Eleanor Raymond and Maria Telkes. The Dover Sun House, Dover, MA, 1948. Courtesy the Frances Loeb Library, Harvard Graduate School of Design.

The World Solar Energy Project, ca. 1954

DANIEL A. BARBER

> *Someday, our appetite for energy will probably be satiated, and energy production will remain about constant. We shall have become a nation of philosophers.*[1]
>
> —Eugene Ayres, 1952

> *What is happening to modern architecture is that it is just barely beginning to feel the impact of the social attitudes and technical facts of the new world in the making.*[2]
>
> —George Nelson, 1948

In 1957 the office of Charles and Ray Eames produced what they called a *Solar Do-Nothing Machine*. Developed as part of a marketing campaign for the Aluminum Company of America (Alcoa), it consisted of a twenty-four-inch elliptical aluminum platform supporting moving pinwheels and star shapes, all made of brightly colored anodized aluminum. On the side, a freestanding reflector screen of polished aluminum strips captured sunlight and reflected it into twelve photovoltaic cells, converting sunlight into electricity.[3] As *Life* noted in 1958, "the toy has no use and is not for sale, but ALCOA is sending it on tour as an enchanting harbinger of more useful sun machines for the future."[4]

On the one hand, the Eameses' toy is a concise expression of the place solar power occupied in the expansion of energy infrastructure right after World War II. In the context of the strategic development of a global oil network, of investment in nuclear power, and of a dramatic increase in electrical grid and natural gas pipeline capacity, solar energy was able to do, if not exactly nothing, then certainly very little. On the other hand, the *Solar Do-Nothing Machine* is symptomatic of an emergent perspective on the relative utility of the machine, and on how design strategies in architecture began to focus on the challenges presented by increasing knowledge of global ecological contingencies; that is, an emergent perspective on the ability of a solar machine, and of ecotechnologies more generally, to *do something* and, in particular, to contribute to the development of more useful architectures in the future.[5]

Concerns over the usefulness of midcentury architecture have generally been read through the contemporaneous historical interventions of Reyner Banham, who encouraged the architect to "discard . . . the professional garments by which he [*sic*] is recognized as an architect" in order to learn how to "run with technology."[6] Banham's embrace of technology as a means to provide architectural solutions to social problems was straightforward: rather than be solely concerned with "symbolic expression," attention to the performative aspects of a building could lead architects—and architectural historians—to an expanded conception of the social consequences of design proposals. "It is impossible to discuss the building," Banham insisted at a gathering of architectural historians and critics in 1964, "without discussing what it is for. . . . If you leave out the fact of utility, you leave out the 'why' of architecture as a human activity."[7] At the dawn of what Samuel P. Hays calls "the environmental era," Banham was aggressively reframing architecture as an ecotechnological tool—arguing for a "more useful" architecture that was focused on directing technological innovations toward social and environmental problems.[8]

A number of recent analyses offer a check to Banham's technophilic instrumentalism and suggest that both the looming environmental crisis and the apparent crisis in architecture's technological investment allow for a more nuanced consideration of the relationship between architecture and the machine.[9] While a clear distinction exists between the Eameses' mechanically useless sun machine, operating solely as a medium for speculation, and the immediacy of Banham's imperative for social utility, between these positions lies a discursive space for reassessing those midcentury architectural practices and projects that were experimenting with how to encounter increased knowledge of environmental complications.[10] Of interest here is a range of architectural and ecotechnological experiments in the 1940s and 1950s that failed to redefine the facts of utility—and thus were invisible

Charles and Ray Eames et al. *The Solar Do-Nothing Machine*, 1957. Courtesy John and Marilyn Neuhart.

to Banham—but nonetheless opened up a new space for discussion about how to live in a future of global environmental threats. Explorations of shading devices and natural ventilation systems, of prefabrication techniques and strategies for off-site production, and of the organization of design methods toward a careful placement of the building within its bioclimatic region are all significant, albeit underanalyzed, elements of midcentury architectural discourse.[11] Such a reassessment serves not merely to add to the database of postwar historiography but also shifts the terms of architectural history toward the complicated economic and political dynamics embedded in Banham's facile distinction between symbolic expression and technical utility.

