cell just sort of happened,” Fuller later recalled.³¹⁴ Fabricating a working silicon solar cell, the team found, involved simply adapting techniques first conceived in the transistor labs to the slightly different purpose of electricity generation. After only three months, Fuller, the pioneer of the diffusion technique, found he could vaporize small amounts of phosphorus or arsenic on to the silicon to give the ingot a negative charge. Then, by “baking” a trace amount of boron gas on the ingot in the furnace, he created a thin p layer on the surface. The challenge was to create as thin a p layer as possible. If it were thicker than 0.0001 inches, the team found, electron holes created by light photons would simply reconnect to their lost electrons rather than pass over the junction barrier to attach with free electrons. This was one of the aspects of the fabrication process that they believed they could refine to further improve efficiency. The solar battery which they unveiled in April of 1954 could convert approximately six percent of the light striking its surface to electricity, far exceeding the previous best of one percent as reported by Maria Telkes from her experiments with thermoelectric generation in 1947. Pearson, Fuller, and Chapin believed that by refining the diffusion process and limiting the reflectivity of the cell, they could theoretically achieve as high as twenty-three percent efficiency.³¹⁵

³¹³ Perlin, *From Space to Earth*, 25-29.

³¹⁴ Calvin S. Fuller, interview by James J. Bohning, Vero Beach, Florida, 29 April 1986 (Philadelphia: Chemical Heritage Foundation, Oral History Transcript #0020): 44.

³¹⁵ D.M. Chapin, C.S. Fuller, and G.L. Pearson, “A New Silicon pn Junction Photocell for Converting Solar Radiation into Electrical Power,” *Journal of Applied Physics* 25 (1954): 676-677.; For description of diffusion see C.S. Fuller and J.A. Ditzenberger, “Diffusion of boron and phosphorus into silicon,” *Journal of Applied Physics* 25

In April 1954, Bell unveiled the prototype “solar battery.” At the initial press conference, the team used the battery to power a twenty one inch Ferris wheel. A day later, at the annual meeting of the NSF, Bell scientists demonstrated a solar-powered radio transmitter. Although the battery could produce only a few meager watts, the press had high expectations for the future. *US News and World Report* predicted that silicon cell photovoltaic technology might eventually “provide more power than all the world’s coal, oil, and uranium.” The *New York Times* called the device a “modern version of Apollo’s chariot.” Solar cells heralded “a new era,” the *Times* declared, “leading eventually to the realization of one of mankind’s most cherished dreams – the harnessing of the almost limitless energy of the sun for the uses of civilization.”³¹⁶ Photovoltaic electricity was also cleaner and simpler than energy produced from conventional sources and nuclear. “Nothing is consumed or destroyed in the conversion process,” the *Times* reported. The solar battery also generated some 50 million times more power than a much-touted “atomic battery” announced a few weeks earlier by RCA. Furthermore, the battery was made from silicon, the basic ingredient of common sand and one of the most abundant elements in nature.³¹⁷

Science and trade periodicals were especially optimistic. “The universe’s greatest source of potential power” could now be harnessed for commercial purposes, announced *Popular Electronics*.³¹⁸ “There’s something really new under this summer’s sun,” declared Volta Torrey, editor of *Popular Science Monthly*. “It’s about half the size of this magazine, and it ‘taps’ sunlight for electricity.” Torrey proposed that “conceivably, at least, a roof built of strips of silicon will someday convert the sunlight shining on it into electricity to run the air-conditioner

(1954): 1439-1440.; Maria Telkes, “The Efficiency of Thermoelectric Generators,” *Journal of Applied Physics* 18 (1947): 1116.; “Power from the Sun,” *Scientific American* 190, 6 (June 1954): 45-46.

³¹⁶ “Vast Power of the Sun is Tapped by Battery using Sand Ingredient,” *New York Times*, April 26, 1954: 1.

³¹⁷ “Vast Power of the Sun,” *New York Times*, 1.; Also see the similar report in “Sun’s Energy,” *U.S. News*, 18.; RCA atomic battery described in “Bean-Size Battery Converts Atomic Energy to Electricity,” *Popular Science Monthly* 164, no. 4 (April 1954): 112.

³¹⁸ “Solar Battery,” *Popular Electronics* 1 (October 1954).

in the basement.” The cost of the technology was still too high for these kinds of uses to be practical in the short term, he wrote, “but prices are man-made figures that men have often re-made.”³¹⁹ The announcement also received coverage in *Nature*, *Scientific American*, *Chemical Engineering News*, and other periodicals. *Business Week* predicted that the invention would open up a whole new field for entrepreneurial activity and investment.³²⁰

AT&T’s immediate intent was for the battery to supply small amounts of electrical power to telephone line amplifiers in remote areas far from electrical lines. While short term applications were limited, Bell management was confident that together, the transistor and the silicon solar cell would eventually allow for significant advancements in the communications industry and in global communications capabilities. A 1956 company press release announced that “the ability of transistors to operate on very low power...gives solar great potential and it seems inevitable that the two Bell inventions will be closely linked in many important future developments that will profoundly influence the art of living.”³²¹ The company was also confident that while high manufacturing costs made solar cells impractical for large-scale power generation, the technology marked a major step forward in humanity’s quest to harness energy from nature. “Man has at last dipped his hand into the sun and drawn down a spark to warm the hearts of men,” declared a Bell Labs promotional film in 1956.³²² Future applications were

³¹⁹ Volta Torrey, “Sunshine becomes Electricity,” *Popular Science Monthly* 165, no. 1 (July 1954): 71-72.

³²⁰ “Power from the Sun,” *Scientific American* 190 (June 1954): 45.; “Bell Solar Battery,” *Nature* 174 (July 1954): 163.; “Electricity from Sunlight,” *Chemical Engineering News* 32 (May 3, 1954): 1768.; “Silicon Converts Light to Electrical Power,” *Materials and Methods* 39 (June 1954): 7.; “Sunlight Power Silicon Battery,” *Industrial Labs* 5 (June 1954): 58.; “Sun-power makes it Talk,” *Business Week* (May 1, 1954): 100-101.

³²¹ Quoted in John Perlin, “The Silent Revolution Continues,” *Journal of Science Education and Technology* 10, no. 2 (June 2001): 144.

³²² AT&T, “AT&T Archives: The Bell Solar Battery,” 1956, video accessed October 3, 2014 at <http://techchannel.att.com/play-video.cfm/2011/4/18/AT&T-Archives-The-Bell-Solar-Battery>.

essentially limitless. One Bell advertisement predicted, “If this energy could be put to use there would be enough to turn every wheel and light every lamp that mankind will ever need.”³²³

The appeal of the silicon solar battery was its combination of simplicity seemingly limitless potential to derive energy from nature. In an age of increasing technological complexity, the solar cell appeared as a means to strip away the immense machinery then required to convert energy from nature for human use. It could conceivably allow humanity to more directly tap into the energy flows running through and constituting the material universe.³²⁴ Some scientists through the solar cell could provide clues to understanding photosynthesis, the process by which plants made use of energy from the sun. In 1958, University of California photosynthesis researcher Melvin Calvin reported to the *Journal of Chemical Physics* that he had developed an “organic solar battery” consisting of layers of organic dyes which, when exposed to light, produced “a solar battery effect.” A columnist for *Time* commented, “Nature’s green plants...have turned out to be electronic solar batteries invented millions of years before human scientists ever thought of electronics.”³²⁵

The device blurred the line between nature and technology in other ways. As early as 1951, MIT physicist Arthur von Hippel proposed that simply imitating nature’s own methods of energy conversion was “not the best engineering solution.” A truly useable photovoltaic device might take cues from the world of organics, he believed, but unlike plants, it would only have to be an energy converter – it would require no mechanisms for keeping a biological system functioning. In this sense, engineers and scientists might be able to create a device which

³²³ Bell advertisement, accessed October 15, 2012 at http://www.porticus.org/bell/images/solar_battery1.gif.

³²⁴ “Science: Solar Batteries,” *Time* 63, no. 18 (May 3, 1954): 52.

³²⁵ “Nature’s Solar Batteries,” *Time* 69, no. 13 (April 1, 1957): 74.; “Organic Solar Battery,” *Science News Letter* 74, no. 22 (November 29, 1958): 341.

actually functioned better than chlorophyll. Such a “black box” might even be considered an improvement on nature, von Hippel ventured.³²⁶

These projections were based on the idea of photovoltaic technology rather than the actual capabilities of existing technologies. Short term applications were promising but modest. Following the 1954 unveiling, Bell Labs installed a solar battery to generate a small amount of power for a telephone system in rural Georgia. The prototype worked nearly flawlessly for a year, the only problem being that bird droppings would occasionally block incoming solar radiation.³²⁷ A year later, General Motors displayed a solar powered model car at its Powerama show in Chicago. The demonstration was part of a “power for progress” display conceived “to dramatize the importance of diesel and aircraft power.”³²⁸ Larger applications were not yet practical from a technical or cost standpoint. The original Bell Solar Battery could produce approximately 50 watts per square yard, meaning that to generate as much electricity as a conventional power plant (approximately 30,000 kilowatts) a “solar battery” would have to cover some 100 acres. The cost for such an installation would be astronomical.³²⁹

The high cost was in part a result of the expense of obtaining pure silicon. DuPont remained the primary supplier for Bell Labs, offering silicon with as little as one part impurity per ten million parts silicon at \$430 per pound. While this cost also affected the price of transistors, transistors were tiny in comparison to silicon solar cells. In order to produce a useable amount of power, a significant surface area of diffused silicon was required. The fabrication process also involved multiple intricate steps and specialized equipment. First, the

³²⁶ Arthur von Hippel, “Transformation of Solar Energy,” *Proceedings of the American Academy of Arts and Sciences* 79, no. 4 (July 1951): 319-322.

³²⁷ G. Pearson, “Conversion of Solar Electricity to Electrical Energy,” *American Journal of Physics* 25, no. 591 (December, 1957): 591-598.

³²⁸ “GM’s Powerama show will Sport Tiny Car run by Electricity Generated by the Sun,” *Wall Street Journal*, July 25, 1955: 20.

³²⁹ “Power from the Sun,” *Scientific American*, 45.

technician placed a small amount of arsenic in a sample of purified silicon to give it the desired conductivity. The raw sample was then placed in a high temperature electric furnace where the crystal was “grown” from a silicon “seed.” Each wafer-thin cell then had to be cut from the resulting ingot using a diamond saw. The wafers were then polished by hand to remove any imperfections resulting from the cutting process. Next, each wafer was sealed in a quartz tube with a trace amount of boron gas and baked in the furnace at a temperature of 1,100 degrees Fahrenheit to create the ultra-thin p layer. Finally, wires were attached by hand to both the positive and negative sides of the p-n barrier, and the cells were placed in the desired configurations within a plastic casing. While this process was not significantly more complex than transistor fabrication, it required specialized knowledge and skill, and was labor intensive. Transistor production lines were also highly specialized. They could not be readily modified to accommodate other products, even if the manufacturing process was similar.³³⁰

Commercial Solar Cells

That solar cells even went into production was counter to conventional business logic, reflecting the public’s excitement over the technology as well as the semi-protected position of Bell Labs and other private semiconductor divisions within the booming postwar economy. Writing in 1972, Dr. Martin Wolf, professor of electrical engineering at the University of Pennsylvania, observed that from the information available to the typical research manager of the mid-1950s, “it would appear that research money has been wasted in developing the silicon solar cell.” Wolf maintained that a simple market research study “would have shown that the

³³⁰ Fabrication process detailed in AT&T, “AT&T Archives: The Bell Solar Battery.”; Also see P. Rappaport, “The Photovoltaic Effect and Its Utilization,” *RCA Review* 20, no. 3 (September 1959): 377, 396.

application of the device could not have been competitive in most applications.” Even the solar telephone system Bell installed in Georgia could have been achieved at a lower cost by “duplexing” an electrical cable with the telephone wire, he suggested. Not one of the semiconductor divisions that began producing solar cells in the 1950s undertook market research prior to introducing their products in the commercial marketplace.³³¹

Encouraged by a loose management structure, a healthy supply of government contract money, and a general sense that the electronics industry was in a stage of rapid growth, semiconductor research divisions continued to show interest in photovoltaic technologies. The Bell team achieved significant advances in efficiency in a short period of time. By the end of 1954, they had developed a cell which could convert eight percent of incoming light to electricity. The following year, they improved efficiency to eleven percent. By 1958, the best solar cells had achieved fourteen percent efficiency; and researchers believed there was still room for improvement.³³²

Also, as the electronics industry began to transition from vacuum tubes to transistors and other solid state components, the price of pure silicon began to drop rapidly. From its initial offering of \$430 a pound, DuPont dropped the price to \$350 by 1955, then to \$320 in 1956. In 1955, the company also began offering what it called “Solar-Cell grade silicon” of a slightly lower level of purity for \$180 a pound. In 1956, the price was lowered to \$150. The products manager of DuPont’s pigments department also told the *Wall Street Journal* that further decreases are expected as markets for silicon expand and volume increases.”³³³ Company

³³¹ M. Wolf, “Historical Development of Solar Cells,” in *25th Power Sources Symposium, 1972 Proceedings, 23-34-25 May* (Red Bank: PSC Publications Committee, 1972), 121.

³³² M.B. Prince and M. Wolf, “New Developments in Silicon Photovoltaic Devices,” *Journal of the British Institute of Radio Engineers* 18 (October 1958): 583.

³³³ “Price Tags: DuPont cuts Silicon price by \$30 a Pound, Considers New Plant,” *Wall Street Journal*, December 4, 1956: 28.

executives were also discussing building a new factory specifically for the production of semiconductor grade silicon. Texas Instruments and a handful of other companies also began supplying purified silicon during this period.

The semiconductor industry was also expanding beyond the established laboratories at Bell, Texas Instruments, and RCA. With the market for transistors taking shape, a number of researchers sought to make their own way. William Shockley left Bell in 1956 to start Shockley Semiconductor Laboratory in Mountain View, California just outside of San Jose. Although Shockley was soon replaced as manager, the company continued to grow, helping to catalyze the area's transformation into "Silicon Valley."³³⁴ Some owners of smaller firms entering into the increasingly competitive semiconductor market in this period felt that the prospects for photovoltaic energy were good enough to warrant investment. In 1955, National Fabricated Products, Inc., a small Chicago-based electronics manufacturer bought the rights to the Bell Solar Battery and began considering possible market opportunities. By July, the company announced that it had received more than 500 inquiries about the cost and availability of solar cells.³³⁵

A year later, Los Angeles-based Hoffman Electronics bought National Fabricated Products and inaugurated a solar division as part of its semiconductor division in Evanston, Illinois. The company also set up a semiconductor equipment design section at its research laboratory in El Monte, California. Founder and CEO Leslie Hoffman expressed great enthusiasm about the commercial possibilities for solar cells, suggesting that at the present time, they could be profitably marketed as power sources for telephone repeater stations in remote

³³⁴ Riordan and Hoddeson, *Crystal Fire*, ch. 12.

³³⁵ "Science: Sun Electricity," *Time*

desert areas, navigational buoys, and unmanned radio relay stations. Solar cells were lightweight, they had no moving parts, and could “run unattended indefinitely,” he said.³³⁶

In only one year, Hoffman achieved significant cost reductions, mainly by streamlining the fabrication process. From a high of \$1,000 per watt in 1956, by 1957 the company was marketing cells of more than double the efficiency of the original Bell battery for \$60 to \$100 a watt; and Hoffman expected that the price could be lowered even further to \$10 a watt in a short time. The company also introduced a number of novelty consumer gadgets including a solar-powered toy airplane, a flashlight with a rechargeable solar battery, and a portable transistor radio called the “solaradio” which sold for \$100. In the not-too-distant future, Hoffman engineers predicted, Americans would be able to purchase a “solar shingled house,” which after five days of sun exposure could operate without supplementary electricity for a month.³³⁷

While these appeals to the consumer market attracted public attention, the company’s primary source of income during this period was from government contracts for specific, small-scale projects. In 1956, the US Forest Service contracted with Hoffman to build a custom solar converter to power a radio repeater station located on the summit of Santiago Peak in the Cleveland National Forest outside of Riverside, California.³³⁸ According to *Sun at Work*, if the prototype functioned as anticipated, “similar units could be installed by the Forest Service in about 1,000 fire-tower installations, as well as for other remote-area uses, such as measuring depth of water in watersheds and depth of snowfall.” At a symposium for federal agencies in Washington D.C. in 1957, Leslie Hoffman unveiled a device he deemed “Big Bertha.”

³³⁶ H. Leslie Hoffman, “Harnessing the Sun’s Energy,” *Trusts & Estates* 9 (October 1957): 1021.; “Hoffman Solar Activities Expand,” *The Sun at Work* 2, no. 2 (June 1957): 10.

³³⁷ “Hoffman Leads Expanding Market for Solar Cells,” *Sun at Work* 2, no. 4 (December 1957): 8-10.; R.W. Benedict and D.O. Ives, “Companies, Scientists Focus on New Solar Products and Processes,” *The Wall Street Journal*, March 24, 1958: 1.

³³⁸ “Hoffman Electronics,” *The Wall Street Journal*, April 30, 1956: 14.

Consisting of 400 solar cells mounted on a modular frame, Bertha was capable of generating approximately 20 watts in full sunlight. According to *Sun at Work*, government representatives in countries “where sunlight is the only plentiful fuel” were also “vitaly interested in solar cell converters.” In 1957, the Department of Posts and Telegraphs of the Union of South Africa purchased two Hoffman solar converters to supply electricity to remote telephone installations. The company also contracted with the Coast Guard to develop solar powered buoys and lighthouses. The City of Los Angeles was also considering installing solar-powered caution signals and emergency call boxes along its rapidly expanding freeway network.³³⁹

Although Hoffman generated both popular and government interest in solar technologies, Wolf’s later assessment of the market potential of solar at this time was essentially correct. Neither Hoffman nor Bell Labs were recouping anything close to what they had invested in the development, production, and marketing of solar cells and solar cell products. In addition, the increases in efficiency and drops in cost were already showing signs of stalling by 1957. The cost per unit of photovoltaic electricity remained far too high to justify uses beyond the niche applications and novelty toys Hoffman had already introduced.

An unexpected lifeline saved the technology. The appearance in the sky of Sputnik, the Soviets’ “184-pound moon,” on October 4, 1957 abruptly redirected the nation’s private-public partnerships in science and technology towards space exploration. Solar cells, it turned out, offered a promising power source for orbital satellites, and the Cold War race for global technological supremacy in space became a direct catalyst for increased government/industry collaboration in the development of solar photovoltaic technologies.³⁴⁰

³³⁹ “Hoffman Leads Expanding Market for Solar Cells,” 8-9.

³⁴⁰ Richard F. Dempewolf, “A Sky Full of Satellites,” *Popular Mechanics* (January 1958):139.

Solar Energy and the Race for Space

Even before Sputnik, futurists had envisioned space applications for solar energy. Science fiction author Isaac Asimov set his 1941 short story “Reason” on a space station that beamed energy from the sun to the planets of the solar system via microwaves.³⁴¹ During World War II, German scientists drew up plans for a solar-powered space station and a “sun gun,” a huge mirror which would direct a concentrated beam of energy to incinerate targets on earth.³⁴² In 1945, British science fiction author Arthur C. Clarke offered a more realistic short term proposal, suggesting that an adapted V2 rocket might be capable of propelling a 100-pound “artificial satellite” into earth orbit. Such a device, he proposed, could broadcast radio signals indefinitely with “the use of thermocouples and photo-electric elements” as a power source.³⁴³ A year later, the US Navy Bureau contracted with North American Philips to begin work on a solar collector for earth orbiting satellite systems.³⁴⁴ The announcement of the Bell Solar Battery in 1954 further “fired the imaginations of the science fictionists,” *Time* reported, “and the solar system was soon abuzz with solar-powered space ships.”³⁴⁵

The notion of solar-powered space flight took shape alongside other schemes to use gasoline, nuclear energy, hydrogen, or ionized particles to propel spacecraft.³⁴⁶ In 1956, Dr. Ernst Stuhlinger, head of the missile section of the Redstone Research Arsenal, proposed a design for an interplanetary spacecraft powered by 40 “Abbot-type” (a reference to Charles

³⁴¹ Isaac Asimov, “Reason,” *Astounding Science Fiction* (April 1941).

³⁴² “The Station in Space: Sun Power Station Planned by Germans,” *Journal of the American Rocketry Society* 63 (September 1945): 8-9.; “German Space Mirror,” *Life* 19 (July 23, 1945): 78-80.

³⁴³ Arthur C. Clarke, “Peacetime Uses for V2,” *Wireless World* 51, no. 2 (February 1945): 58.

³⁴⁴ Walter A. McDougall, *The Heavens and the Earth: A Political History of the Space Age* (New York: Basic Books, 1985), 101.; Also see R. Cargill Hall, “Earth Satellites: A First Look by the U.S. Navy,” *History of Rocketry and Astronautics: Proceedings of the Third through the Sixth History Symposia of the International Academy of Astronautics*, ed. R. Cargill Hall (San Diego: Univelt, 1986): 253-277.

³⁴⁵ “Science: Solar Batteries,” 52.

³⁴⁶ Dan Q. Posin, “An Eye on Space,” *Popular Mechanics* (April 1960): 87.

Greeley Abbot) solar collectors, each 50 feet in diameter, capable of producing 7,000 to 8,000 kilowatts of power. Although the craft would be enormous, the total weight would be far less than a comparable chemical fuel-powered ship. Resembling “the wings of a giant butterfly,” the solar apparatus would supply thermoelectric power to an ion gas jet propulsion system.³⁴⁷

Political circumstances as much as technical considerations ultimately structured America’s entry into the Space Age. In 1946, the Army Air Forces took over the reins of the Navy Bureau’s exploratory satellite program, issuing a contract to Project RAND, a special wing of the Los Angeles-based Douglas Aircraft Company, to assess the prospects for launching an orbital satellite. RAND (a contraction of the term *research and development*) epitomized the marriage of government and industry in the wake of World War II. In 1948, it separated from its parent company and incorporated as a nonprofit corporation with a mission “to further and promote scientific, educational, and charitable purposes, all for the public welfare and security of the United States of America.”³⁴⁸ Over the next decade, the RAND Corporation became the primary advisory body to the US Armed Forces in weapons development, military technology, and space exploration.

For the scientists and engineers involved in early space exploration research at RAND, the years from 1946 to 1960 were “a golden age” during which there existed “an unprecedented level of interaction between the Air Force, RAND, and industry that made it possible for ideas to be implemented quickly on the heels of conception.” The Cold War became the principal

³⁴⁷ Frank Tinsley, “Flight to the Stars on Sun Power,” *Mechanix Illustrated* (January 1956): 72-77.; Also see Ernst Stuhlinger, “Spaceship Design uses Heat of the Sun,” *New York Times*, August 5, 1954.; Other proposals are detailed in L.J. Grant, “Power Sources for Orbital Rockets,” *Journal of Space Flight* 3 (November 1951):1-3.; and W.M. Conn, “A Note on the Utilization of Radiant Energy from the Sun in Rockets,” *American Journal of Physics* 22 (May 1954): 341.; T.H. Preston, “Interorbital Transport Techniques (with a Special Reference to Solar Derived Power,” *Journal of the British Interplanetary Society* 11 (July 1952): 173-193.; Krafft Ehrlicke, “Solar Power for Spacecraft,” *Missiles and Rockets* 1, 2 (November 1956): 44-46.

³⁴⁸ Quoted in RAND Corporation, “History and Mission,” accessed November 26, 2012 at <http://www.rand.org/about/history.html>.

stimulus for action. “There was a plausible sense of urgency and purpose,” rocketry specialist Bruno Augenstein recalled. “We were bent on harnessing the capabilities of wartime rocket technologies to ensure that the United States acquired strategic information and maintained strategic power in that confrontational era.”³⁴⁹

RAND submitted its first report titled “Preliminary Design of an Experimental World-Circling Satellite” in May 1946. The report was prescient both in its technical predictions and its assessment of cultural and political implications.³⁵⁰ The study group concluded that for approximately \$150 million, an orbital satellite could be built using existing materials, scientific principles, and techniques in roughly five years’ time. Weighing approximately 500 pounds, such a device would have limited capacity for conveying weapons. It might still have military value as a radio relay station and “an observation aircraft which cannot be brought down by an enemy who has not mastered similar techniques.” But it would be valuable chiefly for scientific research, allowing for studies of cosmic rays, gravitation, astronomy, meteorology, and geophysics. Finally, an orbital satellite, however small, represented a preliminary step to the exploration of the solar system and beyond.³⁵¹

The group was also concerned with how the launch of such a device might be received by the American public and, more importantly, by foreign governments. An artificial satellite, they predicted, “would inflame the imagination of mankind, and would probably produce repercussions in the world comparable to the explosion of the atomic bomb.”³⁵² In 1947, James Lipp, the director of RAND’s missile division, added this to the report’s conclusions: “Since

³⁴⁹ Bruno Augenstein, “Space,” in *50th Anniversary of Project Air Force, 1946-1996*: 17, accessed October 15, 2012 at <http://www.rand.org/content/dam/rand/www/external/publications/PAFbook.pdf> .

³⁵⁰ Quoted in Virginia Campbell, “How RAND Invented the Postwar World,” *Invention and Technology* (Summer 2004): 52.

³⁵¹ Douglas Aircraft Company, “Preliminary Design of an Experimental World-Circling Spacecraft,” Report No. SM-11827, Contract W33-038, ac-14105, May 2, 1946 (Santa Monica: RAND, 1946): I, VIII, 10-16.

³⁵² *Ibid.*, 2.

mastery of the elements is a reliable index of material progress, the nation which first makes significant achievements in space travel will be acknowledged as the world leaders in both military and scientific techniques.”³⁵³ In addition to being a matter of technological one-upmanship, the launch of an orbital satellite would also represent a psychological strike in the nascent Cold War with the Soviet Union. The “threat” derived less from the satellite itself than from the means to get it into space. As Lipp observed, “It will make possible an unspoken threat to every other nation that we can send a guided missile to any spot on earth. Combined with our present monopoly of the atom bomb such a threat...will give pause to any nation which contemplates aggressive war against the United States.”³⁵⁴

In partnership with the Air Force, RAND continued to refine its assessment of satellite possibilities through the late 1940s. But since the project had few direct military applications, it remained low on the list of defense priorities. It received even less attention following the Soviet Union’s first test of a nuclear bomb in 1949 and the start of the war in Korea. The increasingly volatile global political situation also created an atmosphere of caution among space analysts. In a 1950 report historian Walter MacDougal deemed “the birth certificate of American space policy,” RAND suggested that because a satellite launch would undoubtedly attract worldwide attention, the program would have to proceed with an eye towards geopolitical implications. If the Soviet Union viewed the launch of a satellite with global surveillance capabilities as an act of aggression, they might claim it as a violation of international airspace law, thus weakening the US’s international standing and impeding the further development of its space capabilities.³⁵⁵

³⁵³ Quoted in Bruno Augenstein, “Space,” 21.

³⁵⁴ Quoted in R. Cargill Hall, “Early U.S. Satellite Proposals,” *Technology and Culture* 4, no. 4 (1963): 423.

³⁵⁵ MacDougal, *The Heavens and the Earth*, 108-109.; Paul Kecskemeti, “The Satellite Rocket Vehicle: Political and Psychological Problems,” RAND RM-567, October 4, 1950 (Santa Monica: RAND, 1950).

These considerations – not simply apathy on the part of the Eisenhower administration as many post-Sputnik analysts charged – lay behind the US’s tentative entrance into the Space Age in the early 1950s. In 1954, Eisenhower finally determined to schedule the nation’s first satellite launch during the upcoming 1957-1958 International Geophysical Year (IGY). Doing so at an international gathering of scientists, he felt, would send a message to the Soviet Union and the rest of the world that space exploration was fundamentally a peaceful, scientific endeavor. Even if the Soviets launched a satellite first, the president reasoned, this would at least establish the concept of “freedom of space” and the US could be free to pursue a space program without fear of breaking international law.³⁵⁶

Concerned primarily with geopolitical relations, Eisenhower vastly underestimated the psychological impact of a Soviet first launch. News of the launch of Sputnik on October 4, 1957 dealt a major blow to American confidence in its technical superiority. An editorial in the *New York Herald Tribune* captured the concern: “We have been set back severely, not only in matters of defense and security, but in the contest for the support and confidence of the peoples throughout the world.” One British commenter called the 22-inch ball of iron and aluminum “a technological achievement which must shatter forever any illusions about western engineering superiority.”³⁵⁷ A Gallup poll conducted in eleven cities around the world after the November launch of Sputnik II (carrying the doomed dog Laika) further indicated the “hard blow to American prestige.”³⁵⁸ The Soviets’ apparent edge in ICBM capabilities also fueled fears of widening “missile gap” between the Soviet Union and the United States. The 1957 Geither Report suggested that the Soviets would soon have the capability to destroy American B2

³⁵⁶ MacDougal, *The Heavens and the Earth*, chapter 5.

³⁵⁷ Both quotes from Hall, “Early U.S. Satellite Proposals,” 434.

³⁵⁸ George Gallup, “Sputnik was Blow to U.S., Poll Shows,” *Los Angeles Times*, November 4, 1957: 13.

bombers on the ground, preventing any possibility of a retaliatory strike.³⁵⁹ The federal government's initial response did little to quell fears. On December 6, 1957, the US Navy's towering Vanguard rocket, slated to send the first American satellite into orbit, erupted in a huge ball of flames just after liftoff at Cape Canaveral, Florida.³⁶⁰

Following the spectacular failure of the navy's "flopnik," Eisenhower fast-tracked the army's existing satellite program. On January 31, 1958, Werner von Braun's massive Redstone rocket deposited Explorer I, America's first artificial satellite, into low earth orbit. The struggles continued for the navy when its second Vanguard rocket, test-launched without a payload on February 5, 1958, exploded four miles off the launch pad. The urgency of the moment compelled Eisenhower and the navy to press ahead despite the second disaster. Finally on March 17, 1958, the grapefruit-sized Vanguard I began transmitting data from orbit, and the race for space joined the nuclear arms race as a major stimulus for developing American science and engineering capabilities in industry, academia, and the military.³⁶¹

Despite being the second American satellite (and the fourth overall), Vanguard I had a disproportionate influence on the subsequent development of satellite electronics. Powered by chemical batteries, the electrical systems on the Sputnik satellites and Explorer I had a lifetime of only a few weeks. In Vanguard I, the chemical battery was supplemented by silicon solar cells, fabricated by Hoffman Electronics for the US Army Signal Corps research division in Fort Monmouth, New Jersey. When the battery died three weeks after launch, the solar cells continued to supply power to the transmitter for an additional six years, far surpassing expectations and impressing the previously skeptical military brass. The long transmission time

³⁵⁹ John Lamberton Harper, *The Cold War* (New York: Oxford University Press, 2011), 113.

³⁶⁰ "Russians Impale U.S. on Own Barbs: Reprint Acid Comment from American Press on Rocket – London sees 'Flopnik'," *The New York Times*, December 8, 1957: 36.

³⁶¹ Robert A. Divine, *The Sputnik Challenge: Eisenhower's Response to the Soviet Satellite* (New York: Oxford University Press, 1993).

allowed the tiny sphere to collect important data about the size and shape of the earth, the density and temperature range of the atmosphere, the frequency of micrometeorites in space, and the presence of radiation in near earth orbit and its effects on electronic equipment.³⁶²

Photovoltaic technology allowed satellites to become more than propaganda stunts. Vanguard I's long life span established that satellites could also be functional, long-lasting research and observation devices. This factor, many military and civilian officials felt, would contribute to justifying the enormous expense of thrusting objects and perhaps even human beings out of the earth's gravity well.

"Yeoman Service to the Space Program"

With the launch of Vanguard, space became the primary physical and political context for the subsequent development of photovoltaic technology. In the years prior, research conducted with high altitude balloons and rockets had already provided measurements of solar radiation in the upper atmosphere. Of course, many of the environmental constraints to direct solar energy utilization on earth did not pose problems in outer space. Above the atmosphere, no clouds, haze, trees, or buildings obscured the sunlight. And while satellites would likely spend time in the shadow of the earth, these periods of darkness would be far briefer than a typical terrestrial night. Other factors including the low weight of solar collectors and the fact that they would not require

³⁶² This also far exceeded the previously expected lifetime of one hundred days as estimated in S.F. Singer, "Orbits and Minimum Lifetimes of Satellite Vehicles," American Rocket Society, ARS Preprint 160-54, 1954.; "Vanguard Radio Fails to Report, Chemical Battery Believed Exhausted in Satellite – Solar Unit Functioning," *New York Times*, April 6, 1958: 37.

maintenance or refueling convinced some space analysts to seriously consider solar energy technologies as a power source.³⁶³

Following the announcement of the Bell Solar Battery, General James O'Connell of the Signal Corps sent Dr. Hans Ziegler, a German-born rocketry scientist who had escaped to the United States with Werner von Braun during World War II, to visit Bell labs and report on its solar cell program. Ziegler was enthused with what he saw. Not only would photovoltaic technologies be useful for military and space applications, he believed. With additional research and development, solar cells might become "sufficient to produce this country's entire demand for electrical power." "In the long run," he concluded, "mankind has no choice but to turn to the sun if he wants to survive." In the immediate future, Ziegler felt the technology could contribute to the Signal Corps' mission to improve and maintain the communications capabilities of the US military. The most promising short term application would be as a power source for the Navy's fledgling satellite programs.³⁶⁴ In a preliminary 1955 report for the newly created Vanguard program, Ziegler concluded that for intermittent but long term operation of electronic equipment, photovoltaic solar converters offered "a great deal of promise."³⁶⁵

Solar, though, was still a prototype technology in 1955. It was also being considered alongside a number of other power sources with different strengths and weaknesses. Chemical batteries were a known quantity and could provide continuous power over a predictable period of time. Although even less established than solar cells, "atomic batteries" were also receiving

³⁶³ S.F. Singer, "Solar Power for 'MOUSE'," *Science News Letter* 67, no. 19 (May 7, 1955): 294.; Heinz Haber, "Space Satellites: Tools of Earth Research," *National Geographic Magazine* (April 1956): 487-509.

³⁶⁴ Quotes and information from Perlin, *From Space to Earth*, 41-42.

³⁶⁵ Signal Corps Engineering Laboratories, "Proposals for Satellite Program, Volume III, Signal Corps Program Proposals to Phase I and Phase II," Signal Corps Engineering Laboratory, Fort Monmouth, NJ, 1955: 202, accessed December 3, 2012 at <http://www.deepspace.ucsb.edu/outreach/the-space-race/the-story-of-vanguard>.

attention as they could potentially supply a large amount of power over a long period of time.³⁶⁶ Both the Army and the Navy remained hesitant to commit to any one path, partly because no one really knew how conditions in space would affect electrical systems. In June 1957, Ziegler made a good case for incorporating solar cells on the first satellite by firing an Aerobee-Hi rocket with a nosecone coated with glass-protected solar cells to an altitude of 190 miles at the White Sands Proving Grounds in New Mexico. The test confirmed that solar cells would function above the atmosphere.³⁶⁷ The Navy continued to resist including solar cells as a power source on Vanguard until August 1957 when a series of setbacks convinced the program leaders to launch a much smaller satellite containing only a transmitter. When the blueprints were drawn up, the committee determined that the unused weight capacity could be filled by solar cells.³⁶⁸

While Vanguard I confirmed the utility of solar cells for powering satellite electronics, the underlying impetus for the continuing government support was Americans' anxiety about falling behind the Soviets in rocket and space capabilities. While the public and members of Congress demanded a response, Eisenhower remained hesitant to commit fully to direct government oversight of the nation's technology priorities, fearing that such a path would run counter to the traditional American regard for limited government, markets, individual enterprise, and academic freedom.³⁶⁹ The president was also influenced by Robert Oppenheimer and other former Manhattan scientists who argued that a government-directed technological race

³⁶⁶ For an evaluation of solar versus chemical batteries see H.K. Ziegler, "Components for Instrumentation of Satellites," in *Scientific Uses of Earth Satellites*, ed. James A. Van Allen (Ann Arbor: University of Michigan Press, 1956), 55-68.

³⁶⁷ Activities of the Signal Corps described in H.K. Ziegler, "Solar-Power Sources for Satellite Applications," *Annals of the International Geophysical Year* 6, 3.3.3 (1958): 300-314.; "Sun Power Held Ideal for Satellite Batteries," *New York Times* 21 June 1957: 37.; "Solar Cells may Power Satellite Instruments," *Machine Design* 29, no. 14 (July 11, 1957): 24-28.; "Solar Energy to Power Satellite Instruments," *Military Electronics* 3, no. 1 (July 1957): 1.; "Sun Batteries for Helmet Radio and Satellite Instruments," *Electrical Engineering* 76 (October 1957): 947.; Prior to this test, Ziegler had received the support of the Technical Panel on the Earth Satellite Program, a panel of civilian scientists assembled to advise the U.S.'s early space program. See Perlin, *From Space to Earth*, 44-45.