Aside from prefabrication, these tendencies have generally not been considered in the architectural historical literature of the period. Too frequently, such environmental strategies have been dismissed because they are seen to have been benign in their formal approach while also failing to attain technological viability—this last either because their technological proposals were tenuous or because the opportunity for further exploration was overwhelmed by other geopolitical and geophysical forces. Rather than a demonstration of Banham's premise of architecture's utility, these compromised experiments are instead significant as examples of what Jean-Luc Nancy terms "ecotechnological enframing." Their historical import lies in the promise of reconceiving the possibilities and limitations of the technological future. "What *forms a world* today," Nancy writes, "is exactly the conjunction of an unlimited process of an eco-technological enframing *and* of a vanishing of the possibilities of forms of life."[12] As "the controlled management of natural life" has become the medium for innovations in governance, the applied sciences, and the built environment, the seemingly endless potential of technology has been deployed not only toward the resolution of environmental complications but also toward novel integrations of material, economic, and political possibility.[13]

Among these ecotechnologies, solar energy has played an especially provocative role. This is in part because of the presumed simplicity, remarked upon early and often in the historical process of industrialization, of harnessing energy from the sun.[14] And it is in part because of a persistent notion that solar energy holds not only the potential to supply new forms of energy but also to reconfigure political relationships. In one well-known example, Langdon Winner describes how alternative energy advocates of the 1970s saw solar energy as desirable "not only for its economic and environmental benefits, but also for the salutary institutions it is likely to permit in other areas of public life."[15] For Winner and others, the democratic potential of energy from the sun was placed in sharp contrast to the centralized systems characteristic of the nuclear energy industry. Solar energy has been seen, especially since the midcentury period, as not only a technological means for mitigating the environmental crises that architects have been increasingly compelled to address but also as an essential part of any vision of how to live in the environmentalist future. The technological vicissitudes of some "solar do-something machines" at midcentury thus suggest a usefulness less in finding means to increase energy efficiency and more in catalyzing a global discourse around the kind of world that new technologies can form.

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One of the most ambitious ecotechnological experiments in the immediate postwar period was the Dover Sun House. Built about twenty miles west of Boston in 1948, it was designed through a collaboration between architect Eleanor Raymond (1887–1989), a Boston modernist, and mechanical engineer Maria Telkes (1900–1995), who, since her immigration to the United States from Hungary in 1925, had been working on various means to convert solar radiation to useful forms of energy.[16] The house is the best known of a remarkable variety of solar houses built during and right after World War II. Even among this group, the Dover Sun House was distinct in being an "all-solar house": it had no conventional furnace and was completely reliant on an innovative system of solar heating, pioneered by Telkes, that involved the manipulation of the heat-storage capacity of phase-change chemicals.[17] Implicitly recognizing the house as both an "enchanting harbinger" and a "useful sun machine," *Life* noted that though it is an "unconventional building . . . resembling a modern house with a superimposed chicken coop, it may turn out to be historic."[18]

Understanding the house's "historic" agency begins with understanding why the house was built in a period that is usually characterized as one of abundant energy and endless economic growth. As numerous historians have recently begun to describe, the period from the end of the war until about 1951—until the extent of Middle East oil reserves became known—was one of significant concern over the future availability of energy resources.[19] Harold Ickes, longtime U.S. secretary of the interior, wrote an article in 1943 titled "We're Running Out of Oil!" in which he decries the possibility of the United States becoming a "Have-Not" nation. Ickes was concerned that domestic energy reserves had been "bankrupted" by "the prodigal harvest" needed to win the war.[20] Anxiety over energy availability ran deep in U.S. government agencies and numerous industries.[21] Alongside familiar efforts to expand oil, nuclear, and hydroelectric capacity, research funding was poured into the most unlikely of experimental projects—not only solar housing but attempts to harness geothermal energy, extract oil from shale, and generate energy from wind.[22]

Concern over the resource limits of the earth and the relative costs and benefits of technological means to overcome them were prominent themes in American cultural discourse just after the war ended. In 1948, the same year the Dover house was built, Fairfield Osborn's *Our Plundered Planet* and William Vogt's *Road to Survival* were best-sellers.[23] These books focus on what their authors see as the terrifying interconnections among limited food supply, exponential population growth, and rising industrial pollution. Both books also focus on the promise of technology to alleviate potential catastrophe.[24]

The promise of technology is another well-known postwar theme, one that often focused on the house. *Life* published an image in 1946 under the title "Family Utopia" in which all of the appliances and technological amenities that wartime technology was seen to have promised, including a helicopter for personal commuting, are displayed in the family yard.[25] The personal helicopter, as Andrew Shanken points out, was a frequent image in wartime advertising as an "anticipatory tease" for the domestication of applied technology once the war, and the industrial production that accompanied it, had subsided.[26] The helicopter was also prominent in interpreting one of the better-known house designs of the immediate postwar moment: Ralph Rapson's 1945 Case Study House no. 4, known as the "Greenbelt House." As Esther McCoy writes, Rapson's drawing of the house "describes well the yearnings of the mid-1940s" for new technologies and new ways of living—but "Rapson's money," McCoy continues, "was on the wrong machine": the husband was commuting home from work by helicopter, while the housewife hung the laundry out to dry in the yard, bereft of the soon-to-be-ubiquitous automatic clothes dryer.[27] Such images made visible the public and professional preoccupation over the direction of technological change in the years right after the war—not just that technologies would develop, but how they would develop, and with what consequences. The singular event in this context was the previously unimaginable destructive force of the atomic bombs dropped on Hiroshima and Nagasaki, an event that was seen as an occasion both to affirm that the future would bring unforeseeable changes and to question the kinds of futures different technologies could bring about.

It was by virtue of both the general concern over technological trajectories and the specific anxieties over energy resources that an emergent field of technocratic experts began, in the late 1940s, to analyze the global energy future in detail. The most prominent expert was Eugene Ayres, the director of research at Gulf Oil.[28]

In 1948, while the Dover Sun House was under construction, Ayres gave a keynote address to the American Petroleum Institute. He suggested that the energy industry should emphasize the distinction between "capital" energy sources—based in accumulated energy stored underground, such as coal, oil, and even uranium—and "income" sources, such as solar, geothermal, and wind that, given adequate research, could be used on a continuous basis. Ayres also insisted that the "host of technologists" working on energy efficiency needed to "focus their efforts on income sources."[29] A graph accompanying his presentation shows the possible contours of industrial growth and decline based on known "capital" sources, with the viability of industrial civilization extended, in two comparative curves, according to moderate or intensive research programs into "income" sources. Ayres's analyses and writings also indicate the optimism that was, perhaps surprisingly, characteristic of much of the period's research on resource scarcity. "This tiny period of earth's life," Ayres wrote in *Scientific American*, "when we are consuming stored riches, is over. But man's resourcefulness continues and becomes more potent with each passing decade. Because of this, the future is bright."[30]

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Ayres's bright future was not only metaphoric. In the same article, he focused his optimism on recent solar house-heating experiments that took advantage of abundant "income" energy falling to the earth. The title of his article, "Windows," would seem to indicate an interest in the copious use of glass in the passive solar houses, most notably those designed by George Fred Keck, that had been dotting the Midwestern suburban landscape since just before the war. Keck's houses were narrow bar buildings with fully glazed south-facing façades and precisely calculated roof overhangs—sunlight penetrated deep into the house in the winter but was blocked in the summer. His use of recently developed insulated glass panels allowed these design innovations to also promise significant savings in heating bills. Though Keck was

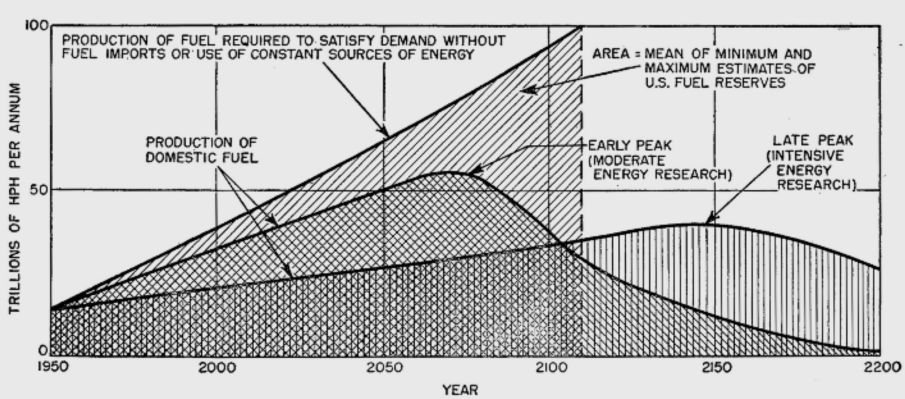


FIG. 5. Some possibilities in our future energy picture.