³⁶⁸ "Sun Rays to Power Satellite Instruments," *Signal* 11 (August 1957): 40.

³⁶⁹ MacDougall, *The Heavens and the Earth*, 5, 10-11, chapters 4 and 5.

with the already avowedly technocratic Soviet Union could not be won since the deciding contest would involve massive annihilation of human life. For these reasons, Eisenhower sought to ensure that the National Aeronautics and Space Act, which created NASA, and the National Defense Education Act – the two catalysts of the US space program – emphasized peaceful space activities and the involvement of American private industry in stimulating both the nation’s space capabilities and technology consumption in the civilian marketplace.³⁷⁰

The combination of unprecedented government investment in space technologies and the relative freedom granted to businesses to adapt those technologies to the civilian market transformed the landscape of American industry. Defense spending and the space program elevated Lockheed, General Dynamics, Northrop, Boeing, DuPont, Alcoa Aluminum, Westinghouse, and other large aerospace, engineering, and materials corporations into symbols of American prestige at home and abroad. These companies also became engines of economic and infrastructure development in the regions where they were located. Southern California in particular became a hub of aerospace technology research and development. Scientists and engineers moved easily between the university research facilities at Cal Tech’s Jet Propulsion Laboratory and the industrial labs at General Dynamics, Hughes Aircraft, and Aerojet. While these labs were responsible for the design and manufacture of high-profile technologies such as rocket boosters, missiles, nuclear warheads, jet aircraft, and space vehicles, the myriad of components that comprised these technologies were contracted out to small and medium-sized companies in the region. Hoffman Electronics and the nearby International Rectifier Corporation, the two semiconductor laboratories which began producing silicon solar cells for

³⁷⁰ “Statement by the President Concerning Commercial Use of Communication Satellites, January 1, 1961,” in *Public Papers of the Presidents of the United States, Dwight D. Eisenhower, 1960-1961* (Washington D.C.: Government Printing Office, 1999), 889.

space applications in the late 1950s, became beneficiaries of the spiral effect of national defense and space spending.

News about Vanguard I's solar powered transmitter also sparked renewed interest in other possible solar energy applications. On March 28, 1958, eleven days after the launch, *The Wall Street Journal* ran a front page article highlighting the various solar energy projects then being pursued in government and industry. In New Mexico, the Air Force was building a \$10 million, fifteen-story solar furnace "to trap and concentrate the enormous energy of the sun's rays...for testing materials going into future missiles, manned space craft, and nuclear reactors." At least nine US houses, including the MIT solar house and George Löf's solar bungalow in Colorado were operating primarily on solar heat while "thousands of households" in California and Florida were outfitted with solar water heaters. "To date," John Yellot told the paper, "we have made virtually no use of this resource in this country because [of] ample supplies of fossil fuels.... But this era is now ending, and the sun is going to have to furnish directly a growing share of our rapidly rising energy needs." For the benefit of the fledgling solar industry and ultimately the nation, George Löf suggested that "pioneer buyers" would have to be willing to take the risk of paying the higher up front cost for solar house heating and other technologies. As they realized the convenience and long term cost savings of solar, Löf believed, the solar industry would be able to grow into a viable supplement or even alternative to conventional energy sources.³⁷¹

A number of small businesses sought to transition the technical success of the Vanguard system into commercial success. The newly formed Umbroiler Company in Denver, Colorado was planning to release a solar barbecue grill manufactured from mylar and resembling "an

³⁷¹ R.W. Benedict and D.O. Ives, "Companies, Scientists Focus on New Solar Products and Processes," *The Wall Street Journal*, March 24, 1958: 1.

upside down lampshade” for the upcoming summer. Several companies were marketing solar pool heaters and cigarette lighters. In New Jersey, Jet-Heet, Inc. began issuing licenses to manufacturers to make solar water pumps and small solar water distillation units. In Florida, at least eleven companies were manufacturing solar home water heating systems similar to the Day and Night systems sold in California in the early twentieth century. Hoffman solar cells were also finding their way into a number of devices including radios, lighthouse beacons, record players, walkie-talkies, clocks, science kits for children, and a variety of mechanical toys. In 1958, the Singer Corporation contracted with Hoffman to provide solar cells for a sewing machine to be marketed in places where “electric power is not available, or is only available on a restricted or irregular basis.” Also that year, Zenith announced its release of a hearing aid powered by a slim bank of solar cells mounted on an eyeglass frame.³⁷² James Zeder, vice-president of the Chrysler Corporation even predicted that with recent advances in technology, solar cars might soon be available to consumers. “Tomorrow the sunmobile may replace the automobile,” he predicted. “The power of bottled sunshine will propel it. Your solar sedan will take energy from sunrays and store it in accumulators that work like a battery. This power will drive your car just like gasoline does today.”³⁷³

Several companies also began producing small photoelectric devices for use “in the less publicized field of ‘control by light’ applications in the industrial electronics devices.” In 1958, the Bell and Howell Company began producing a movie camera which utilized a selenium solar cell to power an automatic light meter. In 1959, the Atwood Vacuum Machine Co. of Rockford,

³⁷² Ibid., 17.; photo and caption depicting the Umbroiler in *The Sun at Work* 3, no. 2 (June 1958): 1.; “Sun-Powered Hearing Aid is Developed by Zenith,” *The Wall Street Journal*, May 2, 1958: 2.; “Solar Powered Sewing Machine,” *The Sun at Work* 5, no. 4 (1960): 18.; Jean Smith Jensen, “Harnessing the Sun Around the World,” *The Sun at Work* 4, no. 1 (March, 1959): 6.

³⁷³ Quoted in Matt Novak, “Chrysler VP Predicts Solar-Powered Cars (1958)” Paleofuture blog, June 20, 2009, accessed October 14, 2013 at <http://paleofuture.gizmodo.com/chrysler-vp-predicts-solar-powered-cars-1958-512626600>.

Illinois introduced a dollar bill changing “robot” which used a reader based on “light-to-electrical energy conversion principles” to verify the authenticity of bills and dispense the correct change. Light sensitive cells were being adapted to read punch cards and punch tape in computer systems. A Texas oil company developed a specialized silicon light detection device to attach to drill bits so that the composition of the substrate could be determined without halting drilling to inspect samples. Similar devices were being used to control temperatures in steel manufacturing systems.³⁷⁴

In 1960, Los Angeles-based International Rectifier announced its entry into the solar industry by introducing the world’s first full sized solar-powered car, a converted 1912 Baker outfitted with a bank of 10,000 solar cells.³⁷⁵ While the panels could be mass produced for roughly \$2,000 to \$3,000 a piece, the car itself had little practical value. Eight hours of exposure to direct sunlight were required to charge the battery for only one hour of use. The invention nevertheless had appeal in the company’s home city of Los Angeles where the phenomenon of “smog” derived from automobile exhaust was becoming a major concern. “Any incentive toward the widespread adaptation of the electric automobile to smog filled cities will be welcomed,” *Sun at Work* reported. Taking advantage of “the inexpensive sun power now wasted” to power the region’s ubiquitous automobiles would also provide “relief from the ever increasing high cost of fuel.”³⁷⁶ While partly a stunt to spark the public imagination, the demonstration of the car was intended to highlight the possibility of using solar cells for “such things as power pumps in the desert or unattended aircraft warning beacons.”³⁷⁷

³⁷⁴ Benedict and Ives, “Companies, Scientists Focus on New Solar Products and Processes,” 1.; “Hoffman Solar Cells enter Control Field,” *The Sun at Work* 4, no. 3 (September 1959): 3.

³⁷⁵ “International Rectifier Contracts,” *Wall Street Journal*, September 16, 1959: 5.

³⁷⁶ “World’s First Sun-Powered Automobile,” *The Sun at Work* 5, no. 1 (1960): 9.

³⁷⁷ “Solar Cells get Test on 1912 Electric Car,” *Wall Street Journal*, March 17, 1960: 7.

These forays into the terrestrial market were direct outgrowths of government funded space and defense research. International Rectifier's solar car was built in conjunction with a \$500,000 contract with Lockheed's missile and space division to develop solar cells for space applications. Hoffman's solar work also continued to be supported primarily by the Signal Corps, which, in addition to contributing to the space program, was seeking to adapt solar cells for use in remote radio transmitters. In 1958, Hoffman designed a solar-powered helmet radio for infantry use. To mark its one hundredth anniversary in 1960, the Signal Corps established cross-country radio contact between solar transmitters at its New Jersey headquarters and on the roof of the Hoffman plant in El Monte. The solar panel installed on the New Jersey facility consisted of 7,800 cells and could produce some 250 watts, about double the output of any previous solar panel. The "sun station" was also capable of establishing contact through the army's Military Affiliate Radio System (MARS) with ham radio stations "in such distant locations as Australia, Africa, and Europe."³⁷⁸

The majority of government-industry solar cell research was concentrated in the field of space electronics. Between 1958 and 1969, the US government spent approximately \$50 million on space applications for solar technologies.³⁷⁹ On February 17, 1959, the navy launched Vanguard II containing a photocell powered camera for recording infrared images of cloud cover.³⁸⁰ Launched in August 1959, NASA's Explorer VI, which sent back the first (albeit indistinct) photo of the earth from orbit, was powered by 8,000 Hoffman solar cells mounted on four "paddles" projecting from the spheroid-shaped body.³⁸¹

³⁷⁸ "Signal Corps makes Solar History: 1st Coast-to-Coast Broadcast," *The Sun at Work* 5, no. 2 (1960): 1.; For the potential usefulness of solar energy communications for soldiers see Earl F. Cook, "Power from the Sun," *Army* (April 1961): 39-42.

³⁷⁹ Perlin, *From Space to Earth*, 50.

³⁸⁰ "Weather Satellite uses Solar Cells," *The Sun at Work* 4, no. 1 (March 1959): 13.

³⁸¹ Hoffman Electronics Press Release re: Explorer VI, undated. Space Technology Laboratories Archive accessed December 10, 2012 at

The efficacy of solar cells for space applications became firmly established with NASA's launch of TIROS (Television Infra-Red Observation Satellite), a weather satellite capable of transmitting television images of cloud patterns over areas as large as 850 square miles. Designed and built by RCA for the Signal Corps, the cylindrical TIROS, powered by 9,200 silicon solar cells, became the blueprint for a generation of meteorological satellites which transformed the fields of weather prediction and climate analysis.³⁸² TIROS also proved valuable for intelligence gathering, becoming "our first military spy in the sky" according to a report in *Science and Mechanics*.³⁸³ In 1961, Paul Rappaport of RCA Laboratories reported that through these projects, the solar cell had "changed from a scientific curiosity to the only reliable long-term power source available to our space program."³⁸⁴

Government funds went not only to satellite research but also to more distant future plans for solar powered spacecraft. "Solar sailing ships to Mars and power stations on the moon have suddenly descended from the extravagant pages of science fiction to the sober reports of government and industrial research laboratories," reported *Sun at Work* in 1958. "The Age of Astronautics is upon us, and with it, solar energy has assumed a tremendous importance in the empty reaches of outer space, where there are no hydroelectric plants or coal-burning turbines or wayside gas stations."³⁸⁵

A profound nationalist enthusiasm for the possibilities of American space exploration propelled this work. In the late 1950s, Americans reimagined outer space as the ultimate peripheral zone, or "the final frontier" in the parlance of *Star Trek* (1966). The federal

<http://www.sdfo.org/stl/Explorer6/pdfs/Contractors%20Hoffman%20Explorer%20VI.pdf>; "Solar Paddlewheel Satellite Launched," *The Sun at Work* 4, no. 3 (September 1959): 1.

³⁸² Seymour H. Winkler, Irving Stein, and Paul Wiener, "Power Supply for the TIROS I Meteorological Satellite," in *Space Power Systems: Progress in Astronautics and Rocketry*, volume 4, ed. Nathan Snyder (New York: Academic Press, 1961), 33.

³⁸³ "How Tiros Photographs the World (including Russia)," *Science and Mechanics* (August 1960): 65-69.

³⁸⁴ Paul Rappaport, "Photoelectricity," *N.A.A. Symposium* 47 (1961): 1303.

³⁸⁵ "Solar Energy in the Space Age," *The Sun at Work* 3, no 4 (December 1958): 3.

government played a direct role in popularizing this idea. In its 1958 *Introduction to Outer Space*, President Eisenhower's science advisory committee presented space exploration as a veritable continuation of manifest destiny. The overriding motivation was "the compelling urge of man to explore and to discover, the thrust of curiosity that leads men to try to go where no one has gone before. Most of the surface of the earth has now been explored and men now turn to the exploration of outer space as their next objective."³⁸⁶

The exploration of space, and as a corollary, the continuing development of the nation, would require a whole new technological regime suited to inhospitable vacuum and unfathomable distance. Systems for harnessing solar energy, many engineers and space enthusiasts believed, would be an important first step towards colonizing the expanse of the solar system. In 1958, engineers at Hoffman proposed that energy capacity could be increased significantly by fitting solar cells or some other type of photosensitive material to an inflatable aluminum "skin" which would expand to a 100-foot diameter sphere after being deployed from the nose cone of a rocket. That same year, a team at Westinghouse assembled a model of a moon-based solar power plant. The actual 6,000 kilowatt plant would consist of huge sheets of plastic, fitted with photosensitive material and backed with wire mesh. The whole apparatus would then be stretched over several acres of the moon's surface. Other projects supported by government funding utilized heat trapping solar technologies. Northrop Aircraft was working on a device "in the form of an eye-ball shaped solar collector" which could be mounted on a spacecraft and continuously servoed to face the sun. The collector would generate thermoelectricity to drive an ion thrust engine. It would also power a refrigeration mechanism. Among the more intriguing projects was an enormous aluminum-coated plastic "solar sail"

³⁸⁶ The President's Science Advisory Committee, *Introduction to Outer Space* (Washington D.C.: Government Printing Office, 1958), 1.

designed through collaboration between Westinghouse and the Los Alamos Scientific Laboratory. The sail would propel a spacecraft by transferring the minute “pressure” of light photons into inertia. According to project engineers, an 800 pound sail would be able to carry a 1,000 pound payload to Mars in approximately two and a half years.³⁸⁷

These projects also continued to be predicated on the idea that government spending on space technology would not only serve national defense needs and increase American technological and scientific prestige, but would also ultimately benefit American consumers and businesses. The most obvious immediate potential commercial use for satellites was in communications. In 1960, NASA offered to front the cost for launching commercial communications satellites into orbit as long as companies agreed to share technical data and to allow the government to use their satellites as platforms for research or surveillance.³⁸⁸

AT&T leapt at the opportunity, and in 1962, the company launched Telstar I, the world’s first communications satellite. Designed and built at Bell Labs, the craft incorporated several Bell innovations including solar cells, transistors, and the world’s first travelling wave tube transponder, essentially a sophisticated relay device. Once in orbit, it relayed the first trans-Atlantic television signal. In November 1963, the second generation Telstar II relayed live news coverage of President John F. Kennedy’s funeral around the world. The subsequent proliferation of communications satellites internationalized television, allowing for the global broadcast of the

³⁸⁷ Ibid., 3-5.; Other projects included a solar propulsion system being designed at Lockheed Aircraft and the 32-foot “Sunflower” solar auxiliary system being developed through a partnership between NASA and the TAPCO Group of Thompson-Ramo-Woolridge in Cleveland, Ohio. See Jensen, “Harnessing the Sun around the World,” 7.; “Sunflower I,” *The Sun at Work* 5, no. 2 (1960): 14-15.; Other large corporations were pushing for increased government spending on solar space propulsion. At the 1960 meeting of the Society of Automotive Engineers (SAE), engineers at General Motors (GM) urged that “if the necessary research programs are initiated now,” a direct solar conversion system would be competitive with nuclear systems for propulsion energy requirements up to one megawatt by the time the U.S. produced its first powered space ships. Solar collectors would also be capable of supplying heat to a fuel cell or a thermoelectric converter, the GM team said. “Push Solar Power for Space,” *The Sun at Work* 5, no. 1 (1960): 4.

³⁸⁸ For a full description of the government’s terms which also included provisions for international cooperation and anti-trust actions see Delbert D. Smith, *Communication Via Satellite: A Vision in Retrospect* (The Netherlands: A.W. Sijthoff International Publishing Company, 1976), 79-80.

1964 Tokyo Olympic Games and other international events. They also became political devices, bringing visual images of the passion and violence of the southern Civil Rights movement into the living rooms of Americans and others around the world. As historian David Reynolds observes, “The mass medium of television,” relayed around the world via satellites, also became “nationalized...during the Cold War era.” Key turning points in the conflict including Richard Nixon’s China tour in 1972 and the 1989 fall of the Berlin Wall “derived their international impact from live television images.” In China and the Soviet Union, meanwhile, satellite television became a “transmission belt” for conveying propaganda to the public.³⁸⁹

In a 1972 paper for the Army’s 25th Power Sources Symposium, NASA research scientist D.T. Bernatowicz praised solar cells for providing “yeoman service to the space program since its inception.”³⁹⁰ Through the 1960s, many analysts in government and industry had believed that higher potential output energy sources, namely nuclear batteries, would eventually supersede solar cells. But engineers at Hoffman, International Rectifier, RCA, Lockheed, Boeing and other companies continued to take advantage of government spending to find ways to adapt photovoltaic technologies to the requirements of the nation’s fast-evolving space aspirations.

The upper load limits for solar powered satellites increased steadily from approximately 200 watts in 1962, to the 500 watts supplied to the Nimbus Spacecraft in 1964, to 1,000 watts for the 1966 Orbiting Astronomical Observatory, and finally to the 20 kilowatt system being developed for the 1973 launch of SKYLAB. While the efficiency of solar cells remained at roughly ten percent from 1962 through the early 1970s, engineers devised other means of increasing power capacity. In 1962, Hoffman introduced a reverse-engineered solar cell in which

³⁸⁹ David Reynolds, “Science, Technology, and the Cold War,” *The Cambridge History of the Cold War*, Volume III, eds. Melvyn P. Leffler and Odd Arne Westad (Cambridge: Cambridge University Press, 2010), 388-389.

³⁹⁰ D.T. Bernatowicz, “Solar Array Cost Reductions,” *25th Power Sources Symposium*, 128.

sunlight struck the “n” as opposed to the “p” layer. This cell was significantly more resistant to the radiation which limited the lifespan of the first generation satellite cells. Other increases in power capacity were attained through “clever structural mechanical design and improved packaging concepts.”³⁹¹ New methods of processing silicon allowed for the manufacture of thinner, lighter cells. Fold-out aluminum frames increased the surface area on which solar cells could be fixed. Researchers at DuPont, Goodyear, and other companies were also developing flexible lightweight polymers which could be fitted with solar cells and extended upon release from the nosecone of a rocket.³⁹²

Unthinking Myths: Pursuing Terrestrial Applications

While major technical advancements were being made in satellite power systems, these were generally oriented towards the requirements of rocket payload carrying capabilities and long term operation in hard vacuum. Satellite solar cells were manufactured from high-purity silicon, fitted with specialized glass coverings to resist radiation, and were usually custom fabricated to meet strict weight, size, and shape requirements of individual space vehicles. Whereas solar devices for the consumer market were judged by the metric of dollars-per-watt, photovoltaic devices for space use, where cost was often less important than function, usually required a high watts-per-pound ratio.³⁹³

To meet specific contract requirements, Hoffman Electronics, International Rectifier, RCA, and the other manufacturers of satellite power supplies typically produced non-standardized devices in small amounts, a formula which by 1972 had failed to “justify a high

³⁹¹ J.V. Goldsmith, “Large Area Silicon Solar Array Development,” *25th Power Sources Symposium*, 130.

³⁹² *Ibid.*, 131-133.

³⁹³ Perlin, *From Space to Earth*, 50-51.

degree of mechanization or automation,” Bernatowicz observed. This isolation from the consumer market also hindered the advancement of satellite electronic capabilities. Following the two-pronged logic of America’s Cold War strategy regarding technology, Bernatowicz proposed that the creation of a large-scale terrestrial market for silicon solar cells would dramatically reduce materials and manufacturing costs and would provide an incentive for a surge in innovation for space uses. “There would then be reverse spin-off,” he predicted, with “terrestrial applications directly benefitting the space applications.”³⁹⁴

For Ernst M. Cohn, manager of the solar and chemical power division of NASA, overcoming stasis in both space and terrestrial applications required federal agencies and both private and public research labs to “unthink myths” associated with solar technologies. In the case of satellite power supplies, assumptions regarding types of materials, manufacturing methods, and efficiency limits had precluded innovation and had begun to convince NASA and other holders of the purse strings that engineers were reaching a point of maximum return in the power generation capabilities of solar cells. One of the most damaging myths, Cohn argued, was the assumption “that one should lower the cost of solar cells to decrease the cost of solar power.” Cutting the costs of producing traditional cells might indeed save dollars and perhaps expand the market for photovoltaics, he explained, but it also took away from projects to increase the power output of each cell. In the field of satellite electronics, in which solar cell costs represented only about twenty percent of the total array cost, reducing production costs would only reduce that twenty percent by a fraction. On the other hand, if engineers could design a cell with double the efficiency, fewer cells would be required to produce the same amount of power, thus reducing not only the overall cost of the solar cells, but also the cost of the array itself. Thinking in terms of the entire system rather than each component, he concluded, would allow NASA to break

³⁹⁴ D.T. Bernatowicz, “Solar Array Cost Reductions,” *25th Power Sources Symposium*, 130.

through the artificial barriers to solar cell “improvement,” and in the process establish a technical process which could translate to consumer applications.³⁹⁵

For Bernatowicz and Cohn, bureaucratic inflexibility had established certain ways of thinking and distributing funds which had impeded NASA’s capacity to develop the nation’s solar energy conversion capabilities. The possibilities were not quite so limited, however. That they could even offer these criticisms reflected the advent of new era in government-industry collaboration in science and technology. While solar cells seemed to reaching a plateau in terms of their effectiveness for space and terrestrial applications, the government apparatus which was in part responsible for this slowdown also allowed for the possibility of exploring new approaches with uncertain short-term commercial returns but important long-term implications.

Taking advantage of this aspect of NASA and other government science institutions was a matter of politics. While the momentum of established technological systems clearly limited possibilities, the kinds of projects that received government support in this period could also be influenced by interested parties offering justifications, not in terms of immediate profitability, but in terms of contributions to national defense, global leadership in science and technology, and the socio-economic development of the nation. Developments in photovoltaic technology from the 1950s to the early 1970s were the product of individuals and businesses working within the federal system using federal dollars to prioritize the development of a technology with limited present market value but significant future promise as defined in the context of Cold War national priorities. In critiquing federal solar cell research and development priorities, Cohn and Bernatowicz were also testing out new rationales for further stimulating both solar energy and space technology capabilities for the future. They were not approaching the topic in the narrow terms of business and profits but as engineers seeking the best possible technology to perform

³⁹⁵ Ernst M. Cohn, “Research Plans for Solar Power in Space,” *25th Power Symposium*, 139-141.

particular tasks within particular technical and environmental constraints. They saw their work as contributing to a long-term project of increasing the resilience and security of the nation by furthering the development of a technological basis for an inevitable post-fossil fuel future. This expanded sense of the value and purpose of solar technologies became an important political rationale for continuing government support in the decades that followed.

Chapter 5

Solar Revival: The 1973 Oil Crisis and the Reimagining of a Solar Future

During the 1960s, while solar cells remained essential to the nation's space capabilities and while the Third World remained a focal point of activity, the possibility that these efforts would give rise to commercially viable applications in the US in the foreseeable future seemed less and less likely as the nation committed more fully to nuclear and as the development of new natural gas and oil supplies drove down energy costs to historic lows. The decade was generally a period of "eclipse" in American solar advocacy, as one historian has put it.³⁹⁶ In 1967, the nonprofit group Resources for the Future, the same group that had recommended strong federal support for solar energy in the 1952 Paley Report, dismissed solar as "not judged to be of sufficient weight in the foreseeable US energy mix" to warrant substantial funding for research and development."³⁹⁷

Surprisingly considering later events, the waning of popular and government support for solar energy occurred simultaneously with the ascendance of the American environmental movement. Both trends reflected a prevailing lack of concern about fossil fuel scarcity. "The environment was not threatened by scarcity of energy," historian Joachim Radkau writes, "but by the abundance of cheap sources of energy."³⁹⁸

In the United States during the 1960s, advocates and opponents of environmental reform alike generally accepted the premise that energy supplies – namely fossil fuels and nuclear sources – existed in sufficient abundance to sustain high levels of economic growth for the

³⁹⁶ Lamont Charles Hempel, "The Politics of Sunshine: An Inquiry into the Origin, Growth and Ideological Character of the Solar Energy Movement in America," Ph.D. diss., Claremont Graduate School, 1983: 92.

³⁹⁷ Quoted in *Ibid.*, 99.

³⁹⁸ Joachim Radkau, *Nature and Power: A Global History of the Environment*, translated by Thomas Dunlap (New York: Cambridge University Press, 2008), 251.

foreseeable future. They differed in how they weighed the environmental risks of maintaining the blistering pace of postwar economic growth against the economic risks of increased government regulation of the market for the sake of environmental protection and public health. Thus, while the suite of environmental legislation passed during this period including the National Environmental Policy Act (1969), the Clean Air Act amendments (1970), and the Clean Water Act (1972) created standards for mitigating the harmful effects of industrial processes, including pollution resulting from the extraction and burning of fossil fuels, these laws did not directly endorse the development of alternative energy sources and technologies.

The catalyst for a revival of public and private interest in solar technology came in October 1973 when the Arab members of the Organization of Petroleum Exporting Countries (OPEC) determined to cut oil exports to the US and other nations which had supported Israel's invasion of Egypt during the Yom Kippur War. The oil embargo marked an abrupt end to the postwar era of cheap, abundant energy. Total oil imports to the US declined by a fifth during November, and by December, the price per barrel of oil had risen 130 percent from \$3.65 to just under \$12. The result was an immediate shortage of supply, leading to around-the-block lines at gas stations and short supplies of heating oil. The embargo also compounded a global recession triggered by the British stock market crash in January 1973.

The reemergence of energy scarcity as a theme in economic and social life elicited a variety of responses. On one hand, environmentalists saw the oil crisis as a reckoning by which Americans and others would have to learn to accept a steady state economy or even a reduction in the size of the economy for the sake of long term ecological sustainability and quality of life.³⁹⁹ At the same time, many Americans doubted that the physical depletion of oil supplies was

³⁹⁹ Howard T. Odum and Eugene C. Odum, *Energy Basis for Man and Nature* (New York: McGraw-Hill, 1976).

really imminent. The possibility of an actual oil shortage, economist Maurice Adelman argued in a controversial *Foreign Policy* editorial, was a fiction perpetrated by the oil industry and producer nations in order to raise profits. That oil companies were collecting record revenues even as American consumers paid up to four times more for heating oil and gasoline by 1974 seemed to support Adelman's argument.⁴⁰⁰

In the wake of the embargo, solar technology gained wide appeal as a means to reduce the nation's dependence on unreliable Arab governments and the oil industry while doing less harm to the environment. At the same time, deep divides formed over how the transition to a solar energy society should occur and what that society should look like. These divisions mirrored tensions in 1970s American political culture over the environmental and health risks of technology, the role of government in regulating economic activity and making decisions about technology, and the merits and risks of a capitalist system that valued short term profits, economies of scale, material abundance, and unending growth. Historian David Nye has argued that Americans' view of the oil crisis as a result of collusion between energy suppliers rather than true material scarcity was indicative of a general unwillingness to change the prevailing culture of consumption.⁴⁰¹ However, the persistent outpouring of literature, political advocacy, and calls for change even within government suggests that while Americans may have been reluctant to change their habits in the present, they were at least conscious that such conservatism might not be sustainable indefinitely – that hard choices for the nation and the world loomed on the horizon.

⁴⁰⁰ A.A. Adelman, "Is the Oil Shortage Real? Oil Companies as OPEC Tax-Collectors," *Foreign Policy* 9 (Winter 1972-1973): 69-107.; Alvin Richman, "The Polls: Public Attitudes toward the Energy Crisis," *Public Opinion Quarterly* 43 (Winter 1979): 576-585.

⁴⁰¹ David E. Nye, "The Energy Crisis of the 1970s as a Cultural Crisis," *European Contributions to American Studies* 38 (1997): 82-102.

This chapter outlines the predominant trends and voices within this debate, focusing on the national context. It provides a summary of the pre-oil crisis philosophical foundations of the solar revival in the United States, the federal government's response to the oil crisis as it pertained to solar, and the various alternative narratives of a solar future that emerged to challenge that response. The central theme is the emergence of a conflict of values between those who continued to see solar technology as a tool for perpetuating a high energy, high technology consumer society and those who came to view it as a technological foundation for reducing energy consumption and allowing for more localized control of technology, social organization, and environmental resource use. I also address the institutional and ideological obstacles to a more aggressive federal commitment to the solar future envisioned by the latter group.

Reestablishing Scientific Legitimacy

Throughout the formative years of the American environmental movement, support for solar energy implementation continued to come mainly from the industrial scientists and NASA engineers who, from their work on space applications, were most familiar with the state of the technology, its promise as a power source, and its shortcomings. In 1972, NASA and the National Science Foundation (NSF) sponsored a conference on the topic of "Solar Energy as a National Resource." The panel brought together nearly 40 scientists and engineers working in the fields of solid state physics, chemistry, microbiology, architecture, electrical engineering, photovoltaics, and thermal sciences. The organizers also invited several economists, environmentalists, and social scientists to comment on the social and political dimensions of solar implementation. Although acknowledging the various social and economic obstacles to

widespread use of solar energy, the panel gave the most positive endorsement of the technology yet to come from the federal government. “Solar energy is no panacea,” William Cherry of NASA’s Goddard Space Flight Center told the media. “But it could solve at least part of our future energy needs. We could make thousands of acres of our sun-rich land produce a marketable, pollution-free crop of electrical energy.”⁴⁰²

The panel argued that the nation received sufficient energy from direct sunlight to make a significant contribution to energy needs in the future. Notably, the report concluded that “there are no technical barriers to wide application of solar energy to meet US needs.” Since World War II, various conversion methods including thermal heat, photovoltaics, photosynthesis, bioconversion, wind, and ocean temperature differences had progressed to a sufficient degree to warrant a “substantial development project.” A government program operating on just a fraction of the cost of the existing nuclear program, the report concluded, could transform solar energy conversion into a cost-competitive, environmentally safe method of supplementing the nation’s energy needs. By 2020, the report predicted that solar energy could provide up to 35% of the nation’s heating and cooling load, 30% of its natural gas load, 10% of its liquid fuel load, and 20% of its electricity requirements. Though the cost of solar energy would likely remain higher than the present cost of conventional fuels, an anticipated increase in oil and gas prices coupled with “increasing constraints on their use” due to concerns about their limited availability and environmental effects, would allow solar to become an economically viable option.⁴⁰³

While partially informed by rising concerns about reliance on nuclear as a future energy source, the report’s conclusions generally reflected the technological orthodoxy of the postwar decades. Many of the technologies that the panel suggested would form the basis for a national

⁴⁰² Cherry quote from “Solar Energy Researchers Try a New Way,” *Business Week* (June 12, 1971).

⁴⁰³ NSF/NASA Solar Energy Panel, *An Assessment of Solar Energy as a National Energy Resource*, University of Maryland, College Park Maryland, December 1972: 5.

solar implementation program had been developed or proposed in conjunction with high tech space research. New large-area solar cell and thermal solar array designs coming out of Lockheed's missile division, Hughes Aircraft, Tyco Laboratories, and other large aerospace corporations operating largely on government contracts provided the principal justification for considering solar as a primary energy source. William Cherry touted the idea of attaching solar cells to enormous, helium-filled "mattresses" which would float above the weather, collecting solar energy and beaming it down to earth from 50,000 feet.⁴⁰⁴ One of the more talked about possibilities came from Peter Glaser, CEO of Arthur D. Little and then-president of the SES. Reviving Isaac Asimov's earlier idea, Glaser's proposal was for a fifty-square-mile, space-based solar array capable of beaming concentrated solar energy to the earth in the form of a kilometer-wide microwave ray. He also suggested the possibility of using high-powered ground-based lasers to propel the huge apparatus into orbit. By 1972, the proposal was supported by an NSF grant and was under review by a team of engineers from Arthur D. Little, the Raytheon Corporation's Microwave and Power Tube division, Grumman Aerospace, and California solar collector manufacturer Heliotek.⁴⁰⁵

The NASA/NSF panel also based its recommendations on an estimated five-fold increase in the nation's energy needs between 1969 and 2020.⁴⁰⁶ The final report did not specifically endorse conservation measures, nor did it suggest that the adoption of solar energy technologies would entail any major changes in lifestyle, social organization, or infrastructure. The idea was

⁴⁰⁴ William R. Cherry, "Solar Energy Research and Utilization," in *The Energy Crisis and Energy from the Sun*, Papers Presented at the Symposium on Solar Energy Utilization and Panel Discussion on Solar Energy Programs and Progress, Shoreham Americana Hotel, Washington D.C., April 30, 1974, ed. Matthew P. Thekaekara (Mount Prospect, IL: Institute of Environmental Sciences, 1974): 14.

⁴⁰⁵ Discussion of NASA/NSF panel findings in William F. Arnold, "Will Solar Cells Shine on Earth?" *Electronics Magazine* (May 22, 1972).; Peter E. Glaser, "Power from the Sun: its Future," *Science* 162 (1968): 857-886.; and Peter E. Glaser, "The Case for Solar Energy," in *Energy and Humanity*, M.W. Thring and R.J. Crookes, eds. (Stevenage, UK: Peter Perigrinus, Ltd., 1974), 149-156.

⁴⁰⁶ NSF/NASA, *An Assessment of Solar Energy as a National Energy Resource*, 2.

that solar energy would supplement conventional sources – it would make up the difference in energy demand which by 2020 could not be met by oil, coal, natural gas, hydroelectricity, and nuclear. Following the model of these other sources, the panel also envisioned solar implementation as a top-down, federally coordinated technology development program, serving to sustain high levels of consumption, rising incomes, and an increasing GNP. A federal program committed to solar research, development, and implementation, the report suggested, would contribute to preserving America’s position as a global superpower in the coming age of increasing energy demand and diminishing reserves.⁴⁰⁷

Moreover, while the NASA/NSF study lent scientific legitimacy to solar technology, a transition to solar was still not a cause that most Americans in 1972 saw as a priority. By 1974, however, with the energy crisis at the forefront of public consciousness, the prospects had changed. “Almost anywhere you look,” one journalist commented, “you will see evidence of that the Arabs may have given solar power the final, crucial push into the marketplace.”⁴⁰⁸ For many Americans, the combination of rising oil prices and mounting environmental problems related to burning fossil fuels made the transition to solar energy not only desirable but inevitable. “A great fringing wave of solar energy technology is overtaking our civilization,” proclaimed one analyst. “It is about to crest, spill and froth, tossing and tumbling us, purifying us, and driving us, even without our consent of comprehension, toward an unexpected and only dimly visible shore – a new age of great wealth based directly and consciously on the sun.”⁴⁰⁹ How that transition to a solar energy society would occur and what the new technological infrastructure would look like became topics of discussion and speculation. While the idea of solar as a means to sustain a high

⁴⁰⁷ Similar conclusions can be found in J.F. Wise, *Proceedings of the 9th IEEE Photovoltaic Specialists Conference*, Silver Spring, MD, May 2-4, 1972.; and Glaser, “The Case for Solar Energy,” 140-158.

⁴⁰⁸ John Fialka, “Solar Energy’s Big Push into the Marketplace,” *Washington Star-News* 17 July 1974.

⁴⁰⁹ Christopher Duffield, “Solar Energy Technosystems in Arid Lands,” Ph.D. dis, The University of Arizona, 1978: 1.

energy, high technology society into the future persisted, many Americans began to associate solar technology with an emergent set of values that rejected the traditional orthodoxy of progress based on perpetually increasing energy use and economic growth.