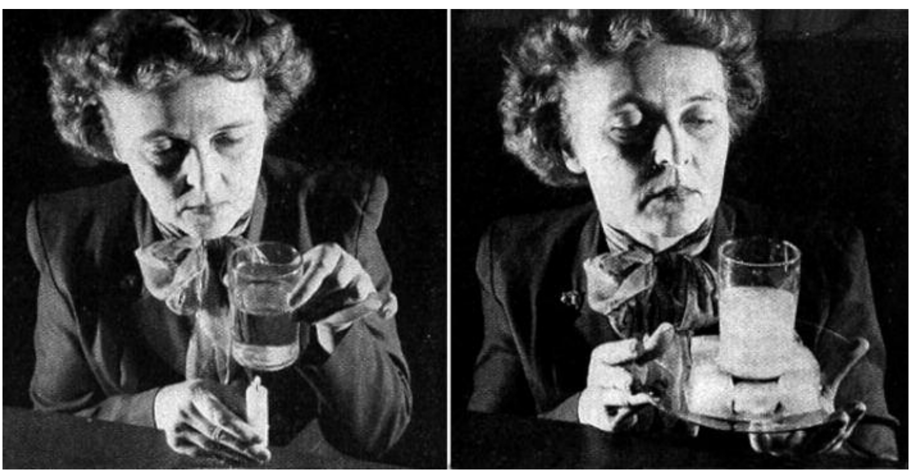
the most prolific, the interest in passive solar houses preoccupied the architectural profession more generally and was the subject of numerous competitions, exhibitions, and publications in the period.[31]

But Ayres, despite the title of his article, was more interested in active solar heating systems. The Dover Sun House was especially enticing, and an image of the house was prominently featured on the first page of the article. With a bank of glass plate heat collectors—not windows—on the second floor, the house used Telkes's phase-change system to collect and store solar radiation. Phase-change compounds change from solid to liquid at a given temperature: as they melt, the heat is absorbed in the liquid state and stored. When the surrounding temperature then cools, the compounds recrystallize, and the heat is released.[32] Telkes wrote in 1945 that "the problem of the solar house is one of heat storage," and her phase-change experiments were focused on developing an effective and affordable mechanism by which solar radiation, collected when the sun was out, could be stored for use at night or under cloudy skies—thus making solar heating a viable replacement for fuel-based systems.[33]

Telkes was part of a solar energy research initiative at the Massachusetts Institute of Technology (MIT). In 1947, she helped build a small experimental structure intended to test the viability of the phase-change process for space heating. As at the later house at Dover, what looked like a bank of windows was in fact a series of glass-faced solar heat storage panels. These panels were the exterior face of seven thermally isolated cubicles, each testing slightly different experimental parameters.[34] For this first experiment, Telkes devised an integrated solar collection and storage unit she called the "Vertical South Panel," designed to store enough heat during the day to warm the structure all night. The panel consisted of two panes of glass separated by an insulating air membrane. The interior face of the panel was adjacent to a vertical container filled with a phase-change chemical compound.[35] Solar radiation would heat the air membrane, which would in turn heat the chemical container. When the salts reached phase-change temperature, they would liquefy and store

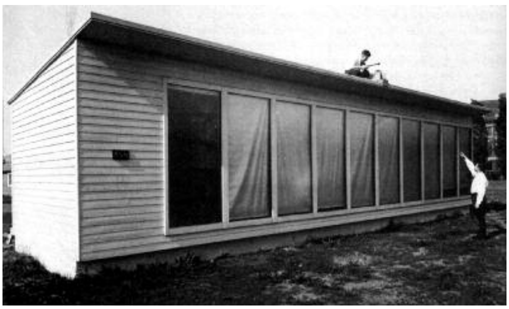
Opposite: Eugene Ayres. "Some Possibilities in Our Future Energy Picture," from *Energy Sources: The Wealth of the World*, 1952.