Rethinking Technology: The Origins of a New Philosophy of Solar Energy

Although solar energy remained a marginal theme in environmental politics through the 1960s, the outpouring of ecological concern, in combination with the general social upheaval of that decade, called into question a prevailing mentality that celebrated large-scale, centrally-controlled, high-energy technological systems. Bestselling critical works such as Rachel Carson's *Silent Spring* (1962), Jacques Ellul's *The Technological Society* (translated into English in 1964), Herbert Marcuse's *One-Dimensional Man* (1964), Ralph Nader's, *Unsafe at Any Speed* (1965), and Barry Commoner's *Science and Survival* (1966) and *The Closing Circle* (1971) drew attention to the risks new technologies including nuclear weapons, nuclear reactors, automobiles, and chemical pesticides posed for the environment, human health and safety, and democratic institutions.⁴¹⁰

These criticisms did not call for rejecting technology outright, but were part of a movement toward a new ethic of technology. Many offered the possibility that just as technology could damage the environment and erode human liberty, it could also become a force on behalf of human freedom and the environment. In 1964, Lewis Mumford established the terms of the argument when he identified two classes of technology, "one authoritarian, the other democratic,

⁴¹⁰ This transition to a more skeptical view of technology is detailed in Hughes, *American Genesis*, chapter 9.; Also see Leo Marx, "The Idea of 'Technology' and Postmodern Pessimism," in *Does Technology Drive History? The Dilemma of Technological Determinism*, ed. Merritt Roe Smith and Leo Marx (Cambridge: The MIT Press, 1994), 237-257.

the first system-centered, immensely powerful, but inherently unstable, the other man-centered, relatively weak, but resourceful and durable.”⁴¹¹ As late as 1971, anarchist critic Murray Bookchin listed both solar and nuclear energy technologies as examples of “liberatory technology” through which people could “regain the sense of oneness with nature that existed in humans from primordial times.”⁴¹² This categorization of technology both reflected and informed a broadening of American environmentalism from an elite movement concerned with romantic notions of purity in nature to “a social practice in harmony with the rise of popular ecology,” as historian Michael Egan writes.⁴¹³ Decisions about technology, in this new context, became decisions about environmental sustainability, democracy, social equity, and the survival of humanity.

These ideas also took shape in a global context, incorporating rising disillusionment with the economic and technological foundations of Third World development. During the 1960s, difficulties encountered in implementing development plans raised questions about the underlying rationale that a society’s prosperity and happiness increased in proportion to increasing economic production as measured in the metric of Gross National Product (GNP). Experience in Africa, South America, and Southeast Asia prompted critiques stressing the importance of addressing other factors including social organization, cultural preferences, the structure and role of the state, ownership of production, and environmental protection when designing and implementing aid programs.⁴¹⁴

⁴¹¹ Lewis Mumford, “Authoritarian and Democratic Technics,” *Technology and Culture* 5, no. 1 (Winter 1964): 2.

⁴¹² Murray Bookchin, *Post-Scarcity Anarchism* (Berkeley: Ramparts Press, 1971), 68.

⁴¹³ Michael Egan, *Barry Commoner and the Science of Survival: The Remaking of American Environmentalism* (Cambridge: MIT Press, 2007), 84.

⁴¹⁴ Gilbert Rist, *The History of Development: From Western Origins to Global Faith* (New York: Zed Books, 1997), 76.; Nils Gilman, *Mandarins of the Future: Modernization Theory in Cold War America* (Baltimore: Johns Hopkins Press, 2003), chapters 6 and 7.

Among the more radical voices questioning the existing paradigm was that of British economist E.F. Schumacher, a protégé of John Maynard Keynes who made a name for himself as an outlier in his profession with his 1955 essay “Economics in a Buddhist Country.”⁴¹⁵ Drawing inspiration from Mahatma Gandhi’s concepts of *Swadeshi* and *Kaddar* – which emphasized self-denial for the sake of community well-being and the dignity of labor, respectively – Schumacher called for the replacement of “the Economics of Materialism” with a new form of developmental economics which factored in considerations of cultural preferences, environmental impacts, and local control of technology. Schumacher’s subsequent efforts through the 1960s to promote incremental technological improvement, self-help, and grassroots solutions formed the basis for a philosophy of what he termed “intermediate technology.” Development projects, he urged, should implement technologies which were simple enough to be manufactured, maintained, and used by local communities and which did not do violence to the environment, workers, or the community.⁴¹⁶

Although ultimately doing little to change the dominant theory and practice of development during the 1960s, the idea of intermediate technology captured attention among many environmentalists and counterculture groups who saw it as equally applicable to problems in the overdeveloped First World as to those facing the underdeveloped Third World. During the late 1960s, these groups extended Schumacher’s original concept into the broad-reaching doctrine of “appropriate technology” (AT) which they envisioned as a basis for challenging a

⁴¹⁵ E.F. Schumacher, “Economics in a Buddhist Country,” paper written from the Government of the Union of Burma, Rangoon, 1955 in *Roots of Economic Growth*, ed. E.F. Schumacher (Varanasi: Gandhian Institute of Studies, 1962), 1-8.

⁴¹⁶ E.F. Schumacher, “Industrialisation through ‘Intermediate Technology,’” in *Industrialisation in Developing Countries*, ed. Ronald Robinson (Cambridge: Cambridge University Press, 1965), 91-99.; E.F. Schumacher, “Levels of Technology” in *Roots of Economic Growth*, 48-56.; and E.F. Schumacher, “The Work of the Intermediate Technology Development Group in Africa,” *International Labour* 106, no. 1 (1972): 75-92.

hegemonic culture that favored large-scale energy-intensive technologies and that defined progress as a natural result of unending economic growth.⁴¹⁷

This critique of the dominant philosophy of technology gave direction and purpose to the American counterculture. In his 1969 *The Making of a Counter Culture*, Theodore Roszak called on young people to unify against “technocracy,” which he defined as a “society in which those who govern justify themselves by appeals to technical experts, who in turn justify themselves by appeals to scientific forms of knowledge.”⁴¹⁸ True social reform could not occur without replacing the present techno-scientific regime with one more suited to individual freedom of action and expression and environmental sustainability. Choosing the right technology became part of the process of choosing a new lifestyle. The aim, Charles Reich wrote in *The Greening of America*, was “transcendence, or personal liberation.” Though presented as a reaction against the traditional teleology of progress, Reich’s argument still professed a belief in the possibility of social betterment through lifestyle and technological change. “It is liberation that is both personal and communal,” he wrote, “as escape from the limits fixed by custom and society, in pursuit of something better and higher.”⁴¹⁹

This alternative technophilia was best captured in the pages of the eclectic *Whole Earth Catalog*, first released in 1968. The brainchild of Stanford biology drop-out Stewart Brand, the essays and product descriptions that comprised *Whole Earth* balanced criticism of large-scale technologies, big business, and bureaucratization with optimism about humans’ mechanical proficiency and capacity for creating healthier, happier, and more humane communities through

⁴¹⁷ Carroll Pursell, “The Rise and Fall of the Appropriate Technology Movement in the United States, 1965-1985,” *Technology and Culture* 34, no. 3 (July, 1993): 632.

⁴¹⁸ Theodore Roszak, *The Making of a Counter Culture: Reflections on the Technocratic Society and its Youthful Opposition* (New York: Doubleday, 1969), 8.

⁴¹⁹ Charles A. Reich, *The Greening of America: How the Youth Revolution is trying to Make America Livable* (New York: Random House, 1970), 363.

the adoption of “human-scale” technologies. The catalog introduced a generation of counterculture drop outs, LSD mystics, backyard inventors, new age homesteaders, and communitarians to simple, accessible tools that would aid in developing the “power of the individual to conduct his own education, find his own inspiration, shape his own environment.”⁴²⁰ Within the covers of *Whole Earth*, historian Andrew Kirk observes, “the seemingly neat bipolar world of twentieth-century environmental politics became a messy mélange of apparently incongruous philosophies and goals united under the banner of whole systems, cybernetics, and alternative technology.”⁴²¹ The reconciliation of juxtapositions found in the pages of *Whole Earth* and in Schumacher’s notion of intermediate technology became a defining feature of the revival of solar energy following the oil embargo.

The larger effect of the appropriate technology movement was to introduce more diverse criteria for making choices about technology. Following the embargo, this expanded criteria provided the basis for a new direction in solar politics. Specifically, it introduced the concept of what Langdon Winner labeled “technology as legislation” as a challenge to the existing model of progressive reform based on regulating technological systems.⁴²² Technology was increasingly viewed not only an object to shape to meet political goals but as a semi-autonomous force which by its material constitution tended to produce certain social and environmental outcomes. While the existing image of solar technologies as compatible with a high-energy, growth economy persisted, this notion increasingly existed in conflict with an emergent view of solar as naturally conducive to more distributed, environmentally benign, and low energy patterns of social organization. This challenge to the existing energy paradigm included a corresponding challenge

⁴²⁰ Stewart Brand, ed., *Whole Earth Catalog: Access to Tools* (San Francisco: Portola Institute, 1968), 1.

⁴²¹ Andrew G. Kirk, *Counterculture Green: The Whole Earth Catalog and American Environmentalism* (Lawrence: The University Press of Kansas, 2007), 15-16.

⁴²² Langdon Winner, *Autonomous Technology: Technics-out-of-Control as a Theme in Political Thought* (Cambridge, MA: MIT Press, 1977), 317-324.

to the role of government as an agent of technological change. In the United States, while economic productivity, efficiency, and national security remained priorities in federal energy policy, considerations of environmental quality and local autonomy in decisions about technology increasingly became part of the equation, putting pressure on policymakers to create new institutions and research agendas to accommodate alternative visions of the nation's future.

Origins of the US Federal Solar Program

These ideas made only limited inroads in the immediate aftermath of the embargo. Initially, the US federal response focused on curtailing the rapid increase in oil prices. On November 27, President Richard Nixon signed the Emergency Petroleum Allocation Act, providing authority for government regulation of fuel allocations and rationing. To mitigate the immediate impacts of the embargo, Nixon also called for reducing gasoline distribution to wholesalers, periodic closures of gas stations, reducing passenger jet travel, and cutting back holiday lighting. The president also outlined a more ambitious long term agenda in his announcement of Project Independence, which was aimed at making the US entirely energy self-sufficient by 1980. Nixon's public statement on the project, however, did not convey a clear strategy for achieving that aim.⁴²³ The project was also announced before the enormity of the task was fully appreciated. While creating an early forum for considering the role solar and other alternative sources might play in the nation's energy future, Project Independence never amounted to more than a "blueprint" and was never adopted as formal policy. It did, however,

⁴²³ Richard Nixon, "Address to the Nation about National Energy Policy," November 25, 1973, *The American Presidency Project*, accessed November 13, 2014 at <http://www.presidency.ucsb.edu/ws/?pid=4051>.

signal a shift toward energy independence and self-sufficiency – as opposed to simply abundance and low cost – as federal priorities for the nation’s energy future.

Overall, while partly aimed at curtailing “fuelish” behavior in the short term, Nixon’s early actions were geared toward protecting American businesses and consumers by stabilizing prices without giving Arab leaders the impression that the embargo had caused the US to panic and radically alter its approach to energy use. To commit to a more ambitious course of curtailing consumption and encouraging the widespread implementation of renewable energy technologies, Nixon and his “arch-priest” of foreign policy Henry Kissinger feared, could lead OPEC to pursue more aggressive actions along the same lines as the embargo. It could also create rifts within the US’s already tenuous relationships with other oil-dependent industrialized nations, including the Soviet Union.⁴²⁴

Other factors limited Nixon’s options. Anti-inflation measures developed in response to the economic crisis conflicted with conservation measures. Backlash from the Watergate scandal also eroded public trust in the president and the federal government in general.⁴²⁵ In working toward a unified national response to the energy crisis, Nixon was also entering uncharted terrain. Federal energy institutions remained largely unchanged since World War II, in part because of the lack of general concern with scarcity, and in part because energy had never been a central focus of either government planning or environmental activism. As a result, no single agency was responsible for overseeing the nation’s energy requirements. Instead,

⁴²⁴ James S. Szyliowicz, “The Embargo and U.S. Foreign Policy,” in *The Energy Crisis and U.S. Foreign Policy*, ed. Joseph S. Szyliowicz and Baed E. O’Neill (New York: Praeger Publishers, 1975), 184, 190, 214-217. In his opening speech at the Washington Energy Conference on February 11, 1974, Kissinger actually called for a far-reaching cooperative effort among nations to support conservation, research and development, Third World development, energy sharing, and research into alternative energy sources, but was rebuked by Western European statesmen, especially from France, who worried about a US-led “new world energy order.”

⁴²⁵ Jack M. Holl, “The Nixon Administration and the 1973 Energy Crisis,” in *Energy and Transport: Historical Perspectives on Policy Issues*, ed. George H. Daniels and Marck H. Rose (Beverly Hills: Sage Publications, 1982), 150-151.; Melosi, *Coping with Abundance*, 284-285.

responsibilities for regulating the supply, production, and distribution of energy were spread out among a spectrum of agencies, and were typically source-specific.⁴²⁶ These factors continued to structure federal energy programs through Gerald Ford's presidency, and while development of non-nuclear energy alternatives including solar became part of the agenda, efforts toward this goal tended to be piecemeal, underfunded, lacking direction, and beset by interdepartmental and interagency conflict.⁴²⁷

The impetus for establishing a more robust federal solar program came from Congress. In November 1973, California Senator Alan Cranston (D) proposed an amendment to the Energy Reorganization Act which would allow consumers a \$1,000 tax credit for adding insulation to their home, installing storm windows, caulking, or taking other measures "to utilize solar energy to provide for heating or cooling." During the same month, in the House of Representatives, Washington Congressman Mike McCormack (D), a former nuclear scientist who adopted solar energy advocacy as a complement to his fervently pro-nuclear stance, introduced the Solar Home Heating and Cooling Demonstration Act, a bill intended to provide government funding for home solar energy research and development. While this bill was still being debated in Congress, McCormack also drafted the more expansive Solar Energy Research, Development and Demonstration Act which would provide for long term research into a wider variety of solar technologies including wind power, ocean thermal, biomass, and photovoltaics. The act also provided for the establishment of a national solar energy research institute and a solar energy information bank for providing consumers with information about available technologies, costs,

⁴²⁶ Neil De Marchi, "Energy Policy under Nixon: Mainly Putting out Fires," in *Energy Policy in Perspective: Today's Problems, Yesterday's Solutions*, ed. Craufurd Goodwin (Washington D.C.: The Brookings Institution, 1981), 398-399.

⁴²⁷ These early struggles as well as the successes are covered in detail in Donald A. Beattie, "The Buildup Years: 1974-1977," in *History and Overview of Solar Heat Technologies*, ed. Donald A. Beattie (Cambridge: MIT Press, 1997), 56-96.

and manufacturers. Buoyed by the administration's desire to act quickly in response to the energy crisis, McCormack's omnibus solar bill sailed relatively easily through Congress and the Senate despite its unpopularity with the Office of Management and Budget (OMB) and the AEC. The bill was signed by President Ford on October 11, 1974, becoming the federal government's first major solar energy subsidy.⁴²⁸

In addition to McCormack's bills, Ford also signed the Energy Reorganization Act (ERA). The bill abolished the AEC, dividing its functions between the newly created Nuclear Regulatory Commission (NRC) and the Energy Research and Development Administration (ERDA). As historian Frank Laird observes, however, while ERDA provided a new forum specifically devoted to energy technology research, the institutional values that had long animated federal energy policy remained firmly in place. With much of the former AEC leadership remaining in leadership positions, the prevailing concern was to find new ways to meet the nation's ever growing demand for energy without an exclusive reliance on oil. Following the pattern of the previous decade, this approach heavily favored nuclear as the most promising alternative.⁴²⁹

ERDA's long term goals also continued to reflect a traditional belief in the link between increasing energy use and social and cultural development. John Love, head of Nixon's emergency energy task force, best expressed this sentiment when he wrote: "I do not believe that it is an overstatement to claim that the distance man travels from his cave – that is both his social and material progress – can be measured by his use of energy to improve his environment, to produce goods, to make things grow and to provide mobility."⁴³⁰ Even in the solar field, this kind

⁴²⁸ Hempel, "The Politics of Sunshine," 114-121.

⁴²⁹ Frank N. Laird, *Solar Energy, Technology Policy, and Institutional Values* (New York: Cambridge University Press, 2001), 88-90.

⁴³⁰ Quoted in *Ibid.*, 95.

of thinking favored high tech research and large-scale, centralized power generation proposals along the lines of the nuclear plants pursued by the AEC. As Laird points out, this focus “left out, or made it difficult to justify, a whole range of policies, particularly those relating to certain solar technologies and decentralized energy production, some of which were beginning to develop a constituency.”⁴³¹

Also, despite increasing public interest in solar and strengthening congressional advocacy, few federal officials took the new solar legislation seriously. Following the oil embargo, AEC chairman Dixy Lee Ray, author of the strongly pro-nuclear 1973 report *The Nation's Energy Future*, referred to solar energy as “a flea on the back of the nuclear elephant.”⁴³² At a 1974 solar energy conference sponsored by the National Science Foundation, Frank Zarb of the OMB told the audience, “I’d like to be able to tell you that solar energy is our first commitment, but it isn’t. Nuclear technologies are. I can’t even tell you it comes second. I’ve already told the coal industry it comes second.”⁴³³

These commitments persisted despite strong opposition from ERDA’s solar research staff and members of Congress. South Dakota Senator James Abourezk was especially vocal, charging the AEC with deliberately misleading the public “about the relative feasibility of generating electrical power by nuclear and solar means.”⁴³⁴ Abourezk further argued that the problem with funding solar energy research and development as part of a broader national energy strategy based primarily on nuclear, coal, and oil was that it allowed powerful corporate interests to secure the vast majority of funding for research. While maintaining the corporate line that

⁴³¹ Ibid.; 111.

⁴³² Quoted in Beattie, “The Early years of Federal Solar Energy Programs,” in *History and Overview of Solar Heat Technologies*, 34.: Dixy Ray Lee, *The Nation's Energy Future: A Report to Richard M. Nixon, President of the United States* (Washington D.C.: Atomic Energy Commission, Government Printing Office, 1973).

⁴³³ Marguerite Villecco, “Sun Power,” *Architecture Plus* (September-October 1974): 85-99.

⁴³⁴ Richard T. Cooper, “Feasibility of Using Solar Energy Reportedly Ignored in AEC Plans,” *Los Angeles Times*, April 3, 1974.

solar “was way down the pike,” he predicted (rightly as it turned out), oil companies would “quietly buy into solar energy companies” with the intent to dictate the course of solar research. In this scenario, solar would continue to be “the neglected stepchild of both federal and corporate entity development programs.”⁴³⁵ An alternative, he proposed, would be “to enact legislation underwriting a private solar energy industry and prohibiting the entry of companies already involved in oil, coal or other competitive energy fields.” A federal program to build an industry from the ground up without intervention “from the enemies of solar power” would address the nation’s energy emergency while opening up a new field for entrepreneurial competition.⁴³⁶

The countervailing pressures on the federal government during this period made a strong new direction in energy policy such as Abourezk proposed unlikely. Pulled in multiple directions by environmentalists lobbying for aggressive conservation measures and exploration into non-nuclear alternatives; by the oil, coal, and nuclear industries seeking to protect their bottom lines and to maintain high levels of demand; by labor, business, and consumer groups advocating for price controls on oil; and by diplomatic considerations, ERDA and the executive office remained focused on developing solar technologies as supplements to the existing energy mix rather than as a basis for a more substantive energy transition.

Though constrained by intuitional and normative barriers, these early federal programs marked the start of the first concerted national effort to come to grips with the impermanence of the present energetic basis of the American way of life. They also provided an institutional framework around which a more serious debate about scarcity, technology, and the future course of industrial society began to coalesce. Even as the immediate effects of the oil embargo diminished during the mid-1970s, these debates continued to intensify, reflecting and

⁴³⁵ “Oil Firms, AEC Accused of Impeding Development, All-out Effort Urged to Utilize Solar Energy,” *Los Angeles Times*, May 2, 1974.

⁴³⁶ *Ibid.*

contributing to a change in cultural attitudes about what constituted a desirable future and how to get there.

The Research and Development Path

A spectrum of viewpoints on solar's future potential took shape in this period. Solar engineers in the aerospace industry maintained a generally conservative stance, supporting the research and development focus of ERDA as a proven method for taking advantage of the nation's scientific and engineering prowess. They also saw it as a reliable funding source for their research. For Peter Glaser, the oil crisis had been "a dress rehearsal of the conditions we can find ourselves in when energy supplies cannot meet energy demands." In preparing for the future, he said, solar energy offered "an inexhaustible alternative energy source if it can be harnessed within economic, environmental, and social constraints." He also argued that while the technological capabilities already existed for solar to meet "our national energy objectives," widespread commercialization was not on the horizon. The problem in the present was a lack of "industrial experience and capacity to produce the devices at the desired low cost," he said. The recent realization of long sought for legislation providing for government research and development funding marked only "the beginning of the development cycle."⁴³⁷ Lloyd Herwig, director of solar energy research at the NSF, echoed the sentiment, expressing excitement about the state of the technology while at the same time calling for additional "Proof-of concept"

⁴³⁷ Peter E. Glaser, "The Solar Power Option," *The Energy Crisis and Energy from the Sun*, 75-77.; The idea that government funds would go towards economically, socially, and environmentally viable commercial applications rather than wholly new technologies further aligned with industrial research objectives. For additional perspective on industry views from the standpoint of the American Institute of Aeronautics and Astronautics (AIAA) see the essays in Harrison J. Killian, Gordon L. Dugger, and Jerry Grey, eds., *Solar Energy for Earth: An AIAA Assessment* (New York: AIAA, 1975).

experiments. Solar, in terms of commercial prospects, was still a future technology, according to this line of thinking. Years of federally funded research and development would be necessary “before practical systems become feasible.”⁴³⁸

Not all industrial scientists supported this gradualist path. Some expressed interest in the possibility of creating a social and environmental revolution by introducing a revolutionary new technology. These viewpoints reflected a shift in the culture of American research institutions by the 1960s in which countercultural philosophies and alternative models of society became sources of inspiration as well as subjects for empirical analysis.⁴³⁹ By the 1970s, America’s top private and public research facilities were filled with “computer nerds with a conscience,” as one writer put it.⁴⁴⁰ This was especially true in California where, as historian Fred Turner details, collaboration between Stewart Brand’s *Whole Earth* network and a new generation of electronics entrepreneurs and research scientists in the San Francisco Bay area launched the personal computer revolution.⁴⁴¹ Meanwhile at Berkeley, a group of young physicists were dabbling in eastern mysticism, mind-reading, and LSD en route to framing much of the theory and practice for the emerging field of quantum mechanics.⁴⁴²

Countercultural ideas also infiltrated industrial and university-based research and development of new energy sources. As early as 1972, Stanford Solar Energy Task Team member Phillip Beinhauer offered to “explore the verbalized realm of ecologically oriented futuristic designers, developers and master planners, particularly the fashioners of new living

⁴³⁸ Lloyd O. Herwig, “Growing Federal Support for Solar Energy Applications,” *The Energy Crisis and Energy from the Sun*, 94.

⁴³⁹ For example, see John H. Martin, “Solar Energy in Providing for Alternate Lifestyles,” *Solar Energy* vol. 18 (1976): 481-488.

⁴⁴⁰ Arthur Allen, “Prodigal Sun,” *Mother Jones* (March/ April 2000). Accessed May 22, 2013 at <http://www.motherjones.com/politics/2000/03/prodigal-sun>.

⁴⁴¹ Fred Turner, *From Counterculture to Cyberculture: Stewart Brand, the Whole Earth Network, and the Rise of Digital Utopianism* (Chicago: University of Chicago Press, 2006).

⁴⁴² David Kaiser, *How the Hippies Saved Physics: Science, Counterculture, and the Quantum Revival* (New York: W.W. Norton & Co., 2011).

situations and residential dwellings, and write summary reports of ‘relevant material’ for distribution among us.” His intent was to familiarize the team with “whole systems oriented thinking, especially that relating to new life-style generating as well as new life-style generated dwelling arrangements” such as those depicted in the pages of *Whole Earth*.⁴⁴³

In a report from that same year, Jerome Weingart, a senior engineer working on solar energy projects at Cal Tech’s Environmental Quality Laboratory in Pasadena, proposed a new approach to “social learning” which addressed the links between social, environmental, and technical issues. The problem of stasis in the field of energy, he said, was “a reflection of our increasing non-adaptability.” Only by rejecting “the ethic of specialization which has accompanied the industrial revolution and the emergence of industrial society” could humanity hope “to survive the implications of the present trends.” He further argued that there was no simple technological fix to current problems. “Simply adding on new sources of energy, such as geothermal, solar energy, breeder reactors, nuclear power systems, to permit us to sustain a little longer the patterns of exponential growth which have characterized much of the industrial and economic dynamics of our society in the past, is no answer at all,” he wrote. A substantive transformation in technology could not occur without a concurrent effort to “develop new approaches to society” – to implement and internalize “a new environmental ethic reflecting the finite and sensitive nature of the global ecosystem.” A more comprehensive, multi-faceted technology introduction program would “provide us with the multiplicity of broad social and

⁴⁴³ Phillip Beinhauer to Solar Energy Task Team and Luther Gerlach, April 4, 1972. Howard Seifert Papers, Stanford University Special Collections, Folder D-V-a, “Corr. And Notes.”

technical options which we will require to create a healthy and stable total human environment, for our children and all the future children of Man.”⁴⁴⁴

While many researchers shared these sentiments, the federal government’s funding structure was not conducive to advancing a broader social agenda. The first major solar research grants issued under the new solar legislation in 1974 went to nuclear powerhouses Westinghouse, General Electric, TRW, and Honeywell, hardly companies that would have an interest in radically transforming the structure of the American economy.⁴⁴⁵ In addition, the project list for solar research at Stanford University for the period from 1973 to 1975 included corporate and government funded research on narrow technical questions regarding solar cell materials, components of satellite arrays, small energy storage systems, and solar systems for providing small amounts of power to oil rigs in the Gulf of Mexico.⁴⁴⁶

Increased federal oversight even frustrated more conservative industrial research lab managers. In 1975, Stanford researcher Howard Seifert wrote to H.E. Maninger of Northrop to inform him that ERDA would likely reject their joint proposal for a research program to study solar heating and cooling of large volume aircraft manufacturing buildings. “It is particularly unfortunate that recent shifts in solar energy R&D management within the government resulted in fundamental changes in the way acceptable research programs are to be approved and funded,” Maninger responded. “I believe that the current attitude of having government

⁴⁴⁴ Jerry Weingart, rough draft of “Introduction, Background, Effective Programs for Social Change,” 25 April 1972. Howard Seifert Papers, Stanford University Library, Special Collections, box 12, “correspondence and notes.”

⁴⁴⁵ Beattie, “The Early Years of Federal Solar Energy Programs,” 34.

⁴⁴⁶ Kent M. Price to Dr. Grayson Heffner, Lawrence Berkeley Laboratory, 9 December 1975. Howard Seifert Papers, Stanford University Library, Special Collections, box 12, “correspondence and notes.”

formulate programs in this relatively new area and then formally solicit offerings from the private sector will fall short of realizing the full potential of the technical community.”⁴⁴⁷

The Revolutionary Path

This introduction of scarcity as a theme in environmental politics after the oil embargo also inspired more radical challenges to the federal government’s approach to solar development. These critiques blended general criticism of the philosophy of unending economic growth with a belief that society’s choice of energy technology would have a powerful bearing on the future character of that society. Social, economic, and environmental reform in the age of scarcity became a matter of selecting a suitable energy technology. These ideas attracted a wide range of adherents including environmentalists, scientists, and economists, linked by a shared apprehension about the limitations and risks of current models of energy use, consumption, and economic development. William Heronemus, a professor of engineering at the University of Massachusetts, captured this view in a 1975 essay calling for a replacement of the “doctrine of substitutability” in energy economics with an accounting system that incorporated non-economic factors including the risks of nuclear energy and the finitude of essential energy resources. Such a transformation could only occur via “a world system organized toward the practical and reasonably paced conversion to solar energy practices,” and would mean “paying maximum attention to things more in keeping with the dignity and aspirations of man.”⁴⁴⁸

⁴⁴⁷ Howard Seifert, Unsolicited Research Proposal to National Science Foundation, Research Applied to National Needs (RANN), “Use of Solar Energy to Reduce Purchased Energy in a Large Aircraft Manufacturing Facility (Northrop Corporation)” Stanford Proposal No. 11-75, February 14, 1975. Howard Seifert Papers, Stanford University Archives, box 12.; H.E. Maninger to Dr. Howard Seifert, 30 June 1975. Howard Seifert Papers, Stanford University Archives, box 12.

⁴⁴⁸ William E. Heronemus, “The Case for Solar Energy,” *The Center Report* 8, no. 1 (February 1975): 6.

The energy crisis also led prominent ecologist Barry Commoner to narrow the focus of his broad critique of technology to energy economics specifically. In his 1976 *Poverty of Power: Energy and the Economic Crisis*, Commoner argued that the creation of a truly “rational” human society would require balancing the three basic systems governing all human activity – the ecosystem, the production system, and the economic system. “Logically,” he wrote, “the economic system ought to conform to the requirements of the production system, and the production system to the requirements of the ecosystem.” In the modern era, however, this chain of dependence had been upended, with the imperatives of the economic system determining production, thus accelerating the degradation of the ecosystem upon which the whole structure rested.⁴⁴⁹

The key to righting the ship, Commoner proposed, was to reorient the economic system around the principles of the second law of thermodynamics, the law of entropy, which described how energy actually performed work in the physical world. To avoid the interconnected environmental, social, and economic crises which would inevitably follow from humanity’s overreliance on ever-increasing amounts of scarce, polluting fossil fuels, the profit basis of the energy economy would have to be jettisoned in favor of an economic system determined by calculations of the thermodynamic requirements of specific tasks. Electricity, for example, should not be considered valuable in and of itself but only in terms of the work it performed. If some other method of converting energy to perform a task – such as the use of solar collectors to heat water for home use – could best electricity in terms of the total units of energy expended,

⁴⁴⁹ Barry Commoner, *The Poverty of Power: Energy and the Economic Crisis* (New York: Alfred A. Knopf, 1976), 2.

the waste generated in the production process, and the long-term availability of the source, then such a method should be adopted even at a higher initial cost.⁴⁵⁰

For Commoner, nothing short of a complete overhaul of the world's economic system could bring about the changes he envisioned. He proposed the elimination of private ownership in favor of a socialized economy in which science informed economic decisions and the public owned the technologies of production. His justification was that a shortage of capital was already threatening free-market capitalism. Rising energy prices, in combination with the massive push to subsidize oil and gas production and especially nuclear energy, suggested that private investment had already become insufficient to meet energy demand. These developments were “empirical evidence that at least in the energy sector there *is* a shortage of capital; that private entrepreneurs are unable to meet capital requirements out of their own earnings; and that they are not so devoted to the ideology of private capital as to reject *social* capital – when they need it.”⁴⁵¹ Commoner proposed to accelerate this transition while shifting the aims from profits to ecological sustainability and social justice. His larger goal was to inaugurate a new stage in human development, to “transform...a threat to social progress into a signal for a new advance.”⁴⁵²

Commoner saw solar energy as an important pillar of a science-based, eco-socialist economy. First, the technologies already existed. The principles were simple, the components were widely available, and, unlike nuclear power plants, solar devices could be mass produced using the nation's existing labor and manufacturing infrastructure. Second, the desirability of solar energy stemmed from its inherent qualities, especially its “*radiant*” nature. Unlike fossil fuels and uranium, he argued, the supply of sunshine was predictable and non-diminishing,

⁴⁵⁰ Ibid., 10, 24, 30-32.

⁴⁵¹ Ibid., 260.

⁴⁵² Ibid., 264.

meaning that the cost of producing solar energy would not increase with increased end use, as was occurring with oil. In fact, the sun could not be embargoed at all. “No giant monopoly can control its supply or dictate its use,” Commoner wrote. Sunlight “is an ephemeral thing...it cannot be possessed.” He also argued that the economic advantages of scale which prompted the consolidation of fossil fuel energy technology systems would not exist in a solar energy economy. The value of solar energy would instead lie in “its use – the outcome of its relation to a process, to a task.” These qualities made solar energy ideally suited to local- and regional-scale development. This aspect, Commoner assured, would counteract the trend towards centralized autocratic control that many Americans associated with socialism.⁴⁵³

While Commoner’s socialism ultimately proved divisive, his concept of solar energy utilization as naturally conducive to democracy became a central tenet of 1970s energy politics.⁴⁵⁴ Many environmentalists echoed the notion of solar energy as inherently different from other energy sources. “Solar energy is democratic. It falls on everyone and can be put to use by individuals and small groups of people,” declared Allen Hammond and William Metz in their influential 1977 article “Solar Energy Research: Making Solar After the Nuclear Model.”⁴⁵⁵

The appeal of these claims may have derived less from their originality than their consistency with an older narrative about the democratic tendencies of certain types of technology, including solar. They recalled the idea of solar energy as naturally conducive to individual freedom that took shape in California in the early twentieth century. They also displayed commonalities with the values attributed to hydropower a generation before. In his 1934 *Technics and Civilization*, Lewis Mumford – also writing from a Marxist standpoint –

⁴⁵³ Ibid., 151-154.

⁴⁵⁴ Egan, *Barry Commoner and the Science of Survival*, 164-166.

⁴⁵⁵ Allen Hammond and William Metz, “Solar Energy Research: Making Solar After the Nuclear Model,” *Science* 197 (July 15, 1977): 241-244.

argued that hydroelectricity would eliminate the need to shackle workers to huge, centralized steam engines; it would disperse manufacturing from the cities to the countryside and give small farmers access to the labor-saving machinery that had previously only been available to large producers. Hydropower, Mumford believed, would enable democracy because it was integrated with natural processes and responsive to the basic requirements of human life.⁴⁵⁶

Commoner's discussion of thermodynamics as a basis for energy choices also reprised arguments from the 1930s. Specifically, it exhibited parallels with tenets of the technocracy movement which flourished briefly during the early 1930s as an alternative response to the Great Depression. Conceived originally by a group of planners and engineers at Columbia University, the idea of technocracy offered a scientific solution to the problems with the present social and economic order. By evaluating all social activities according to thermodynamic expenditures, the technocrats argued, a small centralized ruling body of engineers could transform the current inefficient, unstable, and inequitable profit-driven system into smoothly operating machine that guaranteed long term prosperity for all.⁴⁵⁷ One component of the system would be the issuing of "energy certificates" to each individual member of society. The certificates would be coded to indicate the person's gender, race, and age and would serve as script for obtaining goods and services. The certificates could then be compiled as a record "on the state of consumption of every kind of commodity or service in all parts of the country," according to their "energy cost."⁴⁵⁸ While Commoner specifically rejected top-down management of technology as a basis for his environmental activism, his model of a solar society still seemed to necessitate a system of accounting similar to that proposed by the technocrats.

⁴⁵⁶ Lewis Mumford, *Technics and Civilization* (New York: Harcourt, Brace and Company, 1934), 6, 157, 168-169, 371-372.; Hughes, *American Genesis*, 355-360.

⁴⁵⁷ For an intellectual history of the technocracy movement see William E. Akin, *Technocracy and the American Dream: The Technocrat Movement, 1900-1941* (Berkeley: University of California Press, 1977).

⁴⁵⁸ Technocracy, Inc., *Technocracy Study Course* (New York: Technocracy Inc., 1934), 238-240.

The Countercultural Path

Commoner's premise of restructuring society around the law of entropy was not universally accepted among solar advocates, even those critical of federal programs. Consistent with the techno-libertarianism expressed in the pages of the *Whole Earth Catalog*, many prominent figures in the American counterculture preferred a greater degree of individual choice in energy technology decisions. As solar energy attracted greater public attention in the wake of the oil embargo, a diverse collection of countercultural inventors and alternative lifestyle advocates joined the political conversation, seeking to push the technology in a different direction from both the research and development path envisioned by federal policymakers and the revolutionary path put forward by Commoner.

Rejecting the technocratic implications of Commoner's work, countercultural conceptions of solar energy demonstrated affinities with a more skeptical political sensibility which formed during the 1970s in response to corruption and intransigence in the federal government and the perceived failures of the progressive liberal state to adequately address the social and environmental concerns that had emerged at the forefront of American politics during the 1960s. Although exhibiting a contemporary regard for ecological limits and alternative lifestyles, countercultural solar advocates also built on older ideas, reviving a Jeffersonian view that technology should be scaled to the level of the household, and that the trend toward large-scale, centralized mechanization of production that began in the late eighteenth century violated the American principle of democracy. Writing in 1976, historian John F. Kasson spoke to present

concerns when he identified “social service, industry, frugality, and restraint” as the core principles of late eighteenth century republican ideology.⁴⁵⁹

Reframing these ideas in the context of the crisis decade of the 1970s, countercultural solar advocates adopted solar technology for its potential to promote energy self-sufficiency for individuals and small communities while minimizing impacts to the environment. This involved reinventing the architecture of the living space while adjusting lifestyles and expectations to the constraints of a limited, vulnerable environment. By the mid-1970s, the concern with preserving purity in nature which had propelled the conservation and environmental movements in the 1960s became secondary to considerations about what inventor and countercultural icon Buckminster Fuller referred to as “umbilicals,” the hidden flows of energy and materials which went into the construction and functionality of homes and other structures.⁴⁶⁰ “If many suburbanites looked out the picture window and were motivated to protect what nature remained for self-interest or the common good,” historian Andrew Kirk observes, “alternative technologists stood outside looking in and were trying to think how they could make the home a more ecologically sustainable place.”⁴⁶¹ Through the 1970s, the *Whole Earth Catalog* and its offshoots served as repositories of information about countercultural experiments in architecture, design, and alternative lifestyles.

New Mexico inventor Steve Baer became one of the figureheads of the counterculture design movement. Like many other appropriate technology pioneers, Baer left behind a college education in mathematics and physics to pursue a less orthodox path. In 1965, he helped found

⁴⁵⁹ John F. Kasson, *Civilizing the Machine: Technology and Republican Values in America, 1776-1900* (New York: Grossman Publishers, 1976), 4, 25.

⁴⁶⁰ Chris Zelov and Phil Cousineau, *Design Outlaws on the Ecological Frontier* (Philadelphia: Knossus, 1997), 37.; J. Baldwin, *BuckyWorks: Buckminster Fuller's Ideas for Today* (New York: John Wiley & Sons, 1996), 28.

⁴⁶¹ Kirk, *Counterculture Green*, 82.

the Colorado art colony “Drop City” where he had the opportunity to transform his academic interest in solar energy and geodesic domes into practical solutions. Baer typified a select group of innovators one *Whole Earth* editor referred to as “bailing wire hippies” whose combination of creativity, resourcefulness, practical talents, and willingness to experiment made them invaluable in the day-to-day work of building new communities. He also proved to be an engaging writer and critic. His 1968 *Dome Cookbook*, a primer on geodesic dome construction based on his work at Drop City, became a foundational work in ecological design and an important precursor to the *Whole Earth Catalog* and other counterculture texts. In 1969, Baer founded the company Zomeworks as an outlet for his unique home designs and devices. In addition to “zomes,” the modular passive solar dome structures he had built at Drop City, he marketed dome-shaped steel truss playground climbers and a variety of passive solar components including the “Skylid,” a sunlight-activated hydraulic home ventilator. Business was slow during the early 1970s, despite media exposure and financial support from Stewart Brand’s Point Foundation. The zomes often leaked or required more maintenance than most consumers were willing to put in. Also, the company did not have the finances to manufacture quality products on a competitive basis. “It’s very exciting intellectually to work with these ideas,” Baer told an interviewer in 1973, “but their validity will not really be proven until they start to replace the things they’re meant to replace.”⁴⁶²

Baer was also deeply skeptical of government involvement in solar development, believing that federal subsidies would ultimately work against him and against solar energy technology in general. In 1973, just after the oil embargo, he attended a conference hosted by the Solar Energy Society where he encountered the wide variety of people working in the field.

⁴⁶² “The Plowboy Interview: Steve Baer and Holly Baer,” *Mother Earth News*, 22 (July/August 1973), accessed November 28, 2014 at <http://www.motherearthnews.com/nature-and-environment/steve-baer-holly-baer-dome-home-zmaz73jazraw.aspx#axzz3KOhnl81R>.

These included “representatives of large corporations such as Exxon and Texas Instruments, swarms of scientists and professors – like enormous schools of minnows in a pond. And then of course the rest of us, crackpots, dreamers, small business people.” Baer was less excited than the conference sponsors and the majority of the attendees about the prospect of a greater flow of government money going towards solar research. After all, he pointed out, Arthur D. Little had already pocketed \$200,000 from the NSF and had nothing to show for it except more blueprints for its solar space ray. Baer was also discouraged by an “excited middle-aged reporter from *The Nation Magazine*” who was handing out questionnaires asking how long it would take for solar energy to supply the nation’s energy needs if unlimited funds were available. “My feeling is that if there were unlimited funds it would take an unlimited length of time,” Baer wrote. “Those working on the problem would just keep working and working on it – why should they worry? They’ll always have work and good pay – enough to buy the last gallons of oil.”⁴⁶³

A year later, Baer reported that his company’s applications for NSF funds had amounted to “0, or actually less than 0, figuring the time wasted.”⁴⁶⁴ The federal government, Baer decided, was not interested in supporting the simple, everyday devices he was developing at Zomeworks. “They can’t give the money to kooks, they can’t begin to follow unconventional paths.”⁴⁶⁵ The 11-room passive solar zome house he and his wife Holly built in 1971 served as his prototype of a living space that was “beautiful and simple” as well as comfortable, affordable, and nearly self-sufficient from an energy standpoint. “It’s not very exotic or earthshaking to fill 55-gallon drums with water, paint them black and place them in the walls of a home for use as solar collectors, but it works,” he said. “This is the kind of real innovation that actually makes organizations

⁴⁶³ Steve Baer, “Report on the Meeting of the International Solar Energy Society,” *The Tribal Messenger* (October/ November, 1973): 36.

⁴⁶⁴ Steve Baer, “Gravity Engines and the Diving Engine,” *Coevolution Quarterly* (Summer 1974): 81.

⁴⁶⁵ Baer, “Report on the Meeting of the International Solar Energy Society.”

function and keeps people happy...rather than the grandstand plays made by the Atomic Energy Commission or the National Air and Space Administration.”⁴⁶⁶

This mistrust of any kind of centralized decision-making was what distinguished the countercultural approach to solar development from that of ERDA, industrial scientists, and most environmentalists. Even the best intentioned federal program, Baer believed, would channel research and development energies towards a select few technologies which appeared to make sense from technical, ecological, and economic standpoints but which perhaps overshadowed other paths with less quantifiable benefits. In a 1974 article touting various designs for a “gravity engine,” Baer wrote: “It seems to me we should be building many varieties of engines to see which ones people get along with, which ones are more trouble than they are worth and which one are too dangerous.” How people judged whether or not to adopt a particular technology might not be easily discernible based purely on calculations of cost, efficiency, and output, he argued. “There are some things which people will do without in order to be free of fear or in order to be free of control by others.”⁴⁶⁷ Simple technologies and actions which were difficult to monitor or quantify could also be more effective in meeting larger energy and environmental goals than the types of projects under consideration in Washington D.C. and in the high tech companies lining up for federal project funds.

Baer expressed these ideas most fully in a 1975 article in the journal *Coevolution Quarterly* titled “The Clothesline Paradox.” He argued that the “energy pies” often used to demonstrate solar’s nearly non-existent contribution to the nation’s energy budget misled by failing to take into account the unquantifiable ways in which direct sunlight sustained human activities. Government programs intent upon giving solar a larger slice of the pie would, he said,

⁴⁶⁶ “The Plowboy Interview.”

⁴⁶⁷ Baer, “Gravity Engines,” 81.

end up favoring technologies which produced a measurable output. Thus, a person who installed solar panels to power their clothes drier would, according to the government, be giving a boost to the solar energy economy while someone who elected to dry their clothes in the sun on a clothesline would be contributing only a negative instance. Similarly, the choice to ride a horse, walk, or ride a bike to work rather than drive a car would constitute a subtraction of energy use rather than a positive use of the solar energy required to produce the food calories consumed in these activities. These examples indicated to Baer a fundamental flaw in the federal government's approach to solar energy development:

Now that the experts have started this infantile accounting system which evidently finds us completely independent of the sun, solar energy will be admitted only so long as it has been properly collected, stored and transferred. Legislation aimed at encouraging the use of solar energy equipment by subsidizing the price of certain hardware must end by being pathetic and blundering. It would take an enormous crew of experts to determine the efficiency of different orientations of windows, different arrangements of shade trees, etc., etc., etc. To ignore these efforts and only to reward the purchase of 'off the shelf hardware' is to further the disease of narrow minded quantification.⁴⁶⁸

Overall, Baer thought that any federally directed solar program would constrain individual efforts to design and build functional, energy efficient living spaces. The preoccupation with calculating costs per unit of energy had little relevance to the activity of discovering how to take advantage of the energy extant in the environment. "It's simply surprising," he said, "when you take these dead materials – this glass and metal and insulation – and place them together in very simple, easy-to-build forms and – suddenly! In the middle of winter! – there's *warmth*. From no place, so to speak because the energy wasn't apparent until you made the equipment to collect it and then its *there*."⁴⁶⁹ Baer's countercultural technological

⁴⁶⁸ Steve Baer, "The Clothesline Paradox," *Coevolution Quarterly* 8 (Winter 1975), 4.

⁴⁶⁹ "The Plowboy Interview."

enthusiasm incorporated a traditional optimism about humans' capacity to manipulate nature through technology with a critique of the closed networks of technical experts, corporate executives, and government officials which he felt had alienated most people from the process of invention.

Baer and other "design outlaws" drew inspiration from a variety of sources including design concepts from ancient civilizations, the visions of mid-twentieth century regional and urban planners like Lewis Mumford and Jane Jacobs, the philosophies of New Left social theorists including Murray Bookchin and Herbert Marcuse, and visionary inventors like Buckminster Fuller and low-tech solar pioneer Harold Hay.⁴⁷⁰ Science fiction works including Robert Heinlein's 1966 *Moon is a Harsh Mistress* which celebrated the virtues of local control of technology and Ernest Callenbach's best-selling 1975 eco-libertarian tract *Ecotopia* also became influential texts.⁴⁷¹ Countercultural inventors also built on the work of "ecological design" advocates including Ian McHarg, author of *Design with Nature* (1969), and New Mexico's Peter Van Dresser who Baer credited with coining the term "the clothesline paradox" and whose 1971 *Development on a Human Scale* addressed many of the themes later popularized through Schumacher's *Small is Beautiful*.⁴⁷²

In California, Sim Van Der Ryn, Berkeley professor of architecture and founder of the Farallones Institute in 1970, was also influential in the emerging countercultural design movement. For Van Der Ryn, the value of his and his students' work at the institute lay as much

⁴⁷⁰ Ibid., Jon Kovash, "Steve Baer, Beatnik Engineer," *Mountain Gazette*, August 3, 2012, accessed November 28, 2014 at <http://www.mountaingazette.com/magazine/august-2012/steve-baer-beatnik-engineer/>.

⁴⁷¹ Robert Heinlein, *The Moon is a Harsh Mistress* (New York: Putnam, 1966).; Ernest Callenbach, *Ecotopia: The Notebooks and Reports of William Weston* (Berkeley: Banyan Tree Books, 1975).

⁴⁷² Ian L. McHarg, *Design with Nature* (Garden City, NY: Natural History Press, 1969).; Peter Van Dresser, *Development on a Human Scale: Potentials for Ecologically Guided Growth in Northern New Mexico* (New York: Praeger, 1972).

in the sense of pride gained from creating a self-sufficient living space as in the design concepts themselves or in any specific energy savings. Recalling the first summer at Farallones, he wrote:

Each day and week flowed along, providing new learning and experiences. It wasn't just designing and building, but cooking, foraging for mushrooms, herbs, mussels, and learning how to throw a beach seine for herring. It was sitting around the stove in the Ark telling stories, eating, playing guitars, singing and drumming, and learning to sharpen chisels for the next day's work. It was volleyball and yoga, trips to the beach, and talks by local artisans. It was working out group differences in communication, work habits, and cooperation.⁴⁷³

The aim was not simply to add solar energy to the list of energy sources powering modern life or to reject modern technology, capitalism, or the idea of progress outright, but to draw on the insights of modern science and engineering to create an ecologically sustainable lifestyle from the ground up. The approach was to incorporate relatively simple techniques and technologies which made use of locally available natural resources (including recycled materials), which did not depend on government or expert oversight, and which engendered feelings of self-satisfaction and community cohesion.

Countercultural designers also took advantage of the expansion of media in this period, communicating their ideas through a variety of alternative publishing outlets.⁴⁷⁴ In addition to *The Whole Earth Catalog* and *CQ*, the countercultural literature from this period included an assortment of low-budget periodicals including *Mother Earth News*, *Rain*, *The Tribal Messenger*, *Kilowatt Counter*, *Alternative Sources of Energy*, *Well-Being Magazine*, and *AERO Solar Times*. These publications exposed Americans to an eclectic mix of perspectives on energy, ecology,

⁴⁷³ Regarding the early years of the Farallones Institute, Sim Van Der Ryn, *Design for Life: The Architecture of Sim Van Der Ryn* (Layton: Gibbs Smith, 2005): 43.

⁴⁷⁴ For the rise of the New Left underground media in the 1960s see John Campbell McMillian, *Smoking Typewriters: The Sixties Underground Press and the Rise of Alternative Media in America* (New York: Oxford University Press, 2011).; The alternative print culture developed in the 1960s took on a more individualistic "lifestyle" cast during the 1970s. See Sam Brinkley, *Getting Loose: Lifestyle Consumption in the 1970s* (Durham: Duke University Press, 2007), 101-128.

and technology. The eccentric, far future imaginings of Buckminster Fuller could be read alongside primers on self-contained space colonies, profiles of people living in self-built, off-the-grid homes, and how-to-guides for urban organic farming, solar retrofitting, composting toilets, and the use of discarded tires and beer cans in home construction.⁴⁷⁵

As the editors of these publications recognized their ability to influence American political culture more broadly, their aims shifted from dropping out of mainstream society to offering ideas for improving it. “To the extent that we can develop alternative institutions and technologies effectively,” the editor of *Alternative Sources of Energy* wrote in 1976, “we are more likely to influence other people to adopt these ideas to their lives.” It was not enough to scrutinize “the power of big government and big industry to control and corrupt” through “narrow moralizing.” Instead, the advent of the energy crisis offered an opportunity to “demonstrate working alternatives.... If ERDA or a university builds an expensive and overly complicated solar house, it’s up to us to demonstrate simpler and cheaper methods.... If a business is selling a product which is basically unsound, let us publish information that allows people to make a judgment. Making information available to all is a great equalizer.”⁴⁷⁶

These ideas also stimulated creativity in architecture, giving it a new political dimension. Countercultural designers rediscovered the solar house experiments of the 1940s and 1950s and sought to adapt existing concepts to new social and ecological sensibilities.⁴⁷⁷ Ecological design publications including Lloyd Kahn’s 1973 compilation *Shelter*, Richard Merrill’s *Energy Primer: Solar, Water, Wind and Biofuels* published by the Portola Institute in 1974, and Norma Skurka and photographer John Naar’s 1976 *Design for a Limited Planet* sold hundreds of

⁴⁷⁵ An extensive collection of these publications can be found in the “Earthmind Papers,” University of California, Davis, Special Collections.

⁴⁷⁶ “Editorial,” *Alternative Sources of Energy* 20 (March 1976): 1.

⁴⁷⁷ C.P. Gilmore, “Can Sunshine Heat (and Cool) your House?” *Popular Science* 204, no. 3 (March 1974): 78-81, 160.

thousands of copies. In addition to exposing Americans to a variety of weird but relatively simple approaches to improving home energy efficiency, these works also contributed to a shift in emphasis in design from aesthetics and technical details to the lifestyles and attitudes of the people who elected to build and live in unconventional homes.⁴⁷⁸ Solar living might require enduring lukewarm showers, a range of seasonal home temperatures, and frequent maintenance of non-mass produced equipment; but such inconveniences were offset by freedom from the power structures of industrial society and the experience of living within the constraints of a local ecology. “Living in a solar house is a whole new awareness, another dimension,” observed Karen Terry, one of the solar pioneers profiled in Skurka and Naar’s book.⁴⁷⁹ New Mexico builder Jay Davis described “self-help building” as a form of individual expression. “It is axiomatic that our built containers express and reinforce culture,” he wrote. “In our historical context, contracted building tends to reinforce only majority choices.” Do-it-yourself solar construction, in contrast, allowed the builder “to express unique cultural arrangements, ones that may become very important in a context of cultural change.”⁴⁸⁰ Solar architecture was not simply a personal lifestyle choice, but a political choice with implications for all of society.

Rising countercultural interest in solar design also influenced more mainstream architecture during this period, giving rise to a view that in a future characterized by limited resources, ecological and economic factors might become less at odds. Now that “energy-conscious architect and the engineer may find the accountant on his side,” John Morris Dixon, the editor of *Progressive Architect*, observed in 1975, opportunities to explore unconventional,

⁴⁷⁸ Pierre-Édouard Latouche, “Portraits of Solar in 1975,” in *Sorry, Out of Gas: Architecture’s Response to the 1973 Oil Crisis*, Giovanna Borasi and Mirko Zardini, eds. (Montreal: Canadian Centre for Architecture, 2007), 89.

⁴⁷⁹ Norma Skurka and Jon Naar, *Design for a Limited Planet* (New York: Balentine Books, 1976), 75-76.

⁴⁸⁰ Jay Gilbert Davis, “Solar Heating in Self-Help Building,” M.A. Thesis: University of New Mexico, 1976: 7.

energy-efficient designs that had seemed superfluous and cost-prohibitive in the age of energy in abundance were becoming practical and perhaps necessary for the long-term welfare of humanity. Solar design offered an exciting, socially redeeming, and potentially lucrative new field for architecture firms to explore.⁴⁸¹

Creating a Solar Movement

By the mid-1970s, countercultural design principles became filtering into the broader environmental discourse. In 1974, ecologist Howard Odum acknowledged the role of the counterculture in devising less energy intensive technological lifestyles. With the prevailing “human system” becoming “frozen into a...path toward cultural crash,” he asked: “Are alternatives already being tested by our youth so that they will be ready for the gradual transition to a fine steady state that carries the best of our recent cultural evolution into new, more miniaturized, more dilute, and more delicate ways of man-nature?”⁴⁸²

At the core of this interest in countercultural design concepts was the notion that choices about energy and technology correlated directly with social outcomes, including lifestyles, attitudes towards the environment, and the character of public and private institutions. This implied that Americans and others would not be able to simply substitute conventional energy systems with solar and other renewable energy systems while preserving traditional institutions and ways of living. A substantive transition away from fossil fuels and nuclear would entail lifestyle and institutional adaptations to the realities of a limited environment as well as too the properties believed to be inherent to solar energy sources. Just as fossil fuels would eventually be

⁴⁸¹ John Morris Dixon, “Energy Imperatives,” *Progressive Architecture* 5, no. 75 (May 1975): 45.

⁴⁸² Howard T. Odum, “Energy Ecology and Economics,” *Coevolution Quarterly* (Spring 1974): 15.

used up, E.F. Schumacher argued, the high technology world they made possible would also be transitory. It was not possible to replace fossil fuels with another energy source and still maintain the status quo, he maintained. “The challenge presented by the energy problem is one of developing a new life-style,” one that was adapted to the environmental potentialities of a world without fossil fuels.⁴⁸³

This sense of the inevitability and transformative potential of a major energy transition in the near future made energy an even more complex and pivotal political issue by the mid-1970s. Countercultural solar advocates, many of whom disdained government regulation, were faced with the prospect of supplying a rationale for increased government support for solar that involved considerations of personal lifestyle preference. Their influence in the broader conversation about energy also hinged on a deeper examination of the multiple social and economic aspects of energy production and consumption including the relationships between homeowners, alternative energy businesses, the energy industry, the building and contracting industry, and government regulatory agencies. Analysts from academia, government, industry, and activist organizations also debated long-term projections of the availability and cost of different energy supplies, the merits of conservation measures versus implementation of different kinds of solar systems, and the various “barriers” to the widespread utilization of solar and other renewable energy sources.

Prescriptions varied. While Barry Commoner’s *Poverty of Power* touted the virtues of scientific socialism, Steve Baer’s 1977 collection of essays *Sunspots* celebrated independent inventive creativity and the retreat of the state as a means to achieve both individual liberation and ecological sustainability. In his 1977 *Rays of Hope: The Transition to a Post-Petroleum*

⁴⁸³ E.F. Schumacher, “Western Europe’s Energy Crisis: A Problem of Life-Styles,” *Ambio* 2, no. 6 (1973): 232.

World, Earth Day organizer Denis Hayes put forward a more centrist view, arguing that the interconnected problems of fuel scarcity (both of fossil fuels and wood fuel), materials scarcity, scarcity of capital, pollution, population growth, and poverty would require a combination of technological and political solutions at multiple scales.⁴⁸⁴

A transition away from fossil fuels toward other forms of energy was most likely inevitable, Hayes observed, but the course of that transition was not set. He also maintained that conventional economic analysis oriented toward maximizing production at the lowest cost did not sufficiently account for “the social consequences of energy choices.” Applying Mumford’s (1964) formulation of the dual nature of technology to solar and nuclear respectively, Hayes wrote:

Some energy sources are necessarily centralized; others are necessarily dispersed. Some are exceedingly vulnerable; others will reduce the number of people employed. Some will tend to diminish the gap between rich and poor; others will accentuate it. Some inherently dangerous sources can be permitted unchecked growth only under totalitarian regimes; other can lead to nothing more dangerous than a leaky roof. Some sources can be comprehended only by the world’s most elite technicians; others can be assembled in remote villages using local labor and indigenous materials.⁴⁸⁵

Although solar technology had always been a political as well as a technical field, such arguments significantly increased its visibility as a pivot point of debate over the implications of humanity’s present energy choices. How to appropriately implement solar technology became the focus of an increasingly active movement to transform the energy basis for society, and as a corollary, society itself.

⁴⁸⁴ Denis Hayes, *Rays of Hope: The Transition to a Post-Petroleum World* (New York: W.W. Norton & Company, 1977), 15-23.

⁴⁸⁵ *Ibid.*, 25-26.

Energy specialist Amory Lovins provided an especially influential model of an alternative energy future. In his 1976 *Foreign Affairs* article “Energy Paths: The Road not Taken,” Lovins – then the British representative of former Sierra Club president David Brower’s Friends of the Earth – argued that conventional supply-side energy accounting favoring large-scale, centralized electricity generation (which he termed the “hard path”) threatened the long term durability of modern civilization by causing damage to the environment and generating a tremendous amount of waste. Lovins’s proposed alternative (the “soft path”) would be based on end-use accounting and measures of efficiency. Like Commoner, he believed energy supplies should be matched to specific tasks. While large-scale, centralized electricity generation might be appropriate for certain industrial activities, smaller scale end uses such as space or water heating could be served with more efficient dispersed solar thermal systems or other renewable energy systems. He also proposed implementing a variety of simple “technical fixes” such as waste heat recuperators, thermal insulation, and heat pumps to further improve efficiency.⁴⁸⁶

Lovins also challenged assumptions about the high relative cost of renewable energy technologies, arguing that while solar energy might be more expensive in the short term, its long term marginal costs (over a span of 50 years) would actually be far less than those for fossil fuels which up until the present had been made artificially low by subsidies and adequate supply, and by a lack of accounting for their long term environmental effects. The soft path would also extend the life of fossil fuel reserves, promote local control of energy supplies, reduce the negative environmental effects of the hard path, and mitigate the risks attendant to reliance on a

⁴⁸⁶ Amory Lovins, “Energy Strategy: The Road not Taken?” *Foreign Affairs* (October 1976): 65-96.; These arguments are expanded in Amory Lovins *Soft Energy Paths: Towards a Durable Peace* (San Francisco: Friends of the Earth, 1977).

small number of “vulnerable high-technology devices each costing more than the endowment of Harvard University.”⁴⁸⁷

The appeal of Lovins’s argument lay not only in his attention to efficiency and straightforward writing style but in his reconciliation of countercultural ideas, the concerns of environmentalists, and what he considered to be “traditional values.” Though the soft path would involve a decrease in the amount of energy produced and consumed, putting the nuclear genie back in the bottle, as he put it, could also contribute to “revitalizing the American dream.” A commitment to the soft path could even provide lucrative business opportunities. “Industrial resistance would presumably melt when – as with pollution-abatement equipment – the scope for profit was perceived,” he wrote. Lovins also turned the tables on free market advocates in government and the oil industry by presenting the hard path as “a world of subsidies, \$100-billion bailouts, oligopolies, regulations, nationalization, eminent domain, [and] corporate statism.” The soft path, in contrast, would rely on “small, standard, easy-to-make components and on technical resources dispersed in many organizations of diverse sizes and habits.” Such a system would remove bureaucratic obstacles, allowing anyone to “compete for a market share through ingenuity and local adaptation.”

The values accompanying the soft path were not new, he argued, “they are in the attic and could be dusted off and recycled.” The values of “thrift, simplicity, diversity, neighborliness, humility and craftsmanship – perhaps most closely preserved in politically conservative communities – are already, as we see from the ballot box and the census, embodied in a substantial social movement, camouflaged by its very pervasiveness.” The soft path, though drawing ideas from the counterculture and the environmental movement, was at root a

⁴⁸⁷ Lovins, “Energy Strategy,” 88.

conservative choice, Lovins insisted, one that aligned with the skepticism of authority and regard for pluralism at the heart of American political culture.⁴⁸⁸

The reception of Lovins's work revealed lingering divisions in mid-1970s American society over the issue of the nation's energy future. His assertion that it was possible to "do more with less energy" flew in the face of a deeply rooted belief in a correlation between increasing energy use and progress. Predictably, powerful oil corporations and utilities saw his proposal as a threat to their bottom lines. Economists and industrial researchers, especially those connected to the nuclear industry, challenged his estimates of waste generated in large-scale electricity generation processes and his projections of the future costs of fossil fuels and nuclear versus "soft" sources. Critics from both the left and right also charged him with overstating the autocratic nature of conventional energy systems while downplaying the curtailment of individual liberties and economic opportunities that would accompany the soft path. Furthermore, as historian Carroll Pursell points out, Lovins's use of the term "soft" to characterize solar and other renewable energy technologies ran counter to a broader cultural concern with "remasculinizing" the nation in the aftermath of the Vietnam War.⁴⁸⁹

Even many solar advocates responded negatively to Lovins's analysis. Sheldon Butt, executive at chemical manufacturer Olin Brass and president of the recently formed Solar Energy Industries Association (SEIA), a lobby group based in Washington D.C., charged him with falsely promising "that we can abandon much of our present energy capital stock and replace it with 'soft' energy without giving up the material benefits which we have received from our present system."⁴⁹⁰ Additionally, while Lovins's anti-technocratic stance appealed to many

⁴⁸⁸ Ibid., 80, 87, 90-94.

⁴⁸⁹ Pursell, "The Rise and Fall of the Appropriate Technology Movement," 630.

⁴⁹⁰ Sheldon Butt, "A Solar View of the Soft Path" in *Alternative Long Range Strategies: Joint Hearing before the Select Committee on Small Business and the Committee on Interior and Insular Affairs*, December 9,

environmentalists, he still relied on the kind of quantification that countercultural inventors mistrusted. Like Commoner's proposal, his model did not offer a clear way around expert oversight of consumer behavior and technology use. Instead, he seemed to be proposing an even more complex method of quantification which would assign number values to a whole range of non-economic and difficult to measure variables including environmental impacts and cultural values regarding technology.

The differing projections and viewpoints in the solar energy literature of the mid-1970s reflected the fragmented nature of American environmentalism in an era of economic decline, rising concern about scarcity, and diminishing trust in the federal government. Most Americans recognized the oil crisis as the dawn of a new age in which energy supplies could no longer be taken for granted. However, ideas about how to respond varied widely. These divisions reflected a tension between a general recognition of energy's importance to the American way of life and rising skepticism of a traditional model of progress linked to increasing energy use and perpetual economic growth. Solar's transformation into one of the most visible objects of this debate also made it a central focus of federal energy policy during Jimmy Carter's administration beginning in 1977.

Jimmy Carter and the Limits of Federal Reform

Lingering concerns about energy supplies and the environmental consequences of increasing energy use prompted Carter to make energy conservation and the search for alternative energy sources central aims of his presidency. In October 1976, just after his election,

1976 (Washington D.C.: US Government Printing Office, 1977), 889-890.; This record, consisting of over two thousand pages of discussion of alternative energy paths, assembles a broad selection of responses to Lovins's work as well as his detailed responses.

Carter invited a group of specialists including Amory Lovins, Denis Hayes, and ERDA solar division representative Jim Benson on a Georgia retreat where they developed the “Wolf Creek Statement.” The document, which called for an emphasis on small-scale, solar energy technologies, helped shaped the president’s energy agenda and became a source of optimism for solar advocates.⁴⁹¹

In a speech following his inauguration in January 1977, Carter famously referred to the energy crisis as “the moral equivalent of war.” To combat it, he proposed a national energy policy involving a strong emphasis on conservation and the consolidation of the various energy-related federal agencies into a single Department of Energy (DOE). He also called for a plan to introduce solar water and/or space heating systems in 2.5 million homes. In a notable departure from previous administrations, Carter prioritized research and development of “small, dispersed, and environmentally sound production and use of energy.” His plan aimed “to redress the advantage enjoyed by big business in the Government’s research and development program.”⁴⁹²

Carter’s optimism about leading the nation to a more secure, equitable, and environmentally sustainable energy future reflected his personal convictions more so than the actual capabilities of his office. James Schlesinger, Carter’s chief energy strategist, later attributed both the virtues and deficiencies of the administration to the president’s outsider status. Carter’s lack of experience in Washington, Schlesinger said, made him a different kind of politician who, rather than forming his positions depending on where others stood, came into office “imposing...his own moral judgments.”⁴⁹³ The early reception of Carter’s energy program

⁴⁹¹ Morris Herbert Goran, *Ten Lessons of the Energy Crisis* (Newtonville, MA: Environmental Design and Research Center, 1980), 105.; Arthur Allen, “Prodigal Sun,” *Mother Jones*, March April 2000, accessed November 13, 2014 at <http://www.motherjones.com/politics/2000/03/prodigal-sun>.

⁴⁹² Quoted in Hempel, “The Politics of Sunshine,” 146.

⁴⁹³ James Schlesinger, “Interview with Dr. James Schlesinger,” interviewed by Charles O. Jones, Clifton McCleskey, Kenneth Thompson, and James Sterling Young, Carter Presidency Project, Miller Center of Public Affairs, Presidential Oral History Program, July 19-10, 1984: 1-2.

revealed the obstacles to this approach. Progress toward his solar agenda remained slow through the first year of his presidency as he faced opposition in Congress and the energy industry, and as he dealt with warring divisions within the nascent DOE. Persistent economic weakness, unemployment, and rising tensions in the Middle East further diverted attention and resources away from solar.⁴⁹⁴

The most important development during 1977 was the kickoff of the Solar Energy Research Institute (SERI), located in Golden, Colorado. Authorized by the 1974 Energy Reorganization Act, SERI was meant to serve as both a research institution and an advisory body.⁴⁹⁵ Built on high hopes, the institute ended up facing some of the same institutional barriers that limited Carter's ability to carry out his energy program. According to the official history of the federal government's solar programs, SERI became "a classical example of what happens when political expediency overtakes a basically sound idea."⁴⁹⁶ First, Congress authorized only about half of the originally promised \$50 million of funding. Second, the establishment of separate regional centers meant that much of this money would be siphoned away from the SERI headquarters. Disputes emerged between SERI and its satellite offices over their respective roles as a result. SERI was also expected to pursue a wide range of research in a variety of related but not necessarily overlapping fields. The institute did not have the staffing, expertise, facilities, or leadership required to carry out in-depth research into thermal solar, solar heating and cooling, photovoltaics, wind energy, bioconversion, ocean thermal conversion, and small-scale

⁴⁹⁴ Hempel, "The Politics of Sunshine," 149.

⁴⁹⁵ Assembly of Mathematical and Physical Sciences, National Research Council, Solar Energy Research Institute Committee, *Establishment of a Solar Energy Research Institute* (Washington D.C.: National Academy of Sciences, 1975), 3.

⁴⁹⁶ Beattie, "The Buildup Years," in *History and Overview of Solar Heat Technologies*, 78, 82-83, 124.

hydropower. As a result, one author observes, “the analyses turned out by SERI in the early years seem scattershot, lacking the direction expected of it.”⁴⁹⁷

Signs of a turn-around came in March 1978 when Congress agreed to designate May 3 as National Sun Day. The purpose was to draw attention to solar heat technologies and passive solar designs that were available to consumers at the present time. The first Sun Day, historian Lamont Hempel notes, “marked an important change in the nation’s thinking about solar energy.”⁴⁹⁸ Like Earth Day upon which it was modeled, it provided a forum for disparate activists to come together as a more cohesive movement. Events across the country facilitated networking and lent credibility to the idea of rapid solar implementation. At a drizzly rally held on the steps of SERI, Carter announced plans to establish tax incentives and research programs to promote commercialization of existing technologies.

The president took a number of additional steps to address the concerns of the emerging solar movement. First, he directed his staff to compile a Domestic Policy Review (DPR) outlining measures the nation could take to meet a range of targets for future solar energy production. In response to increasingly organized pressure from solar advocates, the DPR staff based their recommendation on the goal of providing 20 percent of the nation’s energy from solar sources by the year 2000.⁴⁹⁹ Carter (after ten months of delays) also succeeded in convincing the Senate to confirm his appointment of Omi Walden, his energy advisor during his governorship in Georgia, as Assistant Secretary for Conservation and Solar Applications in August 1978. Drawing on her experience with more decentralized state and local energy

⁴⁹⁷ Madrigal, *Powering the Dream*, 106.

⁴⁹⁸ Hempel, “The Politics of Sunshine,” 154-155.

⁴⁹⁹ *Ibid.*, 156-157.

programs, Walden pushed for a shift away from high-tech research and development toward policies to accelerate commercialization of existing technologies.⁵⁰⁰

The high point came in November 1978 when after eighteen months of intense deliberations, Congress approved Carter's omnibus National Energy Act (NEA).⁵⁰¹ Although many of the more ambitious conservation measures in the original proposal had been stripped out through the review process, the core of Carter's solar agenda remained mostly intact. The act included the Public Utility Regulatory Policies Act (PURPA) which mandated that utilities pay for power produced by small renewable electricity generation plants. It also included the Energy Tax Act (ETA) which offered tax credits of 30 percent of the first \$2,000 and 20 percent of the next \$8,000 for residential solar installations. Finally, the act authorized up to \$100 million for solar retrofits and demonstrations in federal buildings.⁵⁰²

Still, the NEA did not go as far as solar advocates had hoped. Critics argued that the tax incentives in the act were insufficient to induce homeowners not already committed to solar to install solar systems. In late 1978, the Solar Lobby, a group headed by Denis Hayes, released its *Blueprint for a Solar America* which presented arguments for a more expansive structure of tax incentives and financing options than the DPR proposed. The document also called for a *minimum* goal of 25 percent solar penetration by 2000, noting that present technologies, in combination with rigorous conservation measures, could supply a much higher percentage of the nation's energy than the target set in the DPR.⁵⁰³

⁵⁰⁰ Frederick H. Morse, "The Growth Years, 1977-1980," in *History and Overview of Solar Heat Technologies*, 110-113.

⁵⁰¹ The debate is described in James L. Cochrane, "Carter's Energy Policy and the Ninety-fifth Congress," in *Energy Policy in Perspective*, 547-600.

⁵⁰² Hempel, "The Politics of Sunshine," 151.

⁵⁰³ Solar Lobby, *Blueprint for a Solar America* (Washington D.C.: Solar Lobby, 1978), 13.

Walden also faced an uphill battle in the DOE. Despite increasing budgets and her skill in communicating the benefits of introducing simple technologies into the marketplace, she struggled to counter the prevailing pro-development mindset in the federal government.⁵⁰⁴ She became a scapegoat for solar demonstrations that did not perform as well as expected. The organizational structure of the DOE, in which research and commercialization functions were kept separate, also meant that Walden had to compete with the solar research and conservation divisions for funds. Her office ended up as the “country cousin” in the relationship, earning just one percent of the solar budget for 1979.⁵⁰⁵ Walden’s struggles highlighted the persistence of institutional and normative barriers to a more far-reaching federal solar policy, especially one that could potentially challenge the nuclear and fossil fuel establishment.⁵⁰⁶

Geopolitical circumstances further limited possibilities. The deterioration of US relations with Iran beginning in 1978, in particular, significantly set back Carter’s solar agenda while also undermining the credibility of the administration itself. The overthrow of the Shah of Iran, one of the US’s most valuable allies in the Middle East, in October 1978 escalated tensions while also creating the preconditions for a second oil crisis. During the ensuing months, opposition forces staged strikes at Iran’s oil fields, forcing oil company executives and engineers to flee the region. By 1979, Iranian oil exports had dropped from 5.5 million barrels a day to just 500,000. OPEC responded by raising export prices by 14.5 percent. In an effort to avoid public panic over the energy issue, the administration focused on combatting inflation rather than addressing the oil situation directly. Policy action on energy largely moved out of the public eye. As in 1973, these initial behind the scenes efforts focused primarily on stabilizing oil prices and ensuring adequate supply. Solar programs were also deemphasized, taking a back seat to political damage control

⁵⁰⁴ Morse, “The Growth Years: 1977-1980,” 111-113.