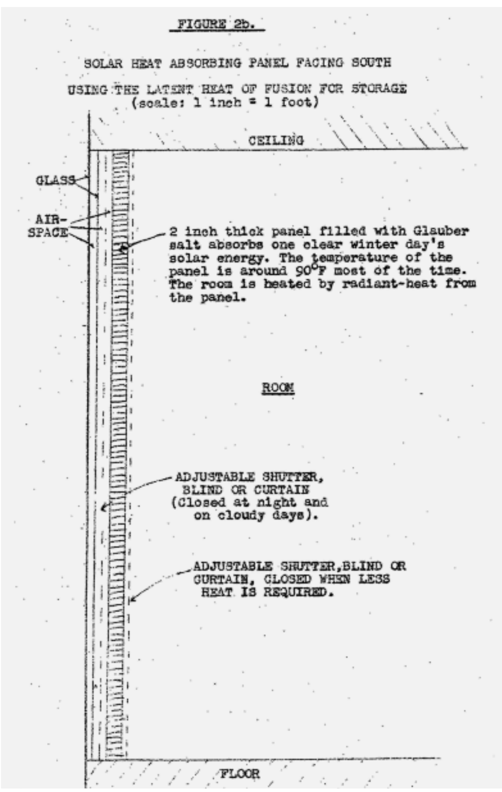
Below: Maria Telkes using a candle and ice cubes to demonstrate the phase-change transition of a chemical compound. From *Christian Science Monitor*, December 31, 1948.



the heat. When the sun went down, an insulated curtain was drawn into the air membrane to keep the chemicals in their liquid state. As the interior of the building cooled, the compounds recrystallized, and the stored heat radiated from the panel into the room.

The experiment did not go well: the phase-change temperature of ninety degrees proved difficult to maintain; the chemical compounds stratified and lost effectiveness; and the vertical containers corroded, cracked, and leaked. After initial disappointing results, the phase-change salts were tried in different solutions, other chemicals were attempted, and a roof overhang was removed so that more heat could reach the panels. The problems persisted. Beyond these technical issues, personal animosity between Telkes and her collaborators led to poor monitoring and lax maintenance. Little institutional impetus existed to make the system work. The experiment was later discussed as part of the "somewhat questionable activities of Dr. Telkes" by administrators reviewing the work of the solar energy research group.[36] This group decided to renovate the building—without Telkes—and to return to a previously tested water-based heat storage system in which rooftop panels heated water and stored it in an insulated tank located inside the panel structure. This heated water was distributed to radiant ceiling tiles to warm the interior.[37] This renovated structure, also completed in 1948 (and also discussed in Ayres's article), demonstrated the success of a water-based system but was both expensive and heavily reliant on supplementary heating sources to maintain a comfortable interior temperature throughout the cold Boston winter.





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Despite the apparent failure of her first phase-change experiment, and despite being ostracized from the MIT group, Telkes was undeterred. She turned to architecture in order to refine the technological utility of the solar heating process. Through engagement with architecture the utility of solar heating was also given expanded significance. Telkes had previously collaborated with Raymond on the solar efficiency of a local greenhouse, and after the failed experiment at MIT she contacted the architect to explore how a new design approach could redirect and redefine the phase-change system.[38]

Raymond was by then well known for adapting the new forms and materials of architectural modernism to the conditions of New England—her 1931 house for her sister, completed just after the two took an architectural tour of Germany, was one of the first modernist buildings in the region. Raymond's Plywood House of 1940 was celebrated as the first anywhere to use plywood as a primary building material. Raymond was also knowledgeable about traditional means of managing solar incidence and other climatic conditions—as evidenced in her exhaustive survey of vernacular structures in her 1931 publication *Early Domestic Architecture in Pennsylvania*, which focused, in part, on the role of the roof overhang in managing seasonal climatic variations.[39] Raymond's houses of the 1940s can be placed next to the postwar work of Walter Gropius, Harwell Hamilton Harris, Pietro Belluschi, and many others, in order to locate the Dover Sun House as part of a broader interest in adjusting the International Style according to regional concerns.