⁵⁰⁵ Hempel, “The Politics of Sunshine,” 183.

⁵⁰⁶ Laird, *Solar Energy*, 148.

and other more immediate priorities, including convincing Congress to pass a windfall tax on oil.⁵⁰⁷

Declining public confidence that the administration could address persistent energy problems without resorting to collusion with the oil industry led Carter to renew his emphasis on solar energy by spring 1979. Stuart Eizenstat, head of the president's energy task force, recommended that a focus on solar might galvanize Carter's base constituency and instill public confidence in the administration. "From both a substantive and political standpoint, solar and renewable resources are the only really bright spots on an otherwise bleak energy horizon," he said.⁵⁰⁸ Rising public mistrust of nuclear following the near meltdown of the Three Mile Island plant in April 1979 further elevated solar's appeal in the public debate.

The centerpiece of the task force's plan was the creation of a Solar Development Bank to subsidize home improvement loans for homeowners and builders who installed solar systems. The plan also allotted \$646 million for research and development of solar technologies. In an attempt to demonstrate to the public his commitment to pursuing commercial applications of small scale solar systems, Carter had a solar water heating system installed in the White House. The June 21 dedication ceremony provided an opportunity to unveil the energy task force plan which Carter touted as a way to renew the nation's capacity to maintain control over its own energy future. "No one will ever embargo the sun or interrupt its delivery to us," the president declared.⁵⁰⁹

After the initial elation wore off, many solar advocates again expressed dissatisfaction with Carter's plans. Some noted that the administration had set a poor example by spending more

⁵⁰⁷ These events are detailed in John Costley Barrow III, "An Era of Limits: Jimmy Carter and the Quest for a National Energy Policy," Ph.D. diss.: Vanderbilt University, 1996: 134-169.; Also see Joseph A. Yager, "The Energy Battles of 1979," in *Energy Policy in Perspective*, 601-618.

⁵⁰⁸ Quoted in Barrow III, "An Era of Limits," 194.

⁵⁰⁹ "Carter Sets Ambitious Effort to Use of Solar Energy," *Congressional Quarterly*, June 23, 1979: 1245.

than was necessary on the White House solar panels. Others considered the Solar Bank a bad idea that would only fuel criticisms that solar was still not technically mature enough to be financed through private institutions.⁵¹⁰ Compounding the problem, Carter was forced to further temper his solar agenda almost immediately after the solar panel dedication ceremony when a spike in oil prices and shortages caused a reprise of the public panic following the 1973 embargo. In an attempt to salvage support from solar advocates, Carter appointed Denis Hayes to replace Paul Rappaport, whose health was declining, as head of SERI, a bold move which for the first time placed an activist at the head of government research institution.⁵¹¹

Hayes's appointment, however, did not change the overall character of the federal energy strategy, and solar advocates continued to express disappointment about their marginalized status.⁵¹² Barry Commoner noted that Carter's vocal support for solar energy obscured the fact that in the scheme of his larger energy agenda, solar continued to rank far below oil, coal, synthetic fuels, and nuclear in terms of funding and scenario planning.⁵¹³ Others criticized the "trickle-down theory" which held that the solar market first had to be established in the upper and middle income sector of the US economy before becoming accessible to low income groups.⁵¹⁴ Commoner also took up this cause, noting that the poor – who could not afford the up-front cost of solar installations even with tax incentives – would bear the immediate burden of a strategy of driving up the costs of traditional sources in order to create a market for alternative sources.⁵¹⁵

⁵¹⁰ Laird, *Solar Energy*, 148.

⁵¹¹ "Solar Activist, Denis Hayes, Heads SERI," *Science*, 205, no. 4406 (August 10, 1979): 563-566.

⁵¹² For example see Kathleen Courrier, "Solar Slighted in Secret," *Sun Times*, July 1980: 2. This article specifically referred to a leaked memo from the president's cabinet which expressed a recommitment to nuclear.

⁵¹³ Barry Commoner, *The Politics of Energy* (New York: Alfred A. Knopf, 1979), 32.

⁵¹⁴ Hempel, "The Politics of Sunshine," 226.; For a more general contemporary critique of the middle class values in mainstream environmentalism, see Andrew Duff, "Environmentalism, Middle-Class Radicalism and Politics," *The Sociological Review* 28, no. 2 (May 1980): 333-352.

⁵¹⁵ Costley, III, "An Era of Limits," 196-205.; Hempel, "The Politics of Sunshine," 166-169.

Overall, such criticisms spoke less to Americans' lack of concern with the problems of overconsumption and scarcity than to the still fragmented nature of the solar movement, and to limitations related to the structure and priorities of the federal government. While some more conservative solar advocates continued to press for more tax incentives and research and development funds, other more radical advocates expressed a general mistrust of the federal government's capacity to address the problem. This was a trend that Carter, in his defining "Crisis of Confidence" speech of July 15, 1979, cited as the root of the "malaise" affecting the American people. Amory Lovins expressed the sentiment most powerfully in an August 1979 editorial for the *Washington Post*, writing:

President Carter's rhetorical tension between encouraging grass-roots and community innovation (the source of virtually all the good news about energy since 1973) and a \$142 billion exercise in Nixonian technocracy reflects a deeper choice that we must make – between traditional ideals of individual enterprise, intelligence and decision, and the less democratic belief that the same distrusted bureaucratic and oligopolistic elites who many feel got us into this mess are the only source of wisdom that we are incompetent to muster ourselves. It is a choice between soft and hard energy paths; between Jefferson and Hamilton; and ultimately between democracy and tyranny.⁵¹⁶

Lovins may have been overstating the case, but his words captured the frustration with centralized government shared by conservatives and many otherwise left-leaning environmentalists alike by the late 1970s. For Lovins, retraction and redirection rather than additional expansion of federal solar programs was necessary to lead the nation to a transition to a soft energy future. "The kind of energy mobilization we need is happening today in hundreds of communities and millions of homes across America," he wrote. "It doesn't need a board; it needs a modest government willing to lend a hand and then get out of the way."⁵¹⁷

⁵¹⁶ Amory Lovins, "Is 'Red Tape' a Code Word for Law?" *The Washington Post*, August 3, 1979: A13.

⁵¹⁷ *Ibid.*

Journalist Ray Reece, in his scathing 1979 expose *The Sun Betrayed: A Report on the Corporate Seizure of US Solar Energy Development*, echoed this, suggesting that even the Solar Lobby's ambitious *Blueprint for a Solar America* came up short by presuming the necessity of top-down federal management. Substantive reform could only come from localities, states, and regional initiatives, Reece urged, suggesting that the appropriate role of the federal government would be to stimulate and support these bottom-up actions.⁵¹⁸

Such views demonstrated significant overlap with the broader conservative uprising which ultimately led to the election of Ronald Reagan in 1980 and the dismantling of the solar programs that Carter had put in place. Yet they also referred to ongoing efforts at the state and local levels which paralleled the national movement and which often went further than federal programs in challenging the traditional faith in economic growth and increasing energy use as preconditions for social improvement. The evolution of this trend in California – the subject of the next chapter – reveals the continuing importance of political geography in shaping different variations of solar technologies and politics through the 1970s.

⁵¹⁸ Ray Reece, *The Sun Betrayed: A Report on the Corporate Seizure of US Solar Energy Development* (Quebec, Canada: Black Rose Books, 1979), 205.

Chapter 6

Beyond the Limits of Federal Reform: Toward a Solar Future in California

While the federal government played a key role in both enabling and limiting the development and implementation of solar technologies in the 1970s, Americans also began to look beyond its immediate purview in pursuit of more accessible, localized solutions to the intertwined problems of environmental degradation, energy shortages, and economic weakness. As public confidence in Congress and the executive office declined in wake of the Vietnam War, Watergate, and the energy crisis in the mid-1970s, state and local governments experienced a revitalization of influence. During the four previous decades, although state governments continued to adapt and innovate, they declined in relative importance with the expansion of interstate commerce and the growing reach of federal programs.⁵¹⁹ California remained among the more active states during this period, enacting the nation's first anti-smog measures and assuming a lead role in planning and financing economic development and infrastructure projects, most notably the California State Water Project (SWP), commenced in 1960 during the administration of Governor Edmund "Pat" Brown.⁵²⁰ In the wake of the 1973 oil embargo, the California government maintained its role as pace-setter, leveraging its authority to regulate utilities, authorize power plant siting, establish environmental and efficiency standards,

⁵¹⁹ Jon C. Teaford, *The Rise of the States: Evolution of American State Government* (Baltimore: Johns Hopkins Press, 2002), 5.

⁵²⁰ James Williams, *Energy and the Making of Modern California* (Akron: The University of Akron Press, 1997), 296-297.; Peter Wiley and Robert Gottlieb, *Empires in the Sun: The Rise of the New American West* (New York: G.P. Putnam's Sons, 1982), 77-83.; For earlier background to the role of the California state government in economic development see Gerald D. Nash, *State Government and Economic Development: A History of Administrative Policies in California, 1849-1933* (Berkeley: Institute of Governmental Studies, 1964).; For the SWP see especially Norris Hundley, *The Great Thirst: Californians and Water: A History*, revised edition (Berkeley: University of California Press, 1992), 276-302.

disseminate information to the public, and levy taxes and incentives to challenge the power and priorities of the federal government.

This chapter documents the origins, evolution, and influence of the California approach to solar energy technology development from the early 1970s through the early 1980s, emphasizing points of departure from the federal model. Reflecting and contributing to the skepticism of a federally managed solar economy as outlined in the previous chapter, a central aim for California solar advocates in government, universities, and private organizations was to create a more competitive grassroots market for solar and other non-nuclear, non-fossil fuel-based energy technologies by incentivizing local-scale entrepreneurial activity, educating consumers, and empowering municipal governments to develop their own programs. Despite failing to meet expectations by the early 1980s, local and state level solar development and conservation programs in California elevated public awareness of the potential social, environmental, as well as economic benefits of solar commercialization; prompted the reevaluation of local building codes and lending practices which impeded solar development; and provided a model for state and local energy planning which challenged the authority of the federal government and large utilities to make decisions about technology and energy at smaller scales. Programs developed at the state level, mainly through the California Energy Commission, and at the municipal level, especially in the City of Davis, offered a potential middle route for solar development. These programs attempted to incorporate the most useful features of both the progressive regulatory, planning model of environmental reform and the countercultural “Jeffersonian” approach which valued freedom of individual action, local control of technology, and limited bureaucratic oversight.

Reducing the Scale: From California Tomorrow to the Davis General Plan

The California approach to solar built on existing state and local level trends in environmental activism and planning. By the late 1950s, in response to mounting problems related to population growth and economic development including suburban sprawl, smog from automobile emissions, and air and water pollution, a small but growing constituency of university professors, politicians, city planners, and conservationists began to call for state-level reform. In 1960, conservationist Alfred Heller joined with Samuel Wood, a member of the state assembly's Committee on Conservation, Planning, and Public Works, to form the non-profit educational organization California Tomorrow. Two years later, Heller and Wood published the booklet *California Going, Going...* which brought the state's pressing environmental problems to the attention of Governor Pat Brown and the public. In 1965, the group inaugurated the journal *Cry California* as a forum for discussing environmental issues and scrutinizing state economic development policies. California Tomorrow's goal was to foster better planning at the state level as the solution to growth-related environmental problems. A task force headed by UCLA's dean of Architecture and Planning Harvey Perloff defined the problem as "too many people, living in the wrong places, consuming resources wastefully."⁵²¹ These ideas formed the basis for the ambitious *California Tomorrow Plan*, released in 1972. The plan recommended vesting state government with powers to implement a range of environmental regulations relating to coastal-zone management, forest management, state parks administration, urban zoning, air pollution, energy resource development, and waste disposal.⁵²²

⁵²¹ Williams, *Energy and the Making of Modern California*, 300-302.

⁵²² Ibid., 302-303.; Samuel Hays, *Beauty, Health, and Permanence: Environmental Politics in the United States, 1955-1985* (New York: Cambridge University Press, 1987), 44, 389.; Alfred Heller, ed., *The California Tomorrow Plan* (Los Gatos: William Kaufmann, Inc., 1972).

The *California Tomorrow Plan*, historian James Williams notes, exemplified a trend toward “viewing California’s society ecologically” that had taken shape during the 1960s.⁵²³ The report called for elevating the importance of environmental quality as a consideration in state infrastructure and economic planning. However, its release also came at a time when many ecologically-conscious Californians were questioning the merits of centralized planning models. In the San Francisco Bay Area, the home of the *Whole Earth Network*, countercultural groups were seeking to transfer the authority to make choices about technology from the impersonal “system” represented by the federal government, big business, and scientific institutions to individuals and local communities. This emphasis on the “user,” in Stewart Brand’s terms, formed the basis for a more locally rooted environmental politics in which community activists, inventors, small business owners, consumers, and municipal governments challenged the primacy of national environmental organizations and government agencies in making decisions about technology and the environment.⁵²⁴

As it grew in strength during the second half of the 1960s, the anti-nuclear movement in California also displayed rising antipathy to bureaucratization and expert control in general and to the federal nuclear regulatory apparatus in particular. This interest in local control of technology appealed to an ideologically diverse constituency of local environmental organizations, counterculture groups, former New Left activists frustrated with the limits of federal reform, and even some populist conservatives resentful of the power of the federal government. The result was the emergence of a new politics which prioritized local technological

⁵²³ Williams, *Energy and the Making of Modern California*, 302.

⁵²⁴ Andrew G. Kirk, *Counterculture Green: The Whole Earth Catalog and American Environmentalism* (Lawrence: The University Press of Kansas, 2007), 15-16.

decision making and more direct public input in the planning process, even as it also relied on government to restructure the energy economy.⁵²⁵

This trend coalesced into policy first at the municipal level. During the 1970s, the city of Davis, located in California's central valley about fifteen miles west of Sacramento, gained international recognition as a model for municipal government implementation of conservation, appropriate technology, and renewable energy measures. The push to remake Davis into an "appropriate metropolis" came initially from faculty and students of the University of California, Davis. During the 1950s and 1960s, UC Davis grew from a small agricultural college with approximately 2,500 students into a full-fledged research university with a student population exceeding 12,000. By the early 1970s, the university was the centerpiece of a community undergoing a rapid transformation from a small farming town into an urban/suburban enclave for mainly white, liberal, highly-educated middle class transplants from Sacramento and the San Francisco bay area. As of 1973, more than half of the city's approximately 37,000 residents were listed as students, faculty, or staff of the university.⁵²⁶ The combination of a politically and socio-economically homogenous population, an activist university, and a rapidly growing community created a unique opportunity for experimentation in municipal energy use and conservation planning.

In 1971, a group of students in the ecology department formed the Greater Davis Research Group (GDRG) and began holding meetings to discuss how the city might limit the negative social and environmental impacts of growth. In 1972, GDRG member Robert Black, a

⁵²⁵ Thomas Raymond Wellock, *Critical Masses: Opposition to Nuclear Power in California, 1958-1978* (Madison: University of Wisconsin Press, 1998), 4, 11, 14.

⁵²⁶ Edward Laurence Vine, "Solar Energy: Two Sociopolitical Perspectives," Ph.D. diss.: University of California Davis, 1980: 25.; Beginning in 1971, students at UC Davis were permitted to register to vote in Davis under their school address. "Consequently," Vine wrote, "the 'student vote' has played an important role in local politics."

former student body president, was elected to the city council on a platform to address the issues of urban sprawl, the loss of high quality agricultural land, recycling, automobile traffic, and air and water pollution. Two other members of the five person council supported Black's plan, and later that year, the new majority succeeded in passing a moratorium on growth pending a review and revision of the city's existing General Plan.⁵²⁷

The new General Plan, released in 1973, contained a host of energy conservation and anti-sprawl measures including an intra- and inter-city public transportation system, plans for bicycle-only lanes, a newspaper recycling program, the lifting of a ban on outdoor clotheslines, water and soil conservation measures, limits on street width, and new zoning and permitting measures to increase the density of new development. The centerpiece of the plan was a proposal for the nation's most rigorous energy conserving municipal building code. The revision of the General Plan became "the turning point in the city's destiny," wrote Mayor Thomas Tomasi. "In contrast to the past, when a laissez-faire attitude prevailed, local control of the city's future...became the central focus of community effort."⁵²⁸

Several factors made the building code a reality. The first was the energy crisis, which spurred an already conservation-conscious citizenry to get behind more stringent municipal regulations. The city council also benefited from its close connection to the university. Beginning in 1973, UC Davis graduate and former GDRG member Jonathan Hammond formed the consulting firm Living Systems to help the city develop environmentally friendly zoning and building standards. With the release of the General Plan, Hammond proposed an intensive study of existing and model homes in Davis to determine the energy efficiency of various design

⁵²⁷ Ibid., 33-36.

⁵²⁸ Thomas J. Tomasi, Mayor, City of Davis, California, "A Strategy for Local Government to Implement Use of Alternative Energy Sources," in Solar Energy Research Institute, *Community Energy Self-Reliance: Proceedings of the First Conference on Community Renewable Energy Systems, University of Colorado, Boulder, Colorado, August 20-21, 1979* (Washington D.C.: Government Printing Office, 1980), 170-171.

features and technologies. The results, released in 1975, became the basis for the building code approved by the city council later that year. Hammond conducted the study with an eye toward practical results. He wanted to convey data that could be easily understood by the public and that could form a set of standards for implementation in an ordinance. Hammond also purposefully focused on energy saving measures that were simple, based on existing materials and construction techniques, and not dependent on expensive “active” solar heating and cooling elements or centralized solar energy production systems. The idea was to introduce energy conserving design techniques and materials that would not significantly impact builders’ bottom lines and that would benefit consumers.⁵²⁹ As Black explained, “the initial push was consumer-oriented. The majority of the council wanted to find ways to save the consumer money and to study various methods of providing energy.”⁵³⁰ The city aimed to adapt local planning to a post-oil crisis reality in which a community’s reliance on ever-increasing energy consumption had become a liability rather than a source of strength.

The local ordinance, argued David Bainbridge, another UC Davis graduate who consulted in the drafting of the building code, was also preferable to state-level regulations which were not ideally suited to local environmental conditions. The state’s recently adopted energy and noise insulation standard, for example, did not address window shading and building orientation, factors that significantly affected energy efficiency in Davis where annual temperatures swung dramatically from as high as 115 degrees in summer to 20 degrees in winter. Bainbridge drew on Hammond’s work to point out that in the Davis climate, “only minor changes in layout and orientation” in combination with window glazing saved fifty percent of the energy requirements for space heating and cooling. “By changing construction to reflect the

⁵²⁹ Ibid.; Vine, “Solar Energy,” 33-35.

⁵³⁰ Quoted in Charlotte Higgins, “The Appropriate Metropolis: Is Davis the City of the Future?” *Cry California* 13, no. 3 (Summer 1978): 14.

value of durability rather than first cost/ profit we will see houses that are oriented to use the sun for winter heating and evaporation, natural ventilation, shade, and other natural cooling principles for summer cooling.” A model home Bainbridge built in the nearby town of Winters in 1974 at a comparable cost to traditional construction relied on passive solar design aspects for 100 percent of its cooling and 90 percent of its heating, the only supplementary heat coming from a small wood burning stove. “The gas heater required by the bank,” he added, “has never been used, a mute testimonial to the value of passive systems.” The cost and efficiency benefits of passive design concepts adapted to Davis’s particular climate were not limited to custom model homes. According to Bainbridge, “Proper layout of houses, streets, and buildings can reduce energy use considerably even in tacky residential construction.”⁵³¹

Builders offered the only sustained objections to the code which they worried would increase construction costs and limit demand. Davis, however, was still a small city with only nine established builders. Most were reluctant to leave, regardless of whether or not the code passed, due to the high demand for new residential development. During the course of the public meetings over the ordinance, builders also came to the conclusion that since the state was likely to pass new building regulations anyway, meeting the Davis code could give them a leg up on potential competition. While a few corporate builders avoided the town after the passage of the code, the smaller developers were willing to adapt. These builders, one city official observed, “are a sophisticated bunch and they live here, which causes them to have a real sense of community.”⁵³² It also soon became apparent that while the code required significant changes to usual building practices, the additional costs would not be as high as initially feared. Most

⁵³¹ David Bainbridge, “Environmental New Town,” *Seriatim: Journal of Ecotopia* (Fall 1976): 82-86. David Bainbridge Papers, box 1, Folder “Solar Rights, 1976,” UC Davis Special Collections.; “Ordinance No. 784, An Ordinance Establishing Energy Conservation Performance Standards for Residential Construction within the City of Davis.” David Bainbridge Papers, Box 1, Folder “Davis Ordinance, 1975,” UC Davis Special Collections.

⁵³² Quoted in Higgins, “The Appropriate Metropolis,” 15.

requirements were simply modifications of existing practices. The code required developers to orient streets and homes to the south and west, to use more insulation, and to extend eaves on sunward facing roofs. The only significant additional costs came from the mandated use of double-paned glass and window glazing. But even these costs added only marginally to the overall cost of construction. Furthermore, the typical homebuyer in Davis was highly enthusiastic about energy conservation, especially when a slightly higher initial investment could result in as much as a fifty percent reduction in their energy costs.⁵³³

One builder in particular not only supported the code but determined to exceed its requirements. In 1970, Mike Corbett and his wife Judy began drawing up plans for Village Homes, a medium-scale housing development that would incorporate not only such energy saving features as solar water heaters and south-facing double paned windows but also a variety of innovative and untried landscape design features including narrow dead-end streets, walking paths, small backyards and larger communal open spaces, community gardens, and a natural absorptive drainage system consisting of a network of open creek channels, ponds, and swales in place of conventional storm drains. The Corbetts' goals were to design "a neighborhood which would reduce the amount of energy required to carry out the family's daily activities" and to establish "a sense of community."⁵³⁴ Their plans reflected a blending of influences including the greenbelt communities of Radburn, New Jersey and Greenbelt, Maryland; the urban renewal vision of Jane Jacobs; and the growing body of literature on ecological planning and smart growth. The Corbetts' backgrounds in architecture, town planning, ecology, and environmental psychology further informed their vision of a suburban community that would "recover some of

⁵³³ Vine, "Solar Energy," 51-58.

⁵³⁴ Michael and Judy Corbett, *Toward Better Neighborhood Design* (East Lansing: College of Human Ecology, Michigan State University, 1983), 1.

the homier aspects of village life” while also enabling residents to “live more lightly on the land.”⁵³⁵

When the Corbetts submitted their plan for Village Homes to the city in 1972, however, they were stonewalled on nearly all the essential aspects. “Everybody had a problem,” Judy later recalled. “The police department didn’t like the dead-end cul-de-sacs. The fire department didn’t like the narrow streets. The public works department didn’t like agriculture mixing with residential. And the planning department picked it apart endlessly.”⁵³⁶ Over the next year, the Corbetts worked to convince city officials of the viability of their plan. The oil crisis and the widespread local support for the new General Plan in 1973 persuaded the newly reconstituted City Council to support Village Homes, but the development still faced hurdles. The most pressing problem was the banks’ refusal to grant a construction loan. According to Judy Corbett, thirty two banks rejected their initial proposal. They were only able to receive funding when they approached the bank that funded Michael’s parents’ subdivisions in Sacramento. (His parents were also developers.) The bank approved the loan on the condition that Corbett’s parents’ firm would build the first homes.⁵³⁷

The banks’ concern that few buyers would be attracted to the unconventional neighborhood proved fully unwarranted. Within a year, the first homes were all sold and buyers were lining up for the next block still under construction. The success of Village Homes and the new Davis General Plan by 1973 demonstrated the potential benefits of reforming institutions at the local level in advance of state and federal action. It also offered a planning model in which homeowner associations, citizen volunteers, and local builders participated in the design and

⁵³⁵ Michael and Judy Corbett, *Designing Sustainable Communities: Learning from Village Homes* (Washington D.C.: Island Press, 2000), 23.

⁵³⁶ Quoted in David S. Jackson, “Back to the Garden: A Suburban Dream,” *Time* (February 22, 1999): 78.

⁵³⁷ “Village Homes History,” accessed December 4, 2013 at <http://www.villagehomesdavis.org/public/about/history>.

implementation of community growth-control actions. Such a system, Corbett stressed, encouraged greater collaboration between government representatives, builders, energy consultants, and the communities in which they worked. In Davis, the emphasis allowed for a more public atmosphere for determining priorities in planning and construction. “The success of communities in the future,” Corbett wrote, “will depend upon the growing availability of...new professionals who, rather than overpowering their clients with their indisputable knowledge, are able to gain professional satisfaction through working with people.”⁵³⁸

“Plentiful Sunshine and Scientists”: The California Energy Commission and the California SERI Proposal

Just as it spurred an attention to energy efficiency in Davis, the oil embargo also became the catalyst for energy planning to become a priority in state government. As at the federal level, the first step was to create an institutional basis for coordinating the government’s approach to energy decision making. Implementation at the state level presented fewer obstacles than at the federal level, and the state government proceeded rapidly. In May 1974, with the energy panic creating a rare moment of consensus between environmentalists and the energy industry, outgoing governor Ronald Reagan reluctantly signed legislation establishing the Energy Resources and Conservation Commission, known as the California Energy Commission (CEC), to oversee power plant siting, energy conservation, and explorations into alternative fuel options for the state.

⁵³⁸ Michael N. Corbett, *A Better Place to Live: New Designs for Tomorrow’s Communities* (Emmaus, PA: Rodale Press, 1981), 135, 141, 146.

The agency's precise role remained uncertain. The legislation creating the CEC was co-written by pro-nuclear senator Alfred Alquist and Assemblyman Charles Warren, a committed anti-nuclear environmentalist. Both men expected the CEC to do their bidding. While Alquist believed a central commission would streamline the power plant siting process, Warren saw it as a triumph of the kind of conservation-oriented planning proposed in the *California Tomorrow Plan*. One journalist described the CEC as "a complicated compromise, with all parties hoping a new high powered agency might – given enough good leadership, expert staffing, scientific research and perhaps blind luck – figure out some way to solve the state's energy problems."⁵³⁹ The CEC's uncertain role made it a focal point of both contestation and experimentation over the ensuing years. While environmental planners and nuclear advocates shaped the debate early on, advocates of more public, local-scale, conservation-based planning models such as that being implemented in Davis increasingly became part of the conversation. The evolution of the CEC's approach to solar technology paralleled this larger transition.

While nuclear power plant siting and oil and gas regulation occupied the CEC during the early years, solar increasingly became an area of activity. The initial push for state government to focus on solar came from California's high technology and research institutions which remained hubs of solar cell development for the military and the space program. The first question facing the commissioners was how to draw from and contribute to the larger federal solar program. ERDA's announcement in early 1975 that it would be accepting proposals for the siting of the solar energy research institute (SERI) became the impetus for the CEC to begin seriously considering the state's capabilities in solar research and implementation for the broader public market.

⁵³⁹ Douglas Foster, "The Energy Commission: The Board you Love to Hate," *Cry California* 13, no. 3 (Summer 1978): 48.

In July, CEC chairman Richard Maullin, co-author of a 1972 RAND report strongly advocating for government programs to incentivize solar commercialization, called for the establishment of an ad hoc committee to discuss strategies for preparing a proposal to locate SERI in California. Maullin was also aware that the state would face stiff competition in its bid. In August 1975, with the assistance of Dr. Paul Craig, the chairman of the University of California Energy and Resources Council, Maullin put together a committee with members from the University of California Systemwide Administration, Lawrence Berkeley Laboratory, the Jet Propulsion Laboratory (JPL) at Cal Tech, Stanford University, and the CEC. The universities were to function as the “co-founders or promoters of a California-based national SERI” while the state provided funding.⁵⁴⁰

The proposal committee felt they had a significant edge over the competition. The state’s abundant sunshine was only part of the draw. More importantly, California offered a dynamic “technology-oriented community” comprised of public and private sector research laboratories with already well-developed connections to federal science and technology agencies. A California SERI, especially one located in Santa Clara county, “California’s breeding ground for industry” according to *Fortune* magazine, would be accessible to federal agencies and linked physically to many of the nation’s largest, most innovative aerospace and electronics businesses.⁵⁴¹ The committee was confident that California had all of the technical, human, organizational, and environmental resources – the combination of “plentiful sunshine and

⁵⁴⁰ Ad-Hoc Committee for a California SERI, “A National Solar Energy Research Institute Located in California,” draft. (September 24, 1975). Howard Seifert Papers, Stanford University Archives, box 12.; ERDA, National Solar Energy Research, Development & Demonstration Program, Division of Solar Energy, “Definition Report,” June 1975.

⁵⁴¹ Gene Bylinsky, “California's Great Breeding Ground for Industry,” *Fortune* 89 (June 1974): 128-135.

scientists” – to help ERDA reach its goal of “developing the Sun as an essentially inexhaustible source of energy.”⁵⁴²

This conclusion was revealed to be premature when ERDA announced its selection of Golden, Colorado as the site for SERI. The California proposal team responded by charging the selection committee with prioritizing political expediency over substantive result. The decision also convinced state leaders to initially refuse to submit a proposal for a regional branch in the state.⁵⁴³ The California-based national laboratories and aerospace companies that had lobbied for a California SERI continued to pursue federal funds for solar research, but ERDA’s rebuke of their proposal marked a point of departure, contributing to the CEC board’s and other state leaders’ openness to pursuing other avenues for solar development outside the framework of federal programs.

Jerry Brown and Post-Liberal Environmentalism

California’s mercurial governor Edmund G. “Jerry” Brown also played a central role in leading the state down a more independent energy path. Brown swept into office in 1974, his ascendance bolstered by his family name – he was the son of former governor Pat Brown – and public antipathy toward republicans in the wake of the Watergate scandal. While relying in part on Californians’ fond memories of his father, he also sought to distance himself from the former governor’s politics, in particular his emphasis on large-scale, publically-funded energy and infrastructure projects. Claiming inspiration from E.F. Shumacher’s *Small is Beautiful*, Brown

⁵⁴² Lieutenant Governor Mervyn Dymally quoted in “Solar Study Favors State,” undated article in papers of the Stanford University Sponsored Projects Office, Stanford University Archives, folder “SERI – Correspondence and Report, 1976-1977.; and Ad-Hoc Committee for a California SERI, “A National Solar Energy Research Institute Located in California.”

⁵⁴³ Beattie, “The Buildup Years,” in *History and Overview of Solar Heat Technologies*, 83.

stated his intent to work toward fiscal restraint, reduction of bureaucracy, and limited public and private sector growth for the sake of a healthy environment.

A master of image production, Brown attempted to trace a middle route that would appeal across the board to traditional liberals, environmentalists, labor unions, industry leaders, and neoconservatives. He maintained a political balancing act which involved supporting collective bargaining for farmworkers and calling on his staff to act “in the spirit of Ho Chi Minh” while simultaneously opposing social welfare policies such as school lunches. In the name of simplicity, he refused to move into the \$1.3 million governor’s mansion, choosing to sleep on a mattress on the floor of a \$250-a-month apartment down the street from the capital building. He also chose to forego the governor’s bulletproof Cadillac for a blue collar Plymouth and made a point to refuse any and all gifts.⁵⁴⁴

For all his eccentricities and apparent contradictions, Brown displayed a consistent contempt for the status quo that mirrored what David Alpern of *Newsweek* described as Americans’ “bitter dissatisfaction with a government that is perceived as inefficient, overindulgent, intrusive and just too damned expensive in an era of economic belt-tightening and post-Watergate cynicism.”⁵⁴⁵ Californians, Brown recognized, no longer trusted the traditional liberal promise of a custodial government ensuring jobs, full stomachs, and material plenty through large-scale public works and social programs. As one journalist observed: “Their heads and, even more importantly, their guts responded to different stimuli than the liberal slogans of the past.”⁵⁴⁶ Brown exhibited a kind of clean-slate existentialism in his appointments, in his statements to the press, and in his policies. His approach was to take each issue as a single piece,

⁵⁴⁴ Richard Reeves, “How does the Governor of California Differ from a Shoemaker?: And why is he so Popular?” *New York Times*, August 25, 1975: 191.

⁵⁴⁵ David M. Alpern, “Big Government,” *Newsweek*, December 15, 1975: 35.

⁵⁴⁶ Paul Jacobs, “Nothing for Everyone: Brown’s New Politics,” *Mother Earth News* 1, no. 5 (July 1976): 24.

to avoid any action that smelled of “agenda,” “systems analysis,” “data,” “expertise,” and “comprehensive planning.”⁵⁴⁷ “I don’t believe in grand schemes,” he told the *Wall Street Journal* in 1976: “All kinds of programs have been heralded as the way to solve cosmic issues when they nothing of the kind.” In most cases, they simply added to the “social pork barrel.”⁵⁴⁸ Brown’s core message was that people would have to accept the harsh reality that there were limits to what government could accomplish. “We’ve been popping out the dough like there’s no tomorrow,” he said, “and there is.”⁵⁴⁹

Despite his emphasis on “lowered expectations,” Brown was not averse to making bold statements and supporting big projects when he felt it fit the circumstances. He also remained committed to a basic notion of economic improvement, even as he questioned the standard definition of what constituted a better future. He believed, for example, that even in a world of limits, a creative approach to government could upset the balance of power that had been the source of America’s current problems and create a new course to progress, one that was not so tightly and detrimentally linked to rising consumption. One of his more controversial moves in this direction was his appointment Sim Van der Ryn of the Farallones Institute to the position of state architect in 1974. Earlier that year, Van der Ryn had drafted a proposal for the creation of an Office of Appropriate Technology (OAT) in the state government. He proposed that the office would serve as a clearinghouse for information on new approaches to waste and resource management, construction, housing, food production, and energy consumption. The point was to “sustain a society of finite resources at a human scale.” Van der Ryn envisioned OAT as “a David in the Governor’s Office that would take on the Goliath of special interests that benefitted

⁵⁴⁷ Reeves, “How does the Governor of California Differ from a Shoemaker?”

⁵⁴⁸ Norman C. Miller, “Brown of California Plays Unusual Game and Wins Popularity,” *Wall Street Journal*, February 24, 1976: 9.

⁵⁴⁹ Peter Goldman with Gerald C. Lubenow, “Mr. Small-Is-Beautiful,” *Newsweek*, December 15, 1975: 47.

from subsidies and regulations such as encouraging agribusiness through water subsidies, wasteful building codes, and health codes preventing water conservation and biological waste treatment.”⁵⁵⁰

Brown was naturally enthused with the idea, authorizing OAT in May of 1976 and granting it a starting budget of \$25,000. Under Van der Ryn’s leadership, the office focused on providing information on appropriate technologies to consumers. This involved demonstrating various energy saving technologies including waste heat recuperators, passive solar design concepts, and various home- and business-based wind and solar devices. OAT developed a mobile version of Van der Ryn’s energy self-sufficient Integral Urban House to display at state and county fairs. The staff also began training low income workers in the construction trade as solar technicians.

OAT continued to grow over the ensuing years, becoming “an acknowledged leader in renewable energy investigations,” as one writer proclaimed.⁵⁵¹ The office operated from the perspective that to fail to work toward the transition to renewable energy would be “reckless,” Van der Ryn said. OAT also became a mouthpiece for the Brown administration’s rising opposition to nuclear energy, unwillingness to accept high levels of air pollution from coal burning plants and automobile exhaust, and recognition that the state’s hydroelectric resources had already been tapped to their full potential. It provided a forum for experimenting with simple solar installations, wind power, alternative building designs, community planning, and the production of energy from biological waste products including wood chips, corn cobs, seaweed, manure, and garbage.⁵⁵²

⁵⁵⁰ Sim Van der Ryn, *Design for Life: The Architecture of Sim Van der Ryn* (Layton: Gibbs Smith, 2005), 60.

⁵⁵¹ Quoted in Williams, *Energy and the Making of Modern California*, 321.

⁵⁵² Hal Rubin, “Woodchips and Windmills,” *California Journal* 9, no. 6 (June 1978): 187.

The CEC and Nuclear Energy

The state's strengthening anti-nuclear movement also contributed to pushing the state government to adopt a more radical approach to energy policy generally and solar specifically. Partly due to his early disinterest in energy issues and partly as a concession to the state's powerful utilities and industrial interests, Governor Brown initially appointed a pro-development board of commissioners to the CEC. Four members of the original five-person board supported nuclear development (Richard Maullin being the exception), a situation that irked environmentalists including Assemblyman Charles Warren who by 1976 was beginning to regret his role in establishing the commission. "Damn it," he told the press, "if the commission is always going to side with the utilities...I might as well repeal my goddamned act that created the thing."⁵⁵³

Rising public concerns about nuclear safety, combined with the availability of new data challenging the nuclear industry's electricity demand projections, led the commission in a new direction by 1976. In advance of a vote over Proposition 15 which would have required proof of safety prior to any approval for a nuclear power plant, the state legislature worked with environmentalists and the nuclear industry to draft its own set of standards for evaluating reactor safety. Voters ultimately rejected Prop 15, but not before the legislature passed three "nuclear fuel cycle" bills requiring the CEC to evaluate the federal government's standards for nuclear waste disposal before approving any standing proposals.⁵⁵⁴ A gradual turn-over in board members, largely in response to mounting public outcry against nuclear development, further

⁵⁵³ Quoted in *Ibid.*, 49.

⁵⁵⁴ Wellock, *Critical Masses*, 176.

decreased the likelihood that the CEC would serve as a one-stop approval mechanism as pro-nuclear interests initially believed.

The turn was completed in 1977 when the CEC determined to apply the new nuclear fuel cycle regulations to San Diego Gas and Electric's (SDG&E's) ambitious Sundesert proposal which called for the construction of two 950-megawatt nuclear reactors near the town of Blythe in the Mojave Desert. The committee ultimately voted to scrap the plan, after SDG&E had already pumped more than \$100 million into the project. The decision infuriated the state's utilities and industrial interests, causing what one observer described as a "lynch mob mentality" in the legislature. CEC co-creator and pro-nuclear senator Alfred Alquist's responded with the comment, "I feel like a Dr. Frankenstein who has created a monster."⁵⁵⁵

Alquist placed the blame on Governor Brown who happily took credit for the defeat of what turned out to be the last major proposal for nuclear development in the state.⁵⁵⁶ The decision, however, reflected a more complex set of circumstances. In response to reporters' questions, Commissioner Ronald Doctor quipped that he had been against nuclear power since "before the governor even knew how to *spell* energy." In addition to safety concerns, the commission also noted flaws in SDG&E's accounting, which raised serious questions about the utility's ability to finance its share of the project and indicated the possibility of rate increases for consumers. This was not "environmental obstructionism," Commissioner Reed insisted: "What about the viability of the plants themselves? What about the finances?"⁵⁵⁷ Charles Warren attempted to deflect criticism by claiming that the Sundesert decision was not "a reflection of the

⁵⁵⁵ Quoted in Ann Bancroft, "Advocates of Nuclear Power Plants Keep their Hopes on the Back Burner," *Los Angeles Times*, August 17, 1976.; Also see Ron Roach, "Senator Frankenstein," *California Journal* 9, no. 6 (June 1978): 189-191.

⁵⁵⁶ Roach, "Senator Frankenstein," 190.

⁵⁵⁷ Quoted in Foster, "The Energy Commisison," 52.

philosophy of the Energy Commission” but was simply “a reflection of the philosophy of the law,” a reference to the recently enacted nuclear cycle bills.⁵⁵⁸

A philosophical shift, not just in the law but in regards to the role of energy in society, played a more central role in the decision than Warren admitted. As historian Thomas Wellock illustrates, the defeat of Sundesert also reflected the CEC’s internalizing of a major shift in values among the people of California. No longer were Californians willing to accept without question the assumption that the risks of a commitment to nuclear energy were worth the benefits of a continuing supply of cheap, abundant energy.⁵⁵⁹ This change in attitude created a cultural and political climate conducive to experimentation in alternative energy futures.

From Anti-Nuclear to Pro-Solar

The CEC’s opposition to nuclear stemmed from a growing certainty among its commissioners, the Brown administration, and much of the public that while future energy needs remained uncertain, the ability to choose from a range of energy possibilities would better prepare the state to adapt to future challenges. Even before the final Sundesert ruling, the CEC was questioning the prevailing wisdom at the heart of federal energy programs which were based on projections of continuously increasing energy demand. In the forward to the 1977 *Biennial Report*, Commissioner Emilio Varanini expressed the CEC’s intent to “mitigate the mono-lithic and uncertain future that will result from the conventional wisdom with its singular and massive

⁵⁵⁸ Quoted in Roach, “Senator Frankenstein,” 190.

⁵⁵⁹ Wellock, *Critical Masses*, 176.

commitment to large-scale supply technologies that require heroic coordination in the governmental, financial, and energy sectors, and speedy conflict resolution.”⁵⁶⁰

This agenda rested on two basic questions. The first was whether California, the US, and the world were in fact “entering an era in which resource scarcity will inevitably force us to change the structure of our economy and the pattern of our lives.” The second addressed political considerations involved in implementing strategies in response to such conditions, specifically how to organize a state government bureaucracy with authority to coordinate a shift toward a more diverse, conservation-oriented energy regime while also encouraging “less intrinsic need for regulation and new or improved regulatory institutions that would streamline the regulatory process.”⁵⁶¹ The challenge was to apply a centralized state government bureaucracy to the task of designing a decentralized, flexible regulatory apparatus that enabled public input and the rapid adaptation of energy technologies and conservation strategies to local needs.

To achieve this, the CEC resisted adopting any one particular philosophy regarding state and national energy needs. The 1977 *Biennial Report* identified three primary positions on the question of energy scarcity: the first, “The Jeffersonian View,” emphasized intensive conservation and the rapid commercialization of small-scale solar and other renewable energy alternatives. This was the “soft path” proposed by Amory Lovins and associated in the public mind with E.F. Schumacher’s “small is beautiful” doctrine. The second, “The Greelian View” – named for nineteenth century journalist and western development advocate Horace Greeley – emphasized streamlining the regulatory process and increasing government support in financing large-scale projects. Utilities, the principal advocates of this view, argued that while prices

⁵⁶⁰ E.E. Varanini, III, “Forward” in California Energy Resources Conservation and Development Commission (CEC), *California Energy Trends and Choices: 1977 Biennial Report of the State Energy Commission, vol. 1, Toward a California Energy Strategy: Policy Overview* (Sacramento: California Energy Resources Conservation and Development Commission, 1977), ix.

⁵⁶¹ CEC, *California Energy Trends and Choices*, 5.

should be determined by market competition and not by government fiat, taxpayers and ratepayers should bear some of the financial risks of energy projects. The third view, “The Periclean View,” most closely resembled Charles Warren’s original vision for the CEC. This view advocated “comprehensive state planning.” It envisioned the CEC as a decision-making body whose role was to resolve conflicts between energy needs and environmental goals through effective regulation. “Pericleans believe that society can decide its energy use, just as an individual does,” the report stated. “It can attempt to shape the future, or it can treat it as a problem if predicting other peoples’ aggregate behavior and seek to outguess the future.”⁵⁶²

The approach the CEC settled on most closely resembled the Periclean view, but it also incorporated the ambivalence to top-down decision-making present in the other two views. The commission operated from a position of skepticism “of its or anyone’s ability to accurately forecast future events.” To rely on a single model of future energy development, they believed, would invite significant political opposition and would limit the state’s options in responding to novel conditions. In 1977, the CEC laid out several principles for its interim strategy based on the premise “that the central problem of energy policy is uncertainty about the levels of demand, about costs and availability of energy resources and technologies, and about the effects of energy use on the local and global environment.” The principles included: “security in diversity,” both of energy sources and the technologies that converted those sources into useable power; emphasis on flexibility in order to mitigate the risks of commitment to a single source, especially one (like nuclear) requiring massive investment in unproven new technologies; a focus on “what we know how to do,” which meant emphasizing simplicity in the implementation of both traditional sources and alternatives including solar; and lastly a commitment to avoiding regulation whenever possible. This last point echoed the Greelian view that “environmental

⁵⁶² Ibid., 66-91.

regulations have been chaotic and irrational.” But it also emerged from a recognition that powerful industrial interests had historically been successful in shaping state and federal regulations according to their short term needs. The first step toward eliminating unnecessary and ineffective regulations, the commission proposed, was to create more opportunities for public interests to contribute to the regulatory process.⁵⁶³

The 1977 *Biennial Report* proposed “a menu of policies from all three points of view.” The aim was to develop “a pragmatic energy strategy as the appropriate response to an uncertain and contentious energy milieu.”⁵⁶⁴ The approach allowed room for experimentation in all facets of energy planning. It included commitments to conservation, cogeneration, natural gas exploration, strict standards for power plant siting, research and development into new sources of energy, and rapid implementation of established renewable energy solutions. By 1977, the CEC also reversed its earlier commitment to coal and oil shale, concluding that these sources offered only short term solutions that did not align with the goal of improving environmental quality. Over the next year, in addition to halting the Sundesert plan, the CEC enacted the nation’s highest state standards for energy efficiency in new construction, appliances, and commercial equipment. It worked with state Public Utilities Commission (PUC), utilities, and municipal governments to develop demand-side load management strategies, energy audits, low-interest loans for conservation-minded consumers, and rate structures that promoted energy savings. It drafted agreements with research institutions including Stanford University and JPL for staff support for research into a variety of solar and other alternative energy options. It also began

⁵⁶³ Ibid., 92-104.

⁵⁶⁴ Ibid., 104, 105.

planning education and incentive programs to attract public interest and private investment in alternative energy technologies.⁵⁶⁵

In moving toward energy efficiency, local planning, and rapid commercialization of existing non-fossil fuel, non-nuclear energy technologies, the CEC departed further from the federal government's continuing emphasis on coal, nuclear, price controls on oil imports, and research and development into high tech, centralized energy systems. The central distinction between the CEC's energy strategy and the DOE's was the commission's willingness to take seriously a new set of criteria for what constituted a desirable future. These ideas emerged from a perception that cheap, abundant energy was not as vital to a smoothly functioning economy as had been previously believed, that it was just one of many factors of production and that "substitutes" in the form of economic policies and new technologies existed that could mitigate the negative social and economic impacts of energy scarcity. "Sound energy planning by the State of California," wrote professor of economics Robert Rooney and professor of business administration Phillip Mitchell (both at California State University, Long Beach), "must be based on explicit recognition that abundant, low-cost energy is *not* essential to the state's economy or social progress." This argument challenged the prevailing idea that the consumer lifestyle of the present day represented the "highest and best" form of existence ever known to mankind." Material abundance, Rooney and Mitchell contended, came at the cost of severe environmental pollution, loss of open space, degenerative diseases, psychological disorders, and loss of personal

⁵⁶⁵ California Institute of Technology, JPL, "Draft Proposal to the California Energy Commission for Staff Support on Solar Energy, March 1976. California Energy Commission Papers (hereafter CEC papers), California State Archives, F3912, box 2, folder 20, "Energy Commission, Administrative Files: Aid (Solar).; Williams, *Energy and the Making of Modern California*, 324.

freedoms “as machine-dominated technologies convert ever-greater numbers of Americans...into urban wage slaves with little hope of escaping the ‘system.’”⁵⁶⁶

The commissioners also became increasingly responsive to critiques of what California solar business owner James Piper referred to as “gold plated turkeys,” projects intended to contribute large amounts of electricity produced in centralized locations to the existing grid.⁵⁶⁷ The editors of the final 1977 *Biennial Report*, for example, decided to eliminate a draft proposal for a “billion-dollar solar bond issue” to construct several pilot solar electricity plants across the state after receiving an unexpected barrage of complaints from “people one would have normally thought would have been quite sympathetic to the idea.” Many solar advocates saw the proposed bond issue as an “anti-solar proposal” since large-scale solar electric plants were not established technologies and could not be relied on to make a significant contribution to the state’s energy budget in the short term.⁵⁶⁸ The preferred alternative was to encourage consumers to consider passive solar construction and simple, low-cost non-electric solar units provided by local and regional suppliers.

In exploring possibilities for leading the state down this path, the CEC found that while a strong pro-solar movement existed, the general public remained ill-informed about commercially available solar technologies. To convince the state legislature to let go of the nuclear vision for the state’s future that had prevailed through the 1960 and early 1970s, the commission recognized, would require demonstrating widespread public acceptance and understanding of an alternative future. “The Commission has a unique opportunity to move solar off dead center,”

⁵⁶⁶ Robert Rooney and Phillip Mitchell, “Learning to Live with Rising Costs: Progress without Cheap Energy,” *Cry California* 12, no. 1 (Spring 1977): 10.

⁵⁶⁷ James A. Piper in United States Senate, Select Committee on Small Business, *The Structure of the Solar Power Industry: Hearings before the Select Committee on Small Business, United States Senate* (Washington D.C.; U.S. Government Printing Office, 1980), 41.

⁵⁶⁸ CEC, *California Energy Trends and Choices*, 180.

wrote members of the solar office staff in September 1977. “We must convince the general public that solar is a social good, that it is economic...and is feasible today. If the public doesn’t buy the concept, the legislature will not be responsive. If the legislature is not responsive, even minimal funding will not be available.”⁵⁶⁹

Beginning in 1977, the solar office undertook surveys of consumers, builders, and lending institutions to determine the level of interest in the state and to assess public understanding of the types of solar technologies available and their prospects for commercialization. The office held public meetings and demonstrations and prepared consumer guides with information about simple solar technologies, local solar manufactures, passive design concepts, and energy conserving strategies. In August 1977, the office provided “informational and technical assistance” to a community in Santa Barbara following a fire that destroyed or severely damaged more than 350 homes. The purpose was “to encourage the incorporation of direct (passive) solar design and solar water heating systems into the homes that are to be rebuilt.”⁵⁷⁰ In the forward to the CEC’s August 1977 “California Solar Information Packet,” Chairman Richard Maullin stressed “that a well-informed and educated public is vital to the rapid and orderly development of solar energy use in California.” The numerous requests for information on solar energy received by the commission signaled to Maullin that “the public desires a better energy future and is earnestly seeking reliable information about the uses of solar energy for home and small business applications.”⁵⁷¹

⁵⁶⁹ Dana Waldie Rains, Jeff Reiss, John Burton, and Susanne Garfield to John Veigel and Gene Lynch, 19 September 1977. CEC papers, box 6, Folder 114, Information Groups.

⁵⁷⁰ “Santa Barbara Solar Rebuilding Project,” August 4, 1977. CEC papers, box 1, folder 15, EC Admin Files: Aid (Solar).; Diana Waldie Rains to John M. Veigel, 23 August 1977. CEC papers, box 1, folder 15, EC Admin Files: Aid (Solar).

⁵⁷¹ Richard Maullin to California Residents, forward to ERCDC, “California Solar Information Packet,” August 23, 1977. CEC papers, box 1, folder 15, EC Admin Files: Aid (Solar).

The CEC also sought to counter the vast majority of information on solar from utilities and the federal government which, solar office staff argued, failed to describe the most cost effective options. One funding proposal stressed the need to counter existing publically distributed information touting “high cost, in many cases overly complex, and in some cases totally inappropriate and impractical solar applications; i.e. solar air conditioning, solar photovoltaics, satellite solar, etc.”⁵⁷² In addition to the limited availability of reliable consumer information on passive solar concepts and solar space and water heating options, practical information for builders, lenders, building inspectors, and local governments was also scarce. The state program aimed to deemphasize high-tech research priorities and solar hardware in favor of information that would better support “the creation of an active growing self-sustaining solar industry in California.”⁵⁷³

Solar office staff were also skeptical of the federal government’s capabilities and focus. In a staff report on the 1977 meeting of the Solar Energy Society, Alexander Jenkins noted that ERDA treated California as a competitor as opposed to a potential partner. Federal officials took “the usual stance of being interested in what California is doing to see if there are implications for ERDA programing, instead of being interested in participating with, or directly supporting, California programs,” he wrote.⁵⁷⁴ Reporting on a visit to SERI in January 1978, office manager Lawrence Murphy wrote, “I tried to get them in some cooperative interchanges and have some of their people come out and spend some time with us.” The staff claimed to be “in too formative a stage” to help “in most areas at the present time.”⁵⁷⁵

⁵⁷² “ECPA Funding Proposal: Consumer and Professional Services for Market Expansion,” 1978. CEC papers, box 6, folder 109, conservation.

⁵⁷³ Ibid.

⁵⁷⁴ Alex Jenkins to Executive Office Division Chiefs re: Trip Report – International Solar Energy Society Annual Meeting, 7 July 1977. CEC papers, box 1, folder 15, EC Admin files: Aid (Solar)

⁵⁷⁵ L.M. Murphy to John Veigel, re: Trip Report on SERI Visit, 24 January 1978. CEC papers, box 7, folder 134, Office Files, 1977-Feb 1978.

The CEC's early focus on consumer education was a lead in to the larger task of implementing the package of solar bills then pending in the state legislature. In 1977, the legislature had enacted the first of these, a law granting a state income tax credit of \$3,000 or fifty five percent of the cost of purchasing or installing a solar energy system, whichever was less. The credit applied to both consumers and builders and constituted "the largest financial incentive in the country to encourage the use of solar energy," according to Jon Veigel of the solar office.⁵⁷⁶ The law represented a first step towards Governor Brown's goal of 1.5 million solar installations by 1985, an aim that the CEC estimated would create 40,000 to 50,000 permanent jobs while saving as much as 100 billion cubic feet of natural gas per year, amounting to \$430 to \$450 million in annual savings for consumers.⁵⁷⁷

To aid the CEC and the state legislature in developing and promoting solar legislation, Governor Brown created the SolarCal Council under the Department of Business, Transportation, and Housing in May 1978. Under the leadership of Tom Hayden of the Campaign for Economic Democracy, SolarCal linked solar energy development with social and economic issues including poverty relief, unemployment, and community self-reliance. Brown's order directed the council to advise the Governor on strategies for rapid implementation of solar energy in the state, to provide information to consumers, builders, and lending institutions, to propose policies to aid in the commercialization of solar technologies, and to promote coordination of private and public interests toward the goal of creating a viable market for solar technologies.⁵⁷⁸ As a subdivision of SolarCal, Brown also authorized a Local Government

⁵⁷⁶ Jon M. Veigel, "the California Experience in Solar Incentives," unpublished report, 1978: 6. CEC papers, F3912: 116, Energy Commission, Solar Energy Office, Subject Files, 1977-1978, Legislation, Local Government.

⁵⁷⁷ Ronald Doctor, "Solar Economics: A different Approach," unpublished essay, May 1978. CEC papers, F3912: 111, Energy Commission – Solar Energy Office Subject Files, 1977-1978, Economics, ECPA.

⁵⁷⁸ Hempel, "The Politics of Sunshine," 191.; See especially Ann Bartz, Jerry Yudelson, Ron Lipton, and SolarCal Council, *Toward a Solar California: the SolarCal Council Action Program* (Sacramento: SolarCal

Commission on Renewable Resources and Conservation staffed by municipal government officials from across the state and headed initially by Robert Black of Davis. The commission provided guidance and support for the drafting of zoning, construction, and transportation ordinances to promote conservation, solar development, and cooperation between state and local government. It also collaborated with other state agencies, community advocacy groups, and local government officials to publish information on solar initiatives implemented in counties and cities across the state.⁵⁷⁹

In working with SolarCal and the legislature to draft public policy for solar commercialization, the CEC sought to avoid putative regulations that called for “constraint-oriented behavior modifications.” The goal was to advance energy conservation and renewable energy development not by limiting economic activity with price controls or other more conventional “command and control” regulations, but by eliminating “present barriers to the use of energy systems by society.” The CEC favored what Veigel referred to as “performance oriented” over “prescriptive” regulations. The commissioners hoped to incentivize or “reward” what they considered “appropriate behavior” rather than explicitly mandate or prohibit activities in both production and consumption.⁵⁸⁰ The emphasis on financial incentives had the advantage “of being non-coercive to the consumer,” Solar Office staff member Stan Kaplan observed. This was an especially important consideration “in a period of growing dissatisfaction with

Council, 1979).; SolarCal Council and California Energy Extension Service, *A Guide to Passive Cooling: A Model Shading Ordinance* (Sacramento: SolarCal Council, 1979).; and Solar Energy Information Services, California, SolarCal Office, *Solar Energy and the Consumer Loan: A Handbook for Financial Institutions* (Sacramento: Solar Business Office, 1979).

⁵⁷⁹ Office of Appropriate Technology and SolarCal Local Government Commission on Conservation and Renewable Resources, *Local Energy Initiatives: A Survey of Cities and Counties in California* (Sacramento: Solar Business Office, 1979).; SolarCal Local Government Commission and California Energy Commission, *Local Ordinances to Improve Energy Efficiency of Existing Housing: A Guide for Local Governments* (Sacramento: SolarCal Local Government Commission on Conservation and Renewable Resources, 1981).; Jerry Yudelson, “Myths of Solar Commercialization” in International Solar Energy Society, American Section, *Proceedings of the 3rd National Passive Solar Conference, January 11-13, 1979, San Jose, California: Passive Solar Takes Off*, volume 3 (Newark: Office of the American Section of the International Solar Energy Society, 1979).

⁵⁸⁰ Veigel, “the California Experience in Solar Incentives,” 1-3.

government regulation.” Some prescriptive regulations would still be necessary, Kaplan explained, to counteract the unpredictable results of incentives including the difficulties of predicting consumer behavior and of monitoring how incentives reached certain parts of the market. But the general focus would be to support “the action of an incentive working through the marketplace,” to allow it to become “automatic and self-reinforcing.”⁵⁸¹

The immediate intent of the tax credit was to offset the high initial cost of solar installations which at that time amounted to approximately \$1,000 to \$2,000 for a solar hot water system, \$2,000 to \$3,000 for a direct space conditioning system, and \$4,000 to \$12,000 for an active solar space heating system. A second set of bills signed by the Governor at the end of the 1978 legislative session provided further protection for solar consumers, builders, installers, and small equipment manufacturers. Made up of both performance oriented and prescriptive laws, the bill package included an act for the establishment of training programs in renewable energy-related jobs; a law subtracting the value of solar installations on homes purchased by veterans; a law requiring the state Public Utilities Commission (PUC) to withhold approval of any utility-led solar equipment manufacturing or marketing program, pending determination that the program would not restrict competition in the solar industry; an appropriation of \$315,000 for a Passive Solar Design Competition; a bill requiring the PUC to investigate the feasibility of using utilities and/ or other lending institutions to finance solar installations; and a law permitting loans for energy conservation equipment to be “rolled into” existing home mortgages.”⁵⁸²

The legislature also approved two bills, the first of their kind in the nation, to ensure consumer access to solar radiation. The first, the Solar Shade Control Act restricted the planting

⁵⁸¹ Stan Kaplan, Solar Office Development Division, CEC, “Incentives for Solar,” July 1978. CEC papers, box 6, folder 113.

⁵⁸² Ann Bartz, Program Analyst, SolarCal Office, “California’s Latest Solar Legislation,” 1978. CEC papers: 7, folder 129, Energy Commission, Solar Energy Office, Subject Files, 1978-1979, SolarCal.

of vegetation which shaded a neighboring property owner's solar collectors for more than ten percent of the time between 10:00 a.m. and 2:00 p.m. The second, a "solar rights" bill, established the right of state residents to negotiate with their neighbors for the protection of "solar easements" allowing "access to sufficient sunlight to operate solar collectors or passive systems."⁵⁸³

Finally, the legislature passed Assemblyman Michael Wornum's "Energy Commission Solar Plan" which required the CEC to submit to the governor "a plan for the maximum feasible solar implementation in this state by the year 1990." The plan was to include recommendations for objectives in various market sectors, incentive proposals, and "corrective measures to overcome technical, economic, and institutional barriers to maximum feasible implementation."⁵⁸⁴ The Governor, the CEC, and the state legislation intended these policies to provide the initial push for the creation of a grassroots solar industry comprised of small and medium sized business that could provide consumers with affordable and environmentally beneficial alternatives to utility-provided gas and electricity.

A primary challenge for the CEC was to define a philosophical rationale that reconciled its mistrust of regulation and centralized control with its recognition of a need for significant short term government intervention in the energy marketplace. The commission based its position on a recently completed Battelle Memorial Institute study which found that since 1918, the federal government had spent at least \$123.6 to \$133.7 billion on incentives to stimulate energy production. (Commissioner Ronald Doctor speculated that the true amount more likely approached \$300 to \$500 billion.) According to the Battelle study, approximately sixty percent of this cost went to the oil industry in the form of tax reductions on drilling costs, disbursements

⁵⁸³ Ibid.

⁵⁸⁴ Ibid.

for developing newly discovered oil fields, maintenance of ports and waterways for oil tanker traffic, and research and development conducted by the United States Geological Survey and the Bureau of Mines. The additional incentives were applied mainly to hydropower, coal, natural gas, and nuclear development. For fiscal year 1976, the study found that of the \$9.97 billion spend on energy development fifty-five percent went to electricity generation and distribution. Out of the remaining forty-five percent, the nuclear industry received \$2.39 billion, the oil industry received \$1.25 billion, and the coal and gas industries received \$500 million each. For the CEC, the most telling number was the comparatively paltry \$100 million in incentives for the solar energy industry during the year.⁵⁸⁵

In a presentation to the DOE, Doctor urged that a massive commitment of federal spending on solar would be necessary “to make up for more than 60 years of subsidies to producers and consumers of gas, oil, coal, and nuclear power.” These subsidies would not be “handouts,” he stressed, but “equalization mechanisms” designed to level the playing field, to make market competition in the energy industry a real possibility.⁵⁸⁶ In California, he explained, the CEC was moving toward the implementation of “massive government programs similar to the bold programs that built the state water project, the state highways, and our renowned university system.”⁵⁸⁷

The approach rested on an economic model predicated on the non-existence of the “traditional free market model of Adam Smith.” While a market allowing unmediated exchange between buyers and sellers may have existed in Smith’s time, Doctor argued, no such free

⁵⁸⁵ Battelle Memorial Institute, “An Analysis of Federal Incentives used to Stimulate Energy Production: An Executive Summary,” March 1978: 2-6.; Ronald Doctor, “Belling the Cat: Moving Toward an Effective Federal Program for Commercializing Solar Energy,” paper presented to the U.S. Department of Energy, Solar Energy Policy Forum, Los Angeles, California, June 15, 1978: 1-2.

⁵⁸⁶ Doctor, “Belling the Cat,” 1.

⁵⁸⁷ Ronald Doctor, “Solar Economics: A different Approach,” unpublished essay, May 1978. CEC papers, box 6, folder 111, Energy Commission – Solar Energy Office Subject Files, 1977-1978, Economics, ECPA

market existed in the present. Consequently, any effort to set energy policy based purely on economic calculations would be “wholly inappropriate for the new exigencies with which we much deal.” Conventional economic theory not only failed to adequately account for the massive structure of past and present subsidies supporting the oil, gas, coal, nuclear, and hydropower industries, he observed, it also tended to “ignore the social and environmental variables that do not fit easily into the economist’s theoretical models.”⁵⁸⁸ Writing to JPL group supervisor Richard O’Toole, Doctor’s assistant Bob Weisenmiller further clarified the position by emphasizing the CEC’s responsibility to act in the public interest. “It would seem that a difficult but necessary part of energy policy work is to always remember that decisions must be based upon economic, technical and political rationality, so that mere economic or technical efficiency arguments will never completely hold sway.” He also urged the JPL to base its recommendations to the agency “upon the perspective of social decision making; our only role is to superimpose social planning upon corporate or individual planning when the public good is aided.”⁵⁸⁹

Drawing on the work of alternative economic thinkers including Hazel Henderson, author of *Creating Alternative Futures* (1978), and E.F. Schumacher, Doctor stressed the necessity of re-orienting economic theory around the principle of scarcity of capital, energy, and materials. Doing so also involved re-envisioning what constituted a desirable future and what the government’s role would be in realizing that vision. In a future in which there seemed to be “plenty for our needs but maybe not for all our greeds,” he said, “we have to re-define what’s better and what’s worse; we have to re-define what we mean by satisfaction.” For Doctor, this

⁵⁸⁸ Ibid.: 5, 6.

⁵⁸⁹ Bob Weisenmiller, Assistant to Commissioner R.D. Doctor, to Dr. Richard O’Toole, Group Supervisor, JPL, 10 August 1977. CEC papers, box 1, folder 15, 1975-1977, Energy Commission, Administrative Files: Aid (Solar).; Also see Jerry Yudelson [director of SolarCal office] to Honorable Charles Warren, Chairman, and Honorably Gus Speth, Member of the Council on Environmental Quality, Executive Office of the President, 22 May 1978. CEC papers, box 7, folder 128.; Yudelson wrote: “The phrase ‘economically competitive’ is misleading. The question is, what level of solar development increases our real national wealth in the future, when all subsidies to all fuel sources are excluded.”

meant letting go of the traditional reliance on “highly capital intensive technological remedies for our technological ills.” Echoing Schumacher, he wrote, “The long binge is over. If we do not manage the economic transition that is upon us, the system will continue to do it for us, with inflation.” The ecological basis for modern society, Doctor concluded, could only be preserved by moving toward a “resource conserving, fully employment, noninflationary economy” based on solar energy and other renewable resources “which pay back rather than consume capital resources.”⁵⁹⁰

Doctor’s philosophy reconciled a planning tradition with roots in postwar California with mounting public skepticism of top-down decision-making and large-scale projects. While stressing a program of intensive government intervention in energy development on a similar scale to such massive undertakings as the California Water Project and the state highway system, he also maintained that the transition to solar should come from “a grassroots thrust.” The primary push, he urged, “must come not from big government and big business but from individuals and citizen movements.” Doctor saw consumer education, the tax credit and attendant solar legislation, and the CEC’s ongoing efforts to convince federal policymakers to promote commercialization and adopt a more conservation-oriented approach to energy economics as necessary means “to remove barriers to widespread solar use” – to allow consumers greater freedom to choose the solar energy and conservation path by eliminating the advantages that a long history of policymaking based on conventional economic calculation had conferred on the traditional high-energy path.⁵⁹¹

As a young state agency with broad decision-making powers and the support of a brazen governor, the CEC faced fewer obstacles than federal agencies in pursuing this more radical

⁵⁹⁰ Doctor, “Solar Economics,” 7.

⁵⁹¹ *Ibid.*, 9.

course for solar implementation. The commission was also operating in a physical and political geography conducive to a more rapid transition to small scale solar and other forms of renewable energy produced and used at the local level. California, journalist Hal Rubin wrote in 1978, was “uniquely situated to take advantage of important sources of ‘soft’ energy.” With 270 days of sunshine on average per year, consistent westerly winds, “almost unlimited access to agricultural and forest waste products,” and a seismically active geology, the state possessed the necessary natural resources for the development of solar, wind, biomass, and geothermal energy. Solar was a particularly attractive option. Rubin reported that current technologies could meet two-thirds of the state’s water heating needs. Solar units could also reduce natural gas and oil consumption for space heating by approximately twenty percent in the short term. A transition to solar energy also complemented Californians’ emerging environmental and political values. As Rubin put it, “Solar energy is nonpolluting, safe, free of control by the Arab nations, immune to terrorist seizure, inexhaustible, delivered every morning – and cannot be metered.”⁵⁹² These conditions provided the context for the CEC and other state agencies to pursue a more aggressive approach to conservation and solar energy implementation.

Municipal Solar: OAT and the Davis Model

A central aim for the CEC and the Brown administration was to support local level solar energy and conservation planning. This was most visible through Sim Van der Ryn’s OAT. One of the office’s priorities was to encourage individual and community-level efforts to “live lightly on the earth” by making use of appropriate technologies. In 1978, Van der Ryn announced merit awards to municipalities and local organizations around the state that demonstrated commitment

⁵⁹² Rubin, “Woodchips and Windmills,” 187.

to “grassroots efforts to improve their communities.” Awards went to Palo Alto for incorporating bicycle transportation into its general plan, the Senior Gleaners of Sacramento for “salvaging tons of food a year” to donate to charities, the community of Westwood for organizing an “electricity boycott” which focused attention on utility abuses and “readily available alternatives to electricity,” and the city of Hercules for installing a low-energy wastewater treatment facility. “These awards,” Van der Ryn said, “are a means of recognizing the efforts of people who are seeking more conserving, more humane ways of improving the quality of life.” The purpose was to reward local efforts toward self-sufficiency. The recipients “are not asking for help, or waiting to be shown how – they are doing it on their own.”⁵⁹³

Van der Ryn left OAT to rejoin the Farallones Institute in late 1978, but with the continuing energy crisis and rising interest in solar and energy conservation among community activists and municipal governments, the office’s budget continued to grow, reaching \$3.2 million by 1981. OAT, according to Robert Judd, Van der Ryn’s replacement, symbolized California’s national leadership in supporting energy conservation efforts at the state, local, and individual levels. “California is the only place where intelligent experimentation is taking place,” he said.⁵⁹⁴

The city of Davis remained the most visible model for local level solar and conservation planning in the state and nationwide. In 1977, *Sunset Magazine* ran an article highlighting Village Homes’ balance of environmental consciousness, community cohesion, and modern convenience.⁵⁹⁵ In 1979, Governor Brown appointed Judy Corbett of Village Homes to head

⁵⁹³ Office of Appropriate Technology, “Appropriate Technology Awards,” press release, April 21, 1978. CEC papers, box 8, folder 142.

⁵⁹⁴ Quoted in Rubin, “Woodchips and Windmills,” 187.

⁵⁹⁵ “Village Homes History.”

SolarCal's Local Government Commission, previously headed by Robert Black of Davis.⁵⁹⁶

Media coverage brought additional national and even international attention to the development.

Rosalyn Carter, President Jimmy Carter's wife, visited the community during a national energy conservation tour. Celebrity activist Jane Fonda also took a bike tour of the neighborhood.

Shortly after the completion of all 242 homes in 1984, French president Francois Mitterrand visited, arriving via helicopter on one of the community playfields where he was greeted by a crowd of residents and reporters.⁵⁹⁷

Local solar business owners and government officials welcomed media coverage and actively promoted Davis's approach as an example for other communities in the state and nationwide. "The people of Davis have broken the myth that the energy problem is far beyond our control and can be handled only by far-away men of great power and expertise," proclaimed local energy consultant David Bainbridge in 1978.⁵⁹⁸ In 1979, Mayor Thomas Tomasi noted a rising interest among municipal governments throughout California in instituting programs such as those proposed by prominent alternative energy advocates including Amory Lovins, the Solar Lobby, and Robert Stobaugh and Daniel Yergin (authors of the influential 1979 *Report of the Energy Project at the Harvard Business School*). The Davis experience, he added, demonstrated the very real possibility that "we can continue economic growth while we decrease our dependence on fossil fuels by increasing our use of renewable resources and greatly improving energy efficiency in our homes, businesses, transportation systems, and work places."⁵⁹⁹

⁵⁹⁶ Judy Corbett and Tom Hayden, "Local Action for a Solar Future," *Solar Law Reporter* 2, no. 5 (1981): 953-969.

⁵⁹⁷ Jackson, "Back to the Garden," 78.

⁵⁹⁸ Quoted in Vine, 122.

⁵⁹⁹ Tom Tomasi, Office of Appropriate Technology, "Local Energy Initiatives: A Second Look: A Survey of Cities and Counties California, 1981," 1. Earthmind Papers, University of California, Davis Special Collections, box 29.

Several California cities adopted programs in the Davis mold. The goal was not just to save energy, but to do so on terms set by local citizens, businesses, and government representatives. In San Diego, the County Board of Supervisors created an Energy Office under the Department of planning “in response to the lack of a coherent energy policy from the federal and to some extent the state governments.” The purpose, County Supervisor Roger Hedgecock explained, was “to provide what leadership they could in local energy planning.”⁶⁰⁰ The office provided analysis of possible energy saving measures and helped draft policies. The most ambitious of these was an ordinance requiring solar water heating units in new residential construction where solar access was sufficient and where natural gas lines did not reach.⁶⁰¹ Also in the late 1970s, the city of Riverside enacted a series of measures designed to encourage the development of alternative fuels in order to mitigate the city’s severe smog problem.⁶⁰² The city of Santa Clara created its own Office of Appropriate Technology to advise the City Council on energy saving measures.⁶⁰³ In 1975, Santa Clara had also established a municipal solar utility to provide alternative choices to residents then dependent on large private utilities. The central theme linking these efforts was an interest in promoting self-reliance in decisions about building codes, zoning, and energy use.

By 1979, these arguments were also entering into debates over the role of local governments in shaping national energy policy. Testifying in support of the Local Energy Management Act of 1979, Republican Senator Charles Percy of Illinois argued that “local units of government are highly appropriate vehicles for the promotion of energy conservation and

⁶⁰⁰ Roger Hedgecock, San Diego County Supervisor, “Local Leadership for Solar Energy in San Diego County,” *Community Energy Self-Reliance*, 175.

⁶⁰¹ *Ibid.*, 176.

⁶⁰² Allen L. White, David A. Ball, and Robert Zweig, “Riverside, California: A Forerunner of Comprehensive Community Energy Planning,” *Community Energy Self-Reliance*, 205.

⁶⁰³ Williams, *Energy and the Making of Modern California*, 328.

renewable resource-based technologies, because of their sensitivity to geographic and climatic variations, their ability to make effective use of available human skills and economic resources, their high visibility, and their capacity to accommodate a high degree of citizen involvement in the study, implementation, and demonstration of new programs.”⁶⁰⁴ At a conference on community energy self-reliance hosted by SERI later that year, Charles Horn, mayor of Kettering, Ohio, attributed the lack of opportunities for local governments to involve in energy decisions to the “growing Federal bureaucracy” which consisted “largely of people who have not had experience in the operation of Local Government but who are designing programs which are mandated upon us.”⁶⁰⁵ The DOE was the worst offender, discouraging experimentation on the municipal level and continually rebuffing the National League of Cities and the US Conference of Mayors in their efforts to participate in national energy programs. “Local Government,” Horn said, “is providing services directly to people, is the closest to the people, is most accessible to the people, and is in a position to materially assist in the implementation of the broad-based Energy Program.”⁶⁰⁶

Municipal efforts to promote solar energy and conservation in California and elsewhere during this period tended to be geared toward middle and upper middle class new home buyers. Surveys also showed that interest in solar was generally concentrated in white communities. However, some community organizations in California, many with assistance from SolarCal, also turned to solar energy as a potential solution for low income minorities struggling with increasing energy costs. For these groups, solar energy utilization was as much an anti-poverty

⁶⁰⁴ Quoted in Robert Odland, “Opening Remarks,” in Solar Energy Research Institute, *Community Energy Self-Reliance: Proceedings of the First Conference on Community Renewable Energy Systems, University of Colorado, Boulder, Colorado, August 20-21, 1979* (Washington D.C.: Government Printing Office, 1980): 54.

⁶⁰⁵ Charles F. Horn, Mayor of Kettering, Ohio, “Role of Local Government in Energy Programs” in *Community Energy Self-Reliance*, 101-102.

⁶⁰⁶ *Ibid.*, 104.

matter as an environmental one. In 1976, a group in San Bernardino formed the West Side Community Development Corporation (CDC) – a non-profit, minority-owned organization – in order to include solar energy as part of a program to rehabilitate abandoned homes. With funds from the state and the US Department of Housing and Urban Development (HUD), the CDC planned, built, and operated a small central solar energy plant that provided space heating and hot water to a block of ten homes in the low income Dellman Heights community. By 1979, the system included seventy-two solar panels, a buried 5,500 gallon capacity heat-storing water tank, and a hydroponic greenhouse. Not simply an energy conserving project, the CDC solar system was also meant to stimulate jobs and provide training to community members in a budding new industry. While the CDC had previously been involved in low-skill job training and placement, the solar project went “one giant step further” as members realized “the potentiality of building a *new* resource of qualified minority people to enter productively into the *Solar Age*.”⁶⁰⁷

Barriers to a Solar California

The growing number of small solar energy businesses and local-level solar energy and conservation planning movements in California by the late 1970s seemed to signal that the state was on the cusp of leading a transition to solar energy that would eventually transform the nation and the world. The actual results, however, largely failed to meet expectations. Davis turned out to be an anomaly in the state. While other municipalities enacted energy conservation codes, the more comprehensive planning regime in Davis was difficult to replicate. Davis’s small size, favorable climate for passive solar construction, predominance of new construction, homogenous

⁶⁰⁷ Valerie Pope Ludlam, President CDC, “The Development and Operation of Successful Neighborhood Solar Energy Projects in San Bernadino, California,” in *Community Energy Self-Reliance*, 59-62.

population, and university ties created a unique set of circumstances for accommodating alternative energy and conservation planning.

The CEC also encountered opposition and doubt from other state agencies, the building industry, and lenders.⁶⁰⁸ The response of J. Foster Fluetsch, president and general manager of State Savings in Stockton, was typical. First, he cited the lack of clear evidence that solar installations would increase home values. He said they might actually deter buyers by causing the home “to look out of place in the neighborhood.” Second, he doubted the CEC’s assurances of the long term productivity and reliability of the largely untested technologies available from vendors, many of which were brand new companies started by people with little or no experience in home construction or traditional plumbing and conditioning systems. Finally, he observed that the frequency which the typical California homeowner moved – approximately every six months to nine years – meant that most would not remain in the same location long enough to recoup the high initial cost of solar installations, even with state incentives. “Personally, I am not negative regarding solar systems,” he said. “But, as you can see, I have little confidence in the lending communities’ willingness to advance funds anywhere near the cost of equipment.”⁶⁰⁹

Appraising the actual market costs of solar retrofitting and how builders and consumers took advantage of the tax credit also proved difficult. Partly this was a result of the large number of new solar businesses in the state (as many as 7,000 by late 1978) and the wide variety of devices available. An October 1978 survey of solar hot water systems by the CEC Solar Projects Office also revealed “considerable variation in the ease of retrofitting solar on different homes.” The authors concluded that “it may have been unreasonable to expect an accurate answer to the

⁶⁰⁸ See especially Dale Stuard with consulting assistant Robert J. Kuntz, “Solar Energy Policy for California: Analysis of the SolarCal Action Program titled ‘Towards a Solar California’,” Prepared by California Building Industry Association Task Force, October 18, 1978. CEC papers, box 7, folder 129.

⁶⁰⁹ J. Foster Fluetsch to Richard L. Maullin, 26 September 1977. CEC papers, box 7, folder 128.

question of how much it would cost to retrofit an ‘average’ home, as opposed to a new home.” The survey results further suggested that larger firms charged “considerably more” for closed water heating systems using antifreeze as the heat exchanger, perhaps a result of higher consumer confidence. This finding, the authors noted, “may be very relevant to ongoing public debates concerning utility involvement on solar” which they thought could lead to a more centralized industry comprised of fewer, larger firms. Another concern was the lack of information on whether builders or consumers were claiming the tax credit, leading to uncertainties about how much savings were passed on to consumers and “what the actual cost of the system is to the home buyer.”⁶¹⁰ Bruce Gilleland of the Solar Office further reported that some builders were not passing savings on to the consumer but were actually inflating the cost of the solar components “over what a person would have to pay if he was to purchase solar directly.” The tax credit was the culprit, he said, because it permitted builders “to factor in various overhead costs in determining the cost of the unit” when making a claim. The credit also enabled builders to take advantage of consumers’ lack of knowledge of the solar market.⁶¹¹

To address the problems of inconsistent costs, faulty equipment, improper installations, “fast buck artists” in the solar industry, and the rapid turnover of solar businesses, the CEC recommended a provision for a state-led quality control and warranty program in the tax credit bill. When the bill passed, the CEC began drawing up plans for a Testing and Inspection Program for Solar Equipment (TIPSE).⁶¹² Disagreements emerged from the start. Industry representatives objected to the plan to mandate compliance. Opponents noted that the testing program only evaluated thermal performance, meaning that even if only the thermal component

⁶¹⁰ Marwan Masri and Prabhunam Sign Khalsa to Robert A. Shinn, re: “Solar Hot Water System Survey,” 19 October 1978. CEC papers, box 6, folder 109.

⁶¹¹ Ibid.

⁶¹² TIPSE Committee, “Committee Report: Accreditation of Laboratories and Certification of Solar Equipment,” 1977. CEC papers, box 7, folder 149.

failed to meet standards, the whole system would be ineligible for the tax credit. Solar business owners were also uncomfortable with being subject to “an as yet totally unproven testing and certification program.”⁶¹³

In response, the TIPSE committee agreed to a partnership with the California Solar Industries Association (CALSEIA), an affiliate of the Washington D.C.-based SEIA, to draft clearer standards and to create a lower cost, streamlined testing and certification process.⁶¹⁴ The resulting program, renamed CALSEAL, went into effect in April 1978. By September, however, the solar office reported a severe backlog of applications. According to office manager Marty Murphy, 200 solar businesses filed applications, double the amount expected. And while they had expected to have three or four staff members assigned to process applications, budget cuts, reorganization of the agency, and a hiring freeze left the office with only one person available.⁶¹⁵ Meanwhile, dozens of businesses were left without the ability to demonstrate to consumers that they met state standards either for the tax credit or for quality assurance purposes.

By late 1979, slow growth in the number of solar installations pointed to the program’s overall ineffectiveness in stimulating consumer confidence to actually buy solar systems. In 1980, the Institute of Governmental Studies at UC Berkeley counted 78,323 residential solar installations claimed under the tax credit since 1976. Despite the rapid growth of the solar industry during that period, and while California continued to lead the nation in new solar installations, the number was well behind the 150,000 installations Governor Brown and the CEC had called for in 1978, making the goal of 1.5 million installations by 1985 appear more

⁶¹³ Ibid.

⁶¹⁴ Dick Pierson, “T-Label Program,” staff draft, 9 March 1978 and CALSEIA, “Description of Proposed Program,” 1978. CEC papers, box 7, folder 148.; CALSEIA Press Release, “Growing California Solar Industry,” November 13, 1978. CEC papers, box 6, folder 107.

⁶¹⁵ Marty Murphy, Solar Office Manager, to Rob Shunn and Ron Kukulka, 19 September 1978. CEC papers, box 7, folder 149.

difficult to meet. Even more disappointing, an estimated seventy-four percent of the claimed products were plastic pool covers, which the legislature had only included in the tax credit after repeated demands from industry representatives.⁶¹⁶ The roughly 17,000 non-pool related solar systems installed since the passage of the tax credit bill was about equal to the number of home solar water heaters installed in Southern California alone by 1920, when the state's population was tenfold less.

Utility Involvement and the Politics of Scale

Slower than expected growth in the solar market in California also provided an opening for utilities to wrest some control away from state government. Utility executives argued that they already had an established system for testing and evaluating new technologies; that the economies of scale they enjoyed allowed them to provide stable, predictable rate structures; and that consumers would feel more confident in their ability to honor warranties, provide service, and guarantee quality products.

The situation created a double bind for solar advocates and the CEC. Since 1977, the CEC had maintained the position that utilities should not be included in plans to commercialize solar equipment through consumer ownership and leasing. This reflected a concern among solar advocates and the SolarCal office that utilities would take measures to control the pace and character of solar implementation in order to reduce competition, stifle innovation, and slow

⁶¹⁶ Edward Vine, "Solar California: Data Update," *California Data Brief* 6 (April 1982).; For the debate over pool covers see CEC committee report, "State Solar Energy Tax Credit: Revised Guidelines and Criteria," adopted April 5, 1978. CEC papers, box 7, folder 137.

demand reductions for traditional energy sources.⁶¹⁷ The battle taking shape in California, as one writer for *The Nation* put it, was “over who shall own the sun.”⁶¹⁸

At the same time, the CEC solar office recognized that public and legislative acceptance of its solar programs hinged on the utilities’ willingness “to count demand reduction from more seriously than they have in the past.” This goal rested on demonstrating “that our commercialization activities are proceeding on schedule so that utilities can realistically be asked to ‘count’ the solar non-electric resource in their forecasts.”⁶¹⁹ Thus, when the limited impact of the solar legislation became apparent by 1979, the CEC was forced into a position of soliciting cooperation from utilities while attempting to continue building a program to increase competition in the energy marketplace.

The utilities had a different agenda that aligned more closely with the federal government’s emphasis on large scale research, development, and demonstration projects. In 1975, Southern California Edison (SCE) announced a plan to partner with the Los Angeles Department of Water and Power to apply for an ERDA grant to build a ten megawatt centralized solar thermal electric plant. The CEC also agreed to a limited role in the project, mainly to maintain its ability to both influence and benefit from federal programs.⁶²⁰ Even as it continued to advocate for nuclear development, SCE recognized advantages to also pursuing the ERDA contract. First, the energy crisis had demonstrated a clear need to pursue a variety of energy

⁶¹⁷ ERCDC, “Written Testimony of: Alexander F. Jenkins, Jr.,” 1977.

⁶¹⁸ Fred Branfman, “California’s Fight for the Sun,” *The Nation*, June 18, 1977.; Also see Tom Hayden, “SolarCal: Making Sense while the Sun Shines,” *New West*, July 18, 1977: 80. Both articles were printed as attachments to a 1978 SolarCal draft proposal released for nationwide circulation. CEC papers, box 6, folder 118.; This argument is most fully expressed in Ray Reese, *The Sun Betrayed: A Report on the Corporate Seizure of U.S. Solar Energy Development* (Boston: South End Press, 1979).; Also see Barry Commoner, *The Politics of Energy* (New York: Alfred A. Knopf, 1979).

⁶¹⁹ ERCDC memorandum re: “Solar Office NOI Strategy,” 15 June 1978. CEC papers, box 6, folder 120

⁶²⁰ This position is described in a 1978 CEC memorandum regarding participation in the DOE-supported Western Solar Utilization Network which proposed the construction and demonstration of a network of large scale solar electric plants in western states. Jon M. Veigel to Executive Office, re: “Background, Issues and Recommendations for WSUN,” 22 March 1978. CEC papers, box 7, folder 141.

paths for the future. Second, the solar thermal project represented an opportunity to garner federal funding and to demonstrate a commitment to solar to a public increasingly concerned with energy scarcity and environmental quality. And third, an early commitment to solar would allow the utility to stay abreast of and possibly challenge any significant new direction in energy policy at the federal and state levels. Specifically, it provided an opportunity for SCE to expand its current solar programs which were limited to consumer surveys, solar equipment demonstrations, and installations of some pilot solar heating systems. Concluding that “the practical widespread use of domestic solar systems still remains a formidable problem,” SCE chairman Jack Horton emphasized the benefits that would accrue from demonstration of the projected \$120 million thermal solar plant, “the world’s first project using the sun’s power to actually generate electricity on a large scale.”⁶²¹

Located outside of Barstow, California, Solar One, as the project was named, became the symbol for more radical solar advocates’ warnings about the corporate takeover and bureaucratization of the solar industry. The project’s central collector, the “Power Tower,” historian Lamont Hempel writes, “was to some solar enthusiasts what the Washington Monument is to probing psychoanalysts.”⁶²² Solar One also promised long term rewards for utilities. For SCE, it served to minimize financial risk while allowing the company to maintain control over the impending transition to a more diverse energy regime. One of the major concerns that came out of SCE’s solar research during the mid-1970s was the “reliability burden on the utility,” the utility’s responsibility to provide auxiliary standby energy to compensate for

⁶²¹ Jack H. Horton, Chairman of the Board, SCE, to Edmund G. Brown, Jr., 3 November 1977.

⁶²² Hempel, “The Politics of Sunshine,” 172, 173.

periodic interruptions to the supply of solar electricity.⁶²³ Involvement in ERDA's program enabled SCE to monitor the results of solar electric generation without exposure to the financial risks associated with actual commercial implementation.

Solar One was the most visible federally-funded, large-scale solar development project in the state. But it was only one of many. In April 1978, PG&E announced its successful bid for DOE funding to build a fifty kilowatt experimental solar facility at a utility-owned site in San Ramon. The plant was to use Fresnel (multi-prism) lenses to concentrate sunlight onto a bank of experimental chemically-treated gallium arsenide photovoltaic wafers developed by Varian Associates of Palo Alto. The project represented an effort to establish greater cooperation between the utilities and the state's electronics industry. It also furthered the utilities' goal of shifting the emphasis of solar policy in the state away from rapid commercialization of existing technologies and toward experimental high-tech solutions. "Although the power plant will not be economic compared with present electric generation options," the company announced, "the little plant will be an important step forward in the continuing effort to find ways to make direct conversion of sunlight to electricity economically competitive with traditional methods."⁶²⁴

In May 1978, PG&E vice president Nolan Daines wrote to Jon Veigel of the CEC solar office to further clarify the utility's position on solar development. While acknowledging that "the future will utilize a greater diversity of energy sources than even imagined in the not-too-distant past," Daines firmly stated the company's resistance to significant short-term changes to existing technologies and priorities. The goal of alternative energy policy, he urged, should be "perfection" of the technology through research, a course requiring "substantially greater time

⁶²³ SCE, "Solar Energy and Southern California Edison Company: Applications for Buildings," report presented at CA Legislature Assembly Committee on Resources, Land Use, and Energy, November 30, 1977. CEC papers, box 7, Folder 142.

⁶²⁴ PG&E News Bureau press release, "PG&E to Construct Prototype Sunlight-to-Electricity Plant," April 3, 1978. CEC papers, box 6, folder 121.

and effort” than the CEC currently recognized. He further warned about the risks of “conditioning approval of traditional generating projects on...premature development of emerging technologies.” While stressing the need to develop “more benign resources for future decades,” Daines expressed a commitment to existing technologies including oil, coal, and nuclear for the next decade. “It is quite valid for research to proceed on the basis of hopes and dreams and visions of a wide variety of renewable alternative energy resources,” he urged. “But planning must be based on firmer basis.”⁶²⁵

The CEC’s lack of direct authority to affect utility spending on renewable energy research limited its ability to challenge this position.⁶²⁶ The commissioners were also not in a position to dictate utilities’ research objectives which remained tied to business objectives and DOE funding. This was partially due to a continuing lack of reliable technical and economic data to challenge utility forecasts. In a March 1978 memorandum, solar office manager Lawrence Murphy recommended limiting the CEC’s participation in a PG&E power plant development proposal to a brief presentation on the potential benefits of greater attention to wind and solar power. While the office had considered presenting a more forceful argument for using smaller scale wind and solar installations to reduce direct thermal capacity requirements, Murphy explained, the office did not have a “technical base sufficiently developed to argue the specifics of passive and wind” as offsetting elements of the system.⁶²⁷

Federal Intervention

⁶²⁵ Nolan H. Daines to Jon M. Veigel, 16 May 1978. CEC papers, folder 3912: 121.

⁶²⁶ John Blees, Legal Counsel to Meir Carasso, re: “Methods to Influence Utility R&D Spending,” 14 October 1977. CEC papers, box 2, folder 20.

⁶²⁷ Lawrence M. Murphy to Bill Miller, 16 March 1978. CEC papers, box 6, folder 119.

Federal policies also both enabled and constrained solar commercialization activities in California during the late 1970s and early 1980s. The most important of these was the Public Utility Regulatory Policies Act (PURPA), passed as part of Jimmy Carter’s National Energy Act (NEA) in November 1978. Meant to reduce the nation’s coal and natural gas demand, PURPA mandated that regulated utilities purchase electricity produced by small energy producers at a price equal to what the utilities would have paid to produce the power by conventional means. The act also exempted “qualifying facilities”—defined as facilities with a capacity of thirty megawatts or less which primarily used renewable sources including solar, wind, hydro, biomass, and geothermal – from federal and state regulations.⁶²⁸

PURPA signaled the Carter administration’s responsiveness to the more radical solar advocates’ resistance to monopoly control of the solar market. However, it also enabled utilities’ to maintain a central role in transitioning to renewable energy while also limiting state and local governments’ ability to determine priorities and standards. In California, the Public Utility Commission’s decision to aggressively implement PURPA beginning in 1979 stimulated rapid diversification of electricity production. Although the energy output from qualifying facilities remained a small percentage of the state’s total energy use (amounting about 10,000 megawatts by 1984), the act resulted in the proliferation of small hydroelectric plants, wind farms, geothermal plants, and cogeneration facilities.⁶²⁹ While PURPA’s potential to increase solar electricity generation attracted popular interest, solar resource development lagged behind these other sources. The new opportunities in the field of *electricity* generation also diverted attention

⁶²⁸ Williams, *Energy and the Making of Modern California*, 325.; Williams points out that the CEC did not mention the act in its *1979 Biennial Report*. For more on PURPA see Robert F. Hirsh, *Technology and Transformation in the American Electric Utility Industry* (Cambridge: Cambridge University Press, 2003), 168-171.; and Martin Melosi, *Coping with Abundance: Energy and Environment in Industrial America* (Philadelphia: Temple University Press, 1985), 326.

⁶²⁹ Williams, *Energy and the Making of Modern California*, 325-344.; Christopher Flavin, “Electricity’s Future: The Shift to Efficiency and Small-Scale Power,” *Bulletin of Science, Technology, & Society* 5, no. 1 (1985): 55-103.

away from the non-electric solar water and space heating technologies that the CEC had championed during the previous two years.

PURPA also became a preliminary step toward restructuring the utility industry “by deregulating it,” as historian Richard Hirsh notes.⁶³⁰ One result of this was that federal laws and private business considerations increasingly took priority over state policies. The law created an entirely new category of non-utility electricity producers which were not subject to state or federal regulation. Some utilities responded with horror to the potential loss of control this change seemed to foretell, but the act also conferred benefits. PG&E, for example, soon discovered that the new industry structure limited the need to develop costly and politically divisive proposals for new power plants. Equally significant, PURPA made possible the decentralization of energy production and the diversification of energy supply without subjecting utilities to more radical state programs such as those pursued by the CEC, which were aimed at creating a grassroots industry in direct competition with utilities. Because utilities were simply paying for energy that they would otherwise have to pay to produce themselves, PURPA did not pose a significant financial risk for utilities during the transition to a more diverse, decentralized energy industry.

The experience of Luz International, a southern California firm started by electrical engineer and businessman Arnold Goldman in 1979, highlighted both the opportunities and limitations created by PURPA. Between 1984 and 1991, Luz built and operated nine photovoltaic “Solar Electricity Generating System” (SEGS) plants in the Mojave Desert, the only such systems in the world at that time. Together, the Luz plants generated more than 350

⁶³⁰ Hirsh, *Technology and Transformation in the American Electric Utility Industry*, 168-169.; For an examination of the connection between PURPA and the push for electricity restructuring (deregulation) in California in the late 1990s see James L. Sweeney, *The California Electricity Crisis* (Stanford: Hoover Institution Press, 2002), 14-22.

megawatts, amounting to approximately ninety-five percent of the world's solar electricity during those years.

Goldman's business model rested on California utilities meeting their obligation under PURPA. But PURPA was not sufficiently flexible to accommodate changes in the market. While providing stable and predictable profits initially, the reliance on PURPA created a major problem for Luz when oil and natural gas prices stabilized then decreased in the late 1980s. Because the law linked disbursements to qualifying facilities to the utilities' existing production costs, SCE's payments to Luz dropped with the drop in fuel prices, allowing the utility to pass off the financial burden created by instability and price differentials in the energy market to Luz and other smaller renewable energy producers. In his analysis of the barriers to renewable energy production that PURPA created, Luz vice president Michael Lokter pointed out that the thirty megawatt limit (later raised to eighty) for qualifying facilities created additional constraints by preventing the company from pursuing economies of scale which might have mitigated the effects of lower fossil fuel prices. In addition to the financial loss, the generating capacity limit also forced the company to "dump" significant amounts of solar electricity. "This was especially unfortunate," Lokter concluded, "since the bulk of this energy would have been generated during SCE's summer on-peak period when avoided energy and capacity payments are highest and when solar energy would have replaced SCE's least efficient and most polluting peaking capacity."⁶³¹

While a variety of additional factors contributed to Luz's downfall, Lokter's critique of PURPA highlighted both the obstacles to solar implementation and the continuing evolution of

⁶³¹ Michael Lokter, "Barriers to Commercialization of Large-Scale Solar Electricity," Sandia National Laboratories, Albuquerque New Mexico, 1991: 17-18.; For additional analysis see Margaret Taylor, "Beyond Technology-Push and Demand-Pull: Lessons from California's Solar Policy," *Energy Economics* 30 (2008): 2829-2854.

values associated with solar energy in the context of the political transformations of the late 1970s and 1980s. While much of the solar activism that had formed in California and nationwide since 1973 favored small home- and business-scale solar installations, Lotker's argument signaled the possibility that smaller was not necessarily better – that large but independently operated centralized solar plants could also contribute to energy conservation and pollution control while still challenging utilities' monopoly control of the market.

Overall, the story of California solar in the late 1970s and 1980s reflected the fundamentally political nature of solar technology development and implementation during that time. Overcoming the risks associated with dependence on fossil fuels and nuclear was not simply a matter of choosing a new technology, but of transforming social and government institutions to actualize the potential social and environmental benefits of adopting that technology. While drawing on an environmental planning model that had emerged in California in the 1960s, these ideas also appealed to counterculture values and a populist regard for local control of technology that formed in the context of the antinuclear movements of the 1960s and early 1970s and declining public trust in federal institutions following the energy crises. To reconcile these agendas, state officials adopted the position that the energy economy was fundamentally a managed economy and had been for at least sixty years before the 1973 embargo. Government incentives for solar development were not subsidies, they argued, but mechanisms for creating a "level playing field," for eliminating the non-market advantages that supported the conventional energy regime.

The struggles of the CEC and the rise and fall of Luz International also underscore the challenges solar advocates faced in reconciling these seemingly incongruous philosophies in a way that addressed not only the problems of overconsumption and environmental degradation

that had occupied the earlier environmental movement, but also more immediate challenges related to declining economic opportunities, social inequality, and the security of the nation's energy reserves which until the mid-1970s, had been widely regarded as the foundation of American prosperity and the American way of life. The energy debates that occupied the Brown administration, the CEC, solar businesses, and the residents of Davis during the mid- and late 1970s hinged less on making stark choices in favor of the economy versus the environment, regulation versus deregulation, or nature versus technology than on uncertainties about the effects of committing to any one of the energy paths that appeared possible in the wake of the energy crisis. By enabling local decision-making, the California approach was meant to encourage creativity, flexibility, and adaptability to changing social, economic, and environmental conditions at smaller scales, which in the aggregate would create benefits at larger scales.

During this period, California became a crucible in which new types of energy technologies and new conceptions of their social meaning were brought together and incorporated into state and local government programs meant to transform how people used energy and engaged with the environment through technology. These programs reflected the influence of alternative, less energy intensive economic models such as those proposed by E.F. Schumacher and Amory Lovins. They also challenged a traditional technological worldview that linked progress to ever increasing energy inputs. While perhaps more policy-driven than countercultural inventors like Steve Baer would have preferred and less revolutionary than the eco-socialist path proposed by Barry Commoner, the energy paradigm that took shape in California in the late 1970s gave legitimacy to a future vision in which conservation, local-scale planning, and aggressive short-term implementation of simple, small-scale renewable energy

technologies could begin to address deep rooted environmental problems while also promoting such traditional American values as self-reliance, community cooperation, small business entrepreneurialism, economic opportunity, and freedom of technological choice.

Ultimately, the California model failed to displace the conventional energy paradigm at the national level. Federal policies also eventually superseded the more radical proposals coming from the Brown administration and the CEC. Through PURPA and other policies, utilities and other industrial interests were able to leverage their political and economic power to control the pace and character of the transition to a more diversified energy economy even at the state and local level. Predictions of a future of permanent energy scarcity which emerged from the oil crises also proved premature. The rapid decline in oil prices during the 1980s further set back the transition to a solar energy society. By 1986, with the phase out of federal solar tax credits and California Governor George Deukmejian's decision to cut the state tax credit to ten percent, what limited consumer interest in solar that had existed effectively disappeared. CALSEIA membership dropped below 200 from a high of more than 600 in 1981, leading one solar businessman to declare: "Solar's dead."⁶³²

The California experience nevertheless created a lasting legacy. It introduced new solar technologies including cheaper, more reliable, and more efficient solar water heating and space heating systems and a variety of passive solar home, building, and neighborhood designs. The California state government also established a precedent for allowing greater public input into energy decisions, for challenging utility projections of future energy demand, and for departing from federal strategies and standards in the development of state and local energy conservation standards. While immediate results were limited, California's solar programs of the late 1970s created a foundation upon which local scale solar development and conservation have since

⁶³² Quoted in Terrence M. Green, "Solar finds itself in the Shade," *Los Angeles Times*, June 15, 1986.

factored more prominently in energy and environmental policy decisions at the local, state, and national levels, and worldwide.

Conclusion

Solar Energy and Sustainability: A Question of Scale

In his 1976 *Poverty of Power*, Barry Commoner noted that the solar energy inventions of the past were “often regarded as quaint sidelights on the history of industrial technology – a kind of museum of devices that have been left behind in the march of energy technology because they were not commercially feasible.” For Commoner, these past experiments constituted an important reserve of technical knowledge for changing the energetic basis for society. “That working examples already exist is an important step toward that goal,” he wrote, “for they give the engineer something to work on, to modify and improve.”⁶³³

This dissertation can perhaps serve this purpose, but there are other reasons to recover past solar experiments from the dustbin of supposedly failed technologies. First, these stories are reminders that concerns over energy scarcity are nothing new. Scientists, inventors, engineers, entrepreneurs, consumers, and policymakers have been seeking alternatives to finite and geographically fixed supplies of fossil fuels since the start of the industrial age. These periodic outbursts of activity usually coincided with the onset of real or perceived crises involving energy, economics, and the environment. These included warnings about the depletion of Britain’s coal reserves in the 1860s, problems associated with commercial expansion into arid and tropical regions of the colonial world during the late nineteenth and early twentieth centuries, periodic oil and coal shortages during and after World War II, the advent of the Cold War in the 1950s, the OPEC oil embargo in 1973, and warnings about the risks of nuclear energy. More recently, concerns over widening global economic disparities, political instability

⁶³³ Barry Commoner, *The Poverty of Power: Energy and the Economic Crisis* (New York: Alfred A. Knopf, 1976), 139, 140.

and violence in oil producing regions, rising fossil fuel costs, and the increasingly tangible threat of climate change have stimulated a renewed push for energy conservation and diversification of energy supplies worldwide.

Second, the long history of solar energy technology provides insight into the aspirations and fears that accompanied changes in society, economic philosophy, and technology during these different periods. Though an outlier in the economic history of energy technology in the modern era, solar technologies, because of their potential to harness the widely available and essentially limitless energy of direct sunlight, stimulated particularly intense visions of the risks of reliance on finite energy supplies and of the great benefits that would come with a transition to regenerative energy supplies. These visions also changed over time in connection with changing cultural visions of a desirable future and in response to the actual experience of developing new energy supplies in particular times and places.

Solar technologies and cultural conceptions of their potential continued to evolve and diversify after the 1970s as new market opportunities appeared and as oil scarcity became a less immediate concern in energy politics. Historians often point to President Ronald Regan's removal of Jimmy Carter's solar panels from the White House in 1981 as the moment in which the solar movement in America came to an end. But while the rollback of solar subsidies at the national and state levels during the early 1980s, coupled with the decreasing cost of oil, significantly set back the transition to a solar society envisioned in the 1970s, these developments did not spell the end of solar technology. The decline of solar in the US in the 1980s was more accurately a decline of the particular ideological construction of solar that had taken shape in the 1970s in conjunction with the rise of the counterculture and the environmentalist critique of the growth society. The technology itself survived and continued to

be redefined to serve a variety of purposes. This chapter provides a summary of developments in solar technology from the 1980s to the present, emphasizing the ways in which existing configurations of technology and politics have been adapted to new political and environmental circumstances.

In the wake of the “crisis decade” of the 1970s, solar technology became linked to the idea of “sustainability” as a new framework for energy and environmental politics worldwide. Emerging out of efforts to reconcile economic needs, social justice, and environmental protection in the Third World dating back to the 1972 Stockholm Conference, sustainability stimulated both optimism and skepticism. By placing human needs and desires alongside environmental needs, it offered a familiar basis for restoring balance in human-environment interactions.⁶³⁴ Departing from the environmental jeremiad of the 1960s and 1970s, it also displayed a generally positive view of humans’ capacity to work within the constraints of the ecosystem without sacrificing core social and economic aims, in part by encouraging the creative application of technology including solar and other renewable energy systems. Sustainability’s most common verb form “sustainable development” became particularly important in this regard, holding out the promise that developing nations could attain the standards of living of the developed world without stressing the regenerative capacity of the environment. While providing a platform for cooperation between previously disparate groups including environmentalists, political leaders in developing nations, business interests, and developed world governments, critics argued that sustainability did not offer a clear path to substantive change in environmental protection, social justice, or economic opportunity. Worse, it seemed to preclude more radical challenges to the

⁶³⁴ Joachim Radkau, *Nature and Power: A Global History of the Environment*, translated by Thomas Dunlap (New York: Cambridge University Press, 2008), 311.

prevailing orthodoxy celebrating free markets, mass consumerism, technological solutions, and economic growth.⁶³⁵

Clearly, a valid argument can be made that the widespread appeal of both solar technology and sustainability in recent decades reflects their capacity to uphold the dominant liberal economic philosophies and power structures of the present age. However, such an argument does not tell the whole story and should not preclude consideration of solar technology as a basis for confronting pressing social and environmental problems related to current patterns of energy use. As documented in the preceding chapters, while solar technologies originated in large part as tools for perpetuating economic growth and industrial expansion beyond the capability restrictions of fossil fuels, they also developed in ways that challenged the ideologies and structures of power at the core of fossil fuel-based industrial society. The adaptability of solar technologies to a variety of often conflicting political agendas and ideologies regarding the relationship between energy and society has been arguably their most distinguishing characteristic. The various models of solar development detailed in this study continued to form the basis for debates over sustainable energy development that began to take shape in the late 1980s. As the concept of sustainability opened the door for debate over what was to be sustained and where the authority to determine sustainability standards and practices should rest, solar technology reemerged as a pivot point of debate over not only the types of energy sources that should be prioritized but also the appropriate geographic scales at which decisions about energy technology should be made. Solar technologies, in their various forms, provided tangible bases

⁶³⁵ For an overview of these criticisms see Sharachandra M. Lele, "Sustainable Development: A Critical Review," *World Development* 19, no. 6 (1991): 607-621.; Also see Donald Worster, "The Shaky Ground of Sustainability," in *Sustainability: Critical Concepts in the Social Sciences*, ed. Michael Redclift (New York: Routledge, 2005), 11-23. This volume assembles a number of other good pieces on the conflicted meanings and implications of the transition to sustainability as the new paradigm in global environmental politics.

for alternatively upholding and contesting the power dynamics surrounding the issue of energy in the age of sustainability.

Solar development and sustainability became aligned early on as mutually reinforcing, albeit loosely defined, political projects. The idea of applying solar technology to the goal of reconciling economic, social, and environmental objectives was more readily embraced in Europe and Asia than in the United States where the view of environmental protection as inherently requiring limitations on economic activity still prevailed. France was particularly active from the late 1970s through the 1980s, seeing solar technology research and development as a way to maintain “friendly economic connections” with its former colonies in Africa.⁶³⁶ Meanwhile, the governments of Germany and Japan passed incentives for solar technology development aimed at enabling their respective nations to lead an expected global transition to a post-fossil fuel future. As the US government returned to an earlier focus on pushing down the costs of fossil fuels while continuing to support the possibility of a nuclear future, German and Japanese companies became the primary suppliers of solar equipment, especially photovoltaic cells, in an emerging market geared toward the estimated two billion people in developing nations who still lacked reliable electricity.⁶³⁷ The 1986 nuclear disaster at Chernobyl, coupled with rising concerns about climate change by the 1990s, also led these governments, and others, to further concede that other sources besides nuclear and fossil fuels would be necessary in the long term to reduce the environmental and human health risks associated with global industrial

⁶³⁶ A. Eggers-Lura, *Solar Energy in Developing Countries: An Overview and Buyers Guide for Solar Scientists and Engineers* (New York: Pergamon Press, 1979), 7.

⁶³⁷ Geoffrey Jones and Loubna Bouamane, “‘Power from Sunshine’: A Business History of Solar Energy,” Working Paper 12-105, Harvard Business School, May 25, 2012, accessed March 18, 2015 at <http://www.hbs.edu/faculty/Publication%20Files/12-105.pdf>.

development. This combination of nationalist, humanitarian, economic, and environmental considerations underlay the revival of interest in solar equipment worldwide.⁶³⁸

As in earlier periods, peripheral areas where fossil fuels were expensive or otherwise impractical became hubs of activity in sustainable energy development. Rapid population growth in still wood-dependent developing nations became especially important in prompting efforts to pursue cleaner, cheaper, healthier, and more abundant alternatives beginning in the late 1970s. In 1982, the government of India created the Ministry of Non-Conventional Energy Sources to investigate a variety of options including more efficient wood and charcoal stoves, energy from industrial waste, solar cells, geothermal, and biogas. Over the next decade, the ministry pursued the development of high quality, efficient, and easy to use solar cookers, based on prototype models introduced in the 1950s. By the mid-1990s, even after a decrease in government subsidies in 1994, solar cooker manufacturers in India were selling roughly 25,000 units a year, providing an example for other developing nations. In 1997, the government partnered with the Swiss and German group ULOG to construct a massive installation at Mount Abu, India capable of preparing food for 1,000 people.⁶³⁹

While India and other developing nations often accepted intervention from international organizations – including UNESCO, the Solar Energy Society, as well as foreign governments and corporations – in developing their solar capabilities, they also saw these relationships as temporary. The long term goal, as a presenter at the 1996 World Renewable Energy Conference put it, was to “unbundle” the process of technology transfer, to achieve “genuine indigenous assimilation of technology with mastery, control, and improved ability to gain future autonomy.”

⁶³⁸ Curtis Moore and Alan S. Miller, *Green Gold: Japan, Germany, the United States, and the Race for Environmental Technology*, revised edition (Boston: Beacon Press, 2001), 1-2.

⁶³⁹ Barbara Knudson, *State of the Art of Solar Cooking*, unpublished manuscript: 241-246. Accessed October 15, 2014 at http://solarcooking.wikia.com/wiki/Barbara_Knudson.

Extending the concept of solar development that took shape in the 1950s and early 1960s, the ability to take advantage of direct sunlight as an indigenous energy source became part of the process of decolonization, offering a means of “narrowing the technological gap between developed and developing countries,” while reducing national debts and avoiding dependency on foreign suppliers.⁶⁴⁰

Similar agendas appeared in the United States in the 1980s and 1990s, most notably in Hawai‘i where the state government adopted local-scale solar commercialization programs similar to those envisioned in California in the 1970s. Released in 1980, the Hawai‘i state energy plan cited the state’s favorable environment and “near total dependence on imported petroleum” which made it especially vulnerable to disruptions in supply, as reasons for continuing to emphasize solar. As California and other states cut back solar subsidies, Hawai‘i maintained a fifty percent state income tax credit for investments in solar water heaters, solar cell modules, heat pumps, ice storage units, and other energy-saving consumer products. By 1996, an estimated fifteen to twenty percent of homes in Hawai‘i were outfitted with solar water heating systems, by far the largest percentage of any state in the nation. Strong public resistance to utility-scale development also kept the state government and the Hawaiian Electric Industries, the umbrella company that owned nearly all the state’s electric utilities, focused on individual and local-level installations.⁶⁴¹

Native Hawaiian advocacy organizations were particularly active in pushing the state in this direction. Beginning in the 1980s, the Pele Defense Fund spearheaded a broad-based movement to prevent the construction of a 500 megawatt geothermal plant in Wao Kele‘o near

⁶⁴⁰ U. Able-Thomas, “Models of Renewable Energy Technology Transfer to Developing Countries,” *Renewable Energy* 9 (September-December 1996): 1104-1107.

⁶⁴¹ Daniel M. Berman and John T. O’Conner, *Who Owns the Sun?: People, Politics, and the Struggle for a Solar Economy* (White River Junction, VT: Chelsea Green Publishing Company, 1996), 20-26.

the Kilauea Volcano on the island of Hawai‘i, an area surrounded by one of the last large native rainforests in the islands. Through media campaigns, marches, and lawsuits, opponents argued that the plant would violate an area sacred to Native Hawaiians, damage the rainforest, affect the health of nearby residents, and strain the state and local economy. In 1995, the State of Hawai‘i cancelled the project, citing these concerns. During the same period, the remote Native Hawaiian village of Miloli‘i, located on the arid southwest coast of Hawai‘i Island, became the first fully solar powered community in the islands. Known as “the last Hawaiian fishing village in the world,” Miloli‘i had never been connected to the grid, producing most of its power with diesel generators. In 1990, a private foundation donated enough solar modules and storage batteries to power some thirty homes. Other residents followed suit, and the village became an example for Hawaiian communities across the islands of the possibility of maintaining independence from the state’s electric utilities.⁶⁴²

Despite cut-backs at the level of state government, California also remained a hub of local-scale solar development and advocacy through the 1980s and 1990s. The City of Davis kept its commitment to solar and conservation-based municipal planning, while Village Homes continued to attract worldwide attention as a functioning example of sustainable suburban construction.⁶⁴³ In Northern California, Mendocino and Humboldt counties – through their support of a variety of public and private local-scale solar development activities – gained recognition as the “solar and energy-conscious capital of the world.” Mendocino was also the home of the Real Goods Trading Company which grew from a supplier for local off-the-grid communities in the late 1970s into the successor of the Whole Earth Network by the 1990s,

⁶⁴² Ibid., 26-28.

⁶⁴³ David S. Jackson, “Back to the Garden: A Suburban Dream,” *Time* 153, no. 7 (February 22, 1999): 78-79.

distributing catalogs with information about solar equipment and suppliers worldwide.⁶⁴⁴ On a larger scale, the publicly owned Sacramento Municipal Utility District (SMUD) became a hub of solar activity following a strong public movement to force the closure of the failing Rancho Seco nuclear power plant in 1988. Beginning in 1990, SMUD incentivized various types of dispersed, small-scale solar systems and conservation measures to make up for the energy deficit from the closure of the Rancho Seco plant.⁶⁴⁵

These local and state level activities paled in comparison to the solar program initiated by the German government in the late 1990s. With the election of a coalition government of Social Democrats and Green Party representatives in 1998, Germany adopted several aggressive measures to promote solar development, primarily at smaller scales. The government passed a 100,000 solar roof program in 1999, designed to stimulate rapid domestic solar deployment at the local level. The following year it passed the even more ambitious Renewable Energy Source Act. The legislation created a feed-in-tariff program which removed many of the remaining cost barriers for homeowners and municipalities to implement solar electric systems.

While critics pointed to Germany's comparative lack of sunshine and the limited benefits of solar installations for less affluent apartment renters, the program created dramatic shifts in the German energy industry, with the four large utilities that had previously dominated losing market share to hundreds of small providers, representing a partial realization of the California Energy Commission's aims in the 1970s to create a more diverse, flexible energy market. By 2008, some 500,000 solar systems had been installed on homes and businesses across the country.⁶⁴⁶ In the former East Germany, coal slag heaps and decommissioned military bases – considered too polluted for any other uses – were rapidly converted into medium scale solar

⁶⁴⁴ Berman and O'Conner, *Who Owns the Sun*, 39-42.

⁶⁴⁵ *Ibid.*, 87-97.

⁶⁴⁶ Jones and Bouamane, "'Power from Sunshine'," 49.

farms, providing electricity to nearby communities. The massive commitment to solar as a preferable alternative to coal and nuclear allowed the industry to thrive, despite the country's intermittent sunshine and long nights during the winter months. On a sunny day in May 2012, solar installations in Germany produced a total of 22 gigawatts of electricity, approximately the same amount as could be produced by twenty typical nuclear plants.⁶⁴⁷

In a 2003 white paper calling on governments worldwide to commit to accelerating a transition to renewable energy sources, the International Solar Energy Society pointed to the German case as an example that “public policy and political leadership” had replaced both technology and economics as the primary drivers of change in global energy use.⁶⁴⁸ This was not a new argument. However, with the convergence of rapidly increasing oil prices, political instability in the Middle East, declining costs of photovoltaic technology, the emergence of sustainability as the organizing concept in global energy and environmental politics, and mounting concerns about climate change, the notion that energy choices were fundamentally political gained wider acceptance. One result of this shift away from purely economic analysis of energy markets was the geographic dispersal of solar energy activities toward Germany and other nations which, while not as environmentally well-suited for solar, had evolved political cultures that encouraged creative ways to use technology to reconcile economic, environmental, and social objectives.⁶⁴⁹

While European nations took the lead, the US government also began taking tentative actions to encourage investment in solar during the early to mid-2000s. Even President George

⁶⁴⁷ Andrew Curry, “Germany doesn’t get much Sun. How did it become a leader in Solar Energy?” *Mother Jones*, April 1, 2013, accessed November 10, 2014 at <http://www.motherjones.com/environment/2013/04/germany-solar-power-energy>.

⁶⁴⁸ Donald W. Aitken, *Transitioning to a Renewable Energy Future*, white paper prepared for the International Solar Energy Society, 2003: 3, accessed March 18, 2015 at <http://whitepaper.ises.org/ISES-WP-600.pdf>.

⁶⁴⁹ “History of Solar Power – Part II: Policy,” September 4, 2014, accessed October 27, 2014 at <http://sustainnovate.ae/en/innovators-blog/detail/history-of-solar-power-part-ii-policy>.

W. Bush – belying his oil industry connections and outward hostility to environmentalists – quietly embraced some “green” practices and policies. His Crawford, Texas ranch home, built between 1999 and 2001, included a rainwater-fed irrigation system, passive solar design features, and geothermal heating and cooling.⁶⁵⁰ In 2002, Bush approved a National Park Service proposal to install 167 photovoltaic solar panels to supply energy to the White House grounds and pool.⁶⁵¹ In 2005, in response to rising oil prices, the president signed the Energy Policy Act, the first federal legislation to promote renewable energy development since 1980. Although strongly weighted toward the development of domestic oil and natural gas reserves and nuclear, the act also offered tax breaks for increasing energy efficiency in existing homes. Significantly, it also required utilities to offer net metering, which allowed individual consumers to offset electricity costs by selling power produced by eligible on-site generating installations to the local grid. The Energy Independence and Security Act (2007) and the Food, Conservation, and Energy Act (2008) offered additional incentives for consumers and businesses to invest in solar energy systems and efficiency improvements. Some high level conservative pundits including Newt Gingrich and Thomas Friedman also began calling on government and industry to invest in solar technology as part of a strategy to increase the nation’s economic competitiveness and “environmental leadership” in a world transitioning toward sustainable, diversified energy systems.⁶⁵²

The election of Barack Obama in 2008 seemed to signal Americans’ readiness to move even further beyond the prevailing “drill baby drill” mentality of the previous decades and

⁶⁵⁰ Nick Rosen, “Meanwhile, Back at the Ranch,” February 18, 2007, accessed October 20, 2014 at <http://www.off-grid.net/landbuddy/land/meanwhile-back-at-the-ranch>.

⁶⁵¹ “Solar Energy is Back at the White House,” January 8, 2003, accessed October 20, 2014 at <http://www.ecomall.com/greenshopping/solarwhitehouse.htm>.

⁶⁵² Newt Gingrich and Terry L. Maple, *Contract with the Earth* (Baltimore: Johns Hopkins Press, 2007).; Thomas L. Friedman, *Hot, Flat, and Crowded: Why we Need a Green Revolution – and how it can Renew America* (New York: Farrar, Straus and Giroux, 2008).

prioritize energy efficiency, conservation, and renewable energy technology development and commercialization. The \$800 billion American Recovery and Reinvestment Act, signed by President Obama in February 2009 in response to the “Great Recession” of 2007 and 2008, contributed to this turn by offering \$4.3 billion in tax credits for homeowners making energy efficiency improvements, \$27.2 billion for research and investment in renewable energy and energy efficiency technologies, and \$21.5 billion for expansion and improvement of the nation’s energy infrastructure.

Despite the massive infusion of funds into the nascent renewable energy sector of the US economy, the intense partisan disputes which characterized the larger debate over the stimulus bill began to create fractures within the consensus that had just begun to form on the issue of green energy. The 2011 bankruptcy of the thin-film solar cell manufacturing firm Solyndra – which had received \$535 million in Department of Energy (DOE) loan guarantees under the 2009 stimulus bill – became the rallying point for a rejuvenated conservative attack on the Obama administration’s efforts to implement renewable energy subsidies. At the outset of the September 2011 Congressional hearing on Solyndra and the DOE loan guarantee program, Republican Representative Cliff Stearns argued that “the rush to push out stimulus dollars may have impacted the depth and quality of DOE and OMB’s review process.” More generally, he saw the incident as confirmation of the risks of embracing green energy “as the savior of our faltering economy.”⁶⁵³

Even as the Solyndra story was cycling through the media, solar cell costs plunged dramatically, leading to a renewed bi-partisan enthusiasm for both private and public solar

⁶⁵³ Cliff Stearns, “Opening Statement of Hon. Cliff Stearns, A Representative in Congress from the State of Florida,” in *Solyndra and the DOE Loan Guarantee Program: Hearing Before the Subcommittee on Oversight and Investigations of the Committee on Energy and Commerce, House of Representatives*, September 14, 2011 (Washington D.C.: Government Printing Office, 2013), 1-3.

investment, in large part as a way to preserve American leadership in the expanding solar market. The price drop was the result of improvements to the technology, increased production worldwide, rising oil prices, and the implementation of government policies in Europe and Asia which were rapidly expanding the geography of the solar market beyond the tropical and desert regions where solar was historically most competitive. Increases in solar cell production, especially in China where the industry received heavy government subsidies, drove the price of photovoltaic modules down to \$1.25 per watt by 2011, a ninety nine percent reduction from the average cost in the 1980s. The DOE predicted that as production and innovation continued, the price would drop by an additional seventy five percent by 2020.⁶⁵⁴

Solar's increasing economic viability became evident in a variety of other measures. Between 2010 and 2013, total worldwide installed photovoltaic capacity skyrocketed from just under 40,000 megawatt peak (MWp) to more than 130,000 MWp.⁶⁵⁵ Beginning in the mid-2000s, electricity produced at new solar installations in the US grew an average of 66% annually, more than any other energy source. During the first quarter of 2014, 74% of new electricity generating capacity came from solar installations.⁶⁵⁶ Such numbers dampened the partisan debate over Solyndra. They also drew attention to government policies in other nations which were creating power shifts in the global market. With China's subsidized production facilities driving down the cost of solar cells to historic lows, a number of US and European firms went bankrupt.

⁶⁵⁴ The DOE's estimate was based on David Feldman, Galen Barbose, Robert Margolis, Ryan Wiser, Naim Darghouth, and Alan Goodrich, *Photovoltaic (PV) Pricing Trends: Historical, Recent, and Near-Term Projections*, Technical Report DOE/GO-102012-3839, National Renewable Energy Laboratory and Lawrence Berkeley National Laboratory, November 2012: 1.; William Pentland, "Could the Cost of Solar Power Fall by 75% by 2020?" *Forbes*, August 21, 2013, accessed October 27, 2014 at <http://www.forbes.com/sites/williampentland/2013/08/21/could-the-cost-of-solar-power-fall-by-75-by-2020/>.

⁶⁵⁵ Lewis M. Fraas, *Low-Cost Solar Electric Power* (New York: Springer, 2014), 7-8.

⁶⁵⁶ Tim McDonnell, "Here comes the Sun: America's Solar Boom, in Charts," *Mother Jones*, November 7, 2014, accessed November 10, 2014 at <http://www.motherjones.com/environment/2014/11/solar-energy-power-boom-charts>.

Even some big oil companies including Shell and BP were forced to back out of the photovoltaic industry which they had largely controlled since the 1970s.⁶⁵⁷

While new players were entering the solar field, the traditional geographic centers of solar technology development remained hubs of activity, adapting existing political models and technologies to new local and global trends. During the 2000s, while federal programs in the US remained tentative, California resumed its role as pace setter. As in the 1970s, a series of crises provided the stimulus for both technological and policy innovation. Between 2000 and 2001, California experienced an electricity crisis, a result of a combination of a poorly conceived and executed electricity restructuring experiment (commonly known as deregulation), drought, and ongoing delays in the approval of new power plants. With the shortage of supply, wholesale prices skyrocketed 800 percent, PG&E filed for bankruptcy, and businesses and consumers were forced to endure a series of “rolling blackouts” as a result.⁶⁵⁸ Global events also stimulated action in the state. Following the attacks of September 11, 2001, escalating violence in oil-producing nations in the Middle East, in combination with market manipulation, created conditions for rising oil prices, and the cost of a barrel of oil increased from \$30 at the end of 2001 to more than \$140 by 2008. Behind all of this, the ominous specter of anthropogenic climate change moved from a fringe concern of environmentalists and climate modelers to a core theme in international diplomacy and domestic politics.

Following the electricity crisis, California – with its heavy reliance on imported oil and penchant for political experimentation – once again jumped out ahead of the federal government and other states in developing strategies for renewable energy development. Solar energy again became a priority for environmentalists, the governor’s office, the legislature, the CEC, the PUC,

⁶⁵⁷ Jones and Bouamane, “‘Power from Sunshine’,” 57, 58.

⁶⁵⁸ James L. Sweeney, *The California Electricity Crisis* (Stanford: Hoover Institution Press, 2002). Regarding PURPA as the leading edge of a movement toward deregulation by the late 1990s, pg. 14-22

and other state agencies. While intended to meet the present crises, state programs incorporated and built on many of the core programs developed during the 1970s. Carryovers were especially apparent in Governor Arnold Schwarzenegger's 2004 plan for "a million solar roofs" in the state by 2018. "I want to pump solar up," the governor proclaimed, by making it directly accessible to consumers.⁶⁵⁹

Schwarzenegger's vision for a ten-year subsidy program aimed at adding 3,000 megawatts of solar electric capacity (equivalent to the total capacity of ten average size coal plants) gained broad bi-partisan support in the notoriously contentious state legislature. Its appeal stemmed from its balancing of economic and environmental objectives. In the process of reducing greenhouse gas output by three million tons, the plan would also stimulate competition in the energy market while enabling California to become the world's leading producer and consumer of solar technologies. "We've got the sixth biggest economy in the world," observed David Hochschild, policy director for the citizen advocacy group Vote Solar Initiative, "which puts us in a better position than any other state to move markets and become the cradle of the clean technologies of the future." Democratic state senator Kevin Murray touted the plan as a rare opportunity in an age of partisan logjams at the federal and state levels. "As much as I'm probably opposed to everything else that has come out of his [Schwarzenegger's] mouth," he said, "this is something we've been able to see eye to eye on.... He's a Republican who is supporting a bill that subsidizes a new environmental program! This is one of those things that in the end if you're a Democrat and you don't support it, there is simply no justification."⁶⁶⁰ This bipartisan support for solar eased the passage of the California Solar Initiative (CSI) in 2007

⁶⁵⁹ Amanda Little, "Schwarzenegger's Solar-Roof Plan could get sidelined by Partisan Squabbling," *Grist*, June 24, 2005, accessed January 16, 2014 at <http://grist.org/article/little-solar/>.

⁶⁶⁰ Quotes from *Ibid*.

which allotted \$2.167 billion over ten years as incentives for consumers and businesses to install rooftop photovoltaic systems to feed into the existing utility grid.⁶⁶¹

In addition to carrying out the million roofs program, which followed a distributed strategy of solar development more in line with the types of programs that the CEC advocated in the 1970s and that Germany had already implemented, the state government also began working with utilities and the federal government to build massive solar thermal and photovoltaic power plants sprawling over hundreds of square miles of federal land in the Southern California deserts. These projects, highly touted by utilities, the Bureau of Land Management, and some large environmental organizations, represented revivals of the large-scale solar development model favored by federal programs in the 1970s. They also stimulated intense opposition from primarily local wilderness and desert conservation advocates, recreation groups, and communities concerned with the environmental and economic compromises involved in “utility-scale” solar development and with the loss of control over local and regional energy markets that it potentially entailed. Interestingly, many critics in California began pointing to Germany, which based its programs in part on the California programs of the 1970s, as a model of a more localized, flexible, and less resource intensive approach to solar policy.⁶⁶²

With his reelection as governor in 2011, Jerry Brown further prioritized solar development in California. While no longer directly espousing the small is beautiful rhetoric of the 1970s, Brown retained his penchant for bold statements and political experimentation. One of his first acts as governor was to sign legislation mandating that the state get 33% of its electricity from renewable sources by 2020. Although opposed by Republicans in the state legislature who raised concerns about electricity rate increases, Brown tailored his rhetoric to accord with both

⁶⁶¹ California Public Utilities Commission, “About the California Solar Initiative,” accessed October 27, 2014 at <http://www.cpuc.ca.gov/puc/energy/solar/aboutsolar.htm>.

⁶⁶² Judith Lewis, “High Noon,” *High Country News*, May 11, 2009, 6-22.

conservative and environmentalist sensibilities. Couching the issue in the reconciliatory language of sustainability, Brown described the bill as a way to protect the environment while stimulating the state economy and leading the nation toward a more prominent leadership role in the global energy economy. “It’s about California leading the country. It’s America potentially leading the world,” he said.⁶⁶³

While state-level debates over utility scale solar development and net metering emerged as immediate concerns during the Brown administration, the governor also sought to involve the state in a larger global transition toward a more sustainable energy mix. In April 2013, he drew sharp criticism when he embarked on a diplomatic tour to China – accompanied by 30 staff members at a cost of \$10,000 each – to explore possibilities for exporting California policies, technologies, and expertise to combat climate change. As Tom Hayden observed in an article for *The Huffington Post*, Brown’s position as state governor allowed him greater flexibility than President Obama in pursuing agreements on energy with the Chinese government. While at the national level, the US was seeking cooperation with China as a “geopolitical pivot” to address such controversies as North Korea’s nuclear program and border disputes in the South China Sea, Brown could seek a “different pivot,” aligning with China on issues of energy conservation, green energy technology, and climate change. As he did in the 1970s, Brown was seeking to utilize advantages related to the capabilities of state government to gain leverage in larger scale energy and environmental issues. By offering to aid China on matters such as air pollution and rural electrification, Brown sought to increase California’s importance in the global energy

⁶⁶³ Patrick McGreevy, “Gov. Brown Signs Law Requiring 33% of Energy be Renewable by 2020,” *Los Angeles Times*, April 13, 2011.

market while at the same time providing “an alternative to Cold War with China,” as Hayden put it.⁶⁶⁴

Brown’s interest in building a global presence for California on issues of climate change and renewable energy also reflected the reemergence of other former peripheries of fossil fuel empire not only as markets for solar products but as sites of experimentation and collaboration for a variety of approaches to solar development. North Africa, the Middle East, and South Asia in particular have again emerged as key sites in solar politics. As in the late nineteenth century, these places have also become focal points of international market competition as well as sites for reimagining the political and physical geography of energy use in a post-fossil fuel future. They are again being envisioned as “fertile ground” for experimenting with technologies which “someday... may be exported to the developed world,” as one writer recently put it.⁶⁶⁵ Many higher profile proposals reproduce earlier imperial forms of solar development. In 2009, a coalition of mostly German shareholders including Deutsche Bank announced a plan to cover some 6,500 square miles of the Sahara and Arabian deserts with solar collectors. Estimated to cost \$506 billion, this revival of Frank Shuman’s 1911 vision of a solar Africa – known as Desertec – would be capable of supplying as much as fifteen percent of Europe’s electricity by 2050. As in Shuman’s time, however, the dream has again been deferred. Citing concerns about political instability in the region, higher than expected costs, and Europe’s own domestic solar boom which may reduce the need for imports, sixteen of the original nineteen shareholders have backed out of the project as of October 2014.⁶⁶⁶

⁶⁶⁴ Tom Hayden, “Jerry Brown’s Energy Diplomacy,” *Huffington Post*, June 3, 2013, accessed October 27, 2014 at http://www.huffingtonpost.com/tom-hayden/jerry-browns-energy-diplo_b_3381336.html.

⁶⁶⁵ Rebecca Clay, “Renewable Energy: Empowering the Developing World,” *Environmental Health Perspectives* 110, no. 1 (January 2002): A33.

⁶⁶⁶ “Desertec Solar Power Project Shareholders Jump Ship,” *The Guardian*, October 14, 2014, accessed November 11, 2014 at <http://www.theguardian.com/environment/2014/oct/14/desertec-solar-power-project-shareholders-jump-ship>.

These kinds of large projects have also been pursued by developing nations themselves as means to provide clean abundant electricity to poor, rural regions while reducing dependence on foreign governments and firms. In 2009, the government of India enacted the National Solar Mission aimed at installing 22 gigawatts of solar electricity by 2022. The goals were to meet projections of an eight to nine percent annual economic growth rate and to supply electricity to the at least 400 million Indians still living without electricity. In 2013, the government announced a plan to attract Indian investors and businesses to build an “ultra-mega” solar project, a 77-square mile photovoltaic array with a capacity of 4,000 megawatts, equivalent to the output of four typical nuclear reactors, to be located on a dry salt lake bed in the northern state of Rajasthan.⁶⁶⁷ The anticipated economic viability of the project was a result of the recent global shift of solar cell manufacturing toward the developing world, especially the availability of cheaper cells from China. While China’s rise in the market became a hindrance to German, Japanese, and American firms unable to compete on a cost basis, it provided a boon for national solar programs in India and other poorer countries.

Increasing oil costs following the attacks of September 11, 2001, compounded by sustainability concerns stemming from rising demand for energy in the developing world, also prompted a revival of interest in space based solar power (SBSP), first envisioned by Isaac Asimov in the 1940s and later explored in the US in the late 1960s. In sponsoring a feasibility study for SBSP in 2007, the US Department of Defense (DOD) contributed significantly to shaping the renewed discussion over the technology’s potential. For the DOD, SBSP offered a way to address the problem of “energy security,” the ability of the US and its allies to maintain predictability and control over their energy supplies in an era of mounting risks associated with

⁶⁶⁷ Sanjay Kumar, “India to build the World’s Largest Solar Plant,” *Nature*, February 4, 2014, accessed November 19, 2014 at <http://www.nature.com/news/india-to-build-world-s-largest-solar-plant-1.14647>.

traditional energy options. From a global perspective, abundant inexhaustible solar energy from space also offered “a hopeful path to avert possible wars and conflict” by decreasing the chances of state failures and “great power conflict.” It could enable the delivery of “rapid and sustainable humanitarian energy” to disaster areas or populations involved in “nation-building activities.” The DOD also recognized military applications for the technology. The ability to beam energy from space could become “a disruptive game changer on the battlefield” by supplying “energy on demand” to combat units and even individual soldiers regardless of their location. The 2007 report also acknowledged that despite the approximately eighty million federal dollars spent on the research of SBSP since the late 1960s, it remained a distant future possibility, requiring a level of government/industry cooperation and spending even beyond what was required for the Manhattan Project and the Apollo Program.⁶⁶⁸

Work on SBSP has proceeded in the US and worldwide despite this. A research program sponsored by the Japanese Aerospace Exploration Agency (JAXA) announced in March 2015 that it had successfully transmitted electrical energy wirelessly to a specified target using microwaves, representing an important demonstration of the feasibility of one of the core aspects of SBSP.⁶⁶⁹ Although JAXA assures that the microwave beams sent through the atmosphere would be too weak to cook birds or damage aircraft, questions remain about the environmental effects and safety of the technology deployed on a large scale. The DOD’s visions for SBSP also exhibit close parallels to the imperial expansionist model of solar development that formed in the nineteenth century and that continued to underlie both solar and nuclear energy development schemes in the 1950s and 1960s. A key consideration, as John Marburger, Science Adviser to

⁶⁶⁸ National Security Space Office, “Space-Based Solar Power as an Opportunity for Strategic Security, Phase 0 Architecture Feasibility Study,” Report to the Director, National Security Space Office, Interim Assessment, release 0.1, October 10, 2007: 3, 12-15.

⁶⁶⁹ Jun Hongo, “Japan Advances in Space-Based Solar Power,” *The Wall Street Journal*, March 11, 2015, accessed March 13, 2015 at <http://www.wsj.com/articles/japan-advances-in-space-based-solar-power-1426100482>.

President Bush put it, was “whether we want to incorporate the Solar System in our economic sphere, or not.”⁶⁷⁰ Although even the DOD recognizes the practical limitations and obstacles for the implementation of SBSP, the technical literature does not scrutinize the political and economic power dynamics associated with this technology. Nor does it include substantive discussion of whether conservation measures – implemented in connection with simpler, existing, and more locally-controlled solar options – might address many of the same problems in the more immediate future with less environmental uncertainties, less public funds and government oversight, and lower vulnerability.

Even with the return of SBSP, a trend toward simpler, more locally-situated models of solar development is presenting a challenge to the big solar model, as indicated by public protest against utility-scale solar in California and the recent unraveling of the Desertec project in Egypt. This revival of the debate over local versus state or corporate control of solar development has increasingly occurred within the framework of environmental policy, again reflecting the increasing importance of sustainability considerations as a basis for energy decisions. In California, for example, the CEC recently stated that it would deny permits to build a large-scale solar thermal electric generation facility in the state based on evidence that such plants can incinerate migrating birds which often mistake the fields of reflective glass for bodies of water.⁶⁷¹ Similarly, India’s “ultra-mega” project has recently come under fire for its potential impacts on nearby wetlands.⁶⁷² While framed in environmental terms, current efforts to block large scale solar projects through the regulatory process are also efforts to introduce a stronger

⁶⁷⁰ Quoted in National Security Space Office, “Space Based Solar Power,” 16.

⁶⁷¹ Judith Lewis Mernit, “California Energy Commission Says No to Desert Solar Plant that could Kill Birds,” *High Country News*, December 24, 2013, accessed November 24, 2014 at <http://www.hcn.org/blogs/goat/california-energy-commission-says-no-to-desert-solar-plant>.

⁶⁷² Shreya Jai, “Rajasthan to Clip 4,000-Mw Solar Project to Save Birds,” *Business Standard*, August 19, 2014, accessed November 24, 2014 at http://www.business-standard.com/article/economy-policy/rajasthan-to-clip-4-000-mw-solar-project-to-save-birds-114081900006_1.html.

public voice in decisions about energy. They are battles over power, electrical as well as social and political, which also have implications for the environment.

Other efforts in this direction are occurring outside the immediate purview of government. These display a blending of libertarian and postcolonial sensibilities reminiscent of the countercultural approach to solar in the 1970s. As the cost of solar equipment has declined, a growing number of small-market foreign and local entrepreneurs – often working in cooperation with foreign non-profit organizations – have created a minor boom in small, home-based solar electric systems for powering light bulbs, television sets, and cell phones in non-electrified areas of Africa, South America, and South Asia. Solar water pumps, similar to those tested in California and North Africa in the early twentieth century, have also begun replacing diesel generators in many rural off-the-grid areas.⁶⁷³

Concentrating its efforts on urban slums in India, the Australia-based non-profit Pollinate, which bills itself as a “services business” committed to “supporting the next generation of social entrepreneurs,” claims to have sold more than 5,600 solar light systems in 2013 and 2014. The organization trains local “micro-entrepreneurs” to introduce solar lights and other products to urban residents as alternatives to costly, polluting kerosene-powered devices. In its 2013/2014 annual report, Pollinate touted its work as contributing to a range of economic, educational, aesthetic, health, and environmental benefits, all without requiring implementation of new government programs to support renewable energy development.⁶⁷⁴ The group also views its work as part of a global movement to introduce “leapfrog technologies” designed to allow “the urban poor in developing nations to skip right over fossil fuels for electricity.” “It’s a nice idea,”

⁶⁷³ David Ferris, “How Solar can Save India’s Farmers,” *Smithsonian*, June 24, 2013, accessed November 24, 2013 at <http://www.smithsonianmag.com/innovation/how-solar-can-save-indias-farmers-2567788/?all&no-ist>.

⁶⁷⁴ Pollinate Energy, *2013/1014 Annual Report: Improving the Lives of the Urban Poor*, accessed November 24, 2014 at <http://pollinateenergy.org/impact/progress/>.

Jamie Chivers, co-founder of Pollinate says, “the poor leap-frogging the rich.”⁶⁷⁵ Such claims are indicative of solar’s continuing appeal not simply as a substitute for fossil fuels but as a means to contest the imperial power relations that defined the fossil fuel age.

These recent developments in solar politics highlight the continuing importance of energy – non-fossil fuel energy in particular – as a focal point of experimentation and contestation at multiple social, geographic, and organizational scales over the future of industrial society. Considering the centrality of energy to current challenges facing the US, California, and the world, the urgency for solar development will likely continue to increase, as will the intensity of debates over its appropriate form and function. As the preceding chapters suggest, choosing solar does not by itself connote a single, clearly identifiable set of social, economic, and environmental outcomes. Solar technologies and cultural conceptions of their potential, while emerging from general concerns about the limits and risks of fossil fuel dependence, have also evolved and differentiated according to contingencies of time and place, and in connection with a variety of often conflicting political projects. This makes solar a useful gauge for tracking past changes and variations in the cultural politics of energy, technology, and progress. But it makes the future of solar difficult to predict. Because actual applications have been limited, solar technology remains unfixed to any singular vision of the future, making it a perennial focal point for political dialogue and debate.

Some specific lessons can still be derived from this history. From a broad perspective, the history of solar underscores a general lesson of energy history that the social, political, technological, and ecological systems that structure energy use are complex and dissimilar across time and space; and that commitment to any single approach to energy technology can tend to

⁶⁷⁵ Mark Bergan, “Selling Solar Power in India’s Slums,” *Mother Jones*, April 2, 2013, accessed November 24, 2014 at <http://www.motherjones.com/environment/2013/04/selling-solar-power-indias-slums>.

create unintended consequences and vulnerabilities that become more difficult to overcome as the chosen path becomes more entrenched. From this standpoint, the still unsettled meanings of solar technology and sustainability should be viewed with caution but also as an opportunity, especially in light of present anxieties about increasing global demand for scarce natural resources especially fossil fuels, an ever-widening gap between rich and poor worldwide, the emergence of new manufacturing and distribution networks, and increasingly clear indications of a warming climate. Such conditions demand flexibility, critical thinking, and responsiveness from governments, advocacy groups, businesses, and individuals. Insofar as the history of solar technology has synced with changing and geographically varied ideas about how to reconcile nature, technology, and society to create a better world, solar will likely continue to be a nexus for thinking about and debating possible energy futures.

While utopian fantasies of a solar future should continue to be taken with a grain of salt, this history nevertheless suggests some promising possibilities. The scalability evident in both past and present forms of solar technology stands out as an especially important basis for debates over its future. Solar's historical adaptability to a variety of different political agendas suggests a need for more serious consideration of the power relations, forms of economic organization, social and environmental practices, and systems of governance required for the realization of the different models of a solar future presently under consideration worldwide. More specifically, this history suggests the benefits of adopting public policies and patterns of economic organization which preserve the ability of individuals and communities to tinker with, develop, and deploy technologies and associated environmental practices adapted to local ecologies and their respective values. For all the benefits large-scale, top-down planning can bring in terms of efficiency and predictability, it can also eliminate opportunities to develop more efficient,

flexible, and less disaster-prone technologies and practices, which might at first glance appear inconvenient or difficult to manage on a widespread basis. Importantly, such an approach does not depend on the kinds of large, imposing government regulatory systems that are typically presumed to be the basis of any environmental agenda. The apparent suitability of both solar development and sustainability to incentive-driven, less putative approaches to environmental policy may be a double-edged sword in that while enabling a more open, competitive market for solar and other “green technologies,” it may also end up privileging companies and industrial practices which treat renewable energy technology as yet another “abundant energy machine” to be mobilized in the service of unending economic expansion.⁶⁷⁶

Close attention to scale is important in ensuring that solar technologies are not mobilized in ways that align them with the traditional technocratic project of ensuring ever-increasing energy inputs. If, as historian Joachim Radkau suggests, the idea of sustainability remains “an empty formula at the global level,” only useful in “narrowly circumscribed frameworks” in which affected populations participate in its application, solar technologies can perhaps serve as a practical means of ensuring that those populations retain a measure of control over their lives in a new era in which energy needs, technologies, and environmental conditions are changing more rapidly and substantively than ever before.⁶⁷⁷ Solar technology may not be a panacea in itself; yet examples exist from its history to suggest that if pursued with a critical eye toward questions of scale and political power, it can be applied in ways that preserve the aspects of modern life that most people value while mitigating many of its worst social, economic, and environmental abuses. In present circumstances, which warrant precious few opportunities for hope for the

⁶⁷⁶ John Byrne and Daniel Rich, “In Search of the Abundant Energy Machine,” *The Politics of Energy Research and Development*, eds. John Byrne and Daniel Rich (New Brunswick, NJ: Transaction Books, 1986), 151-159.

⁶⁷⁷ Radkau, *Nature and Power*, 285.

future, solar remains a promising basis for creative technical and political experimentation aimed at creating a more just, resilient global society.

Overall, the history of solar technology offers more than simply a record of technical successes and failures. It also serves to highlight the complex interplay between new energy technology development and broader, geographically varied developments in politics, government, culture, economics, and human-environment interactions. A central takeaway is that solar technologies, even if they possess a degree of autonomy rooted in their particular material properties, still cannot be considered in isolation from the social and environmental contexts from which they took shape, and that “new” technologies invariably develop from and function to promote existing configurations of power comprised of technical, social, and environmental components. History may not offer a clear path to a solar future, but it can inform a more thoughtful conversation about the future of energy that acknowledges its continuity with the structures, both cultural and material, of the past.

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