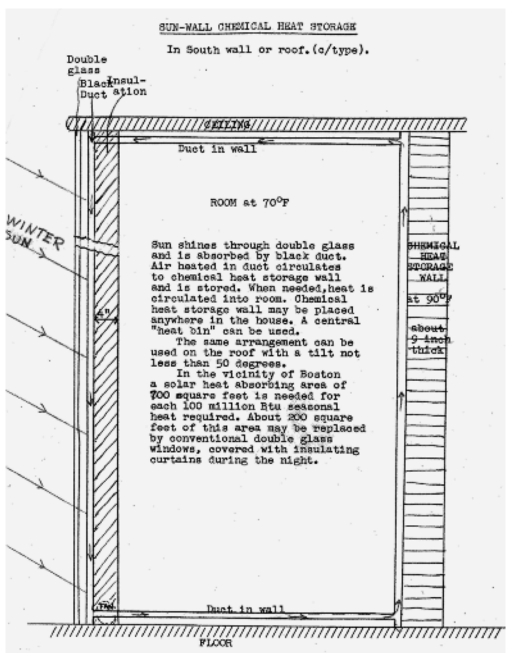
At Telkes's urging, Raymond convinced Amelia Peabody, her client for the Plywood House and other projects, to sponsor a phase-change experiment on one of the numerous Peabody estates.[40] A more considered architectural approach here became instrumental to the problem of solar heating. In the first place, Raymond insisted that "from the architect's point of view" to give up "any part of the south wall . . . to predetermined use" was unfortunate. "I am especially interested," she continued, "in any scheme using the roof for heat storage."[41] Telkes was concerned that the salts would be too heavy for the roof and a month later responded with an important innovation. Suggesting a device she named the "Sun-Wall Chemical Heat Storage" unit, Telkes proposed to separate the solar absorption panel from the chemical storage bins, using fans to draw heated air from one to the other.[42] This was a significant refinement in that it doubled the surface for radiating heat into the interior and also made the system more amenable to different architectural treatments.

In the first scheme for the house, from February 1948, Raymond placed the collector on a set-back A-frame roof, with chemical heat storage in "heat bins" along the central axis. As Raymond later explained, "the heat loss through the walls of the bins would become radiant heat in the rooms, instead of escaping to the attic."[43] The weight problem was also avoided. This basic premise was refined in a second and final scheme from August of the same year. Here Raymond made the plan longer and much more narrow, placing all of the living areas to the south and leaving them

Opposite, top: Maria Telkes and the MIT Solar Energy Fund. Test Building for Phase-Change Heat Storage, Cambridge, MA, 1947.

Opposite, bottom: Maria Telkes. Explanatory diagram of the "Vertical South Panel," 1945. Courtesy the Department of Archives and Special Collections, Arizona State University Libraries.

Below: Maria Telkes. "Sun-Wall Chemical Heat Storage," 1948. Courtesy the Frances Loeb Library, Harvard Graduate School of Design.



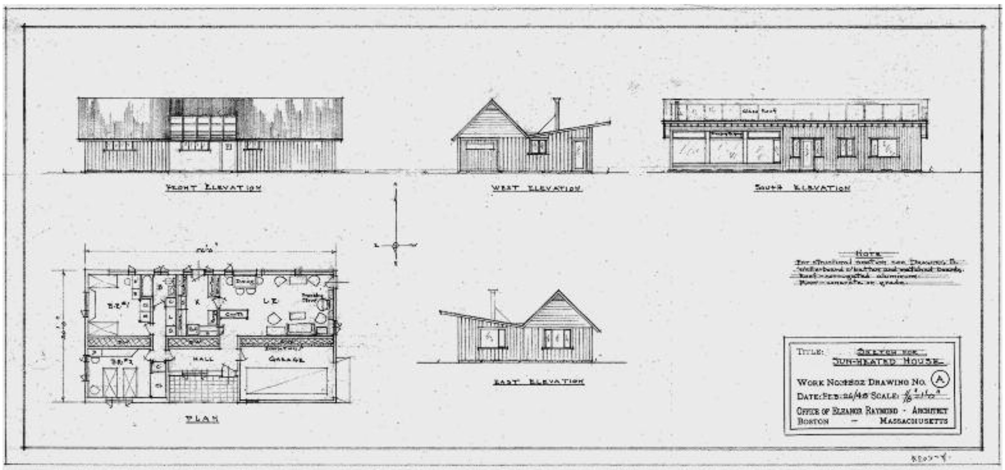
open to passive heat gain, with circulation to the north. In stretching out the plan, she also significantly enlarged the collector. In this scheme the heat bins were more precisely calibrated to load—larger near the bedroom and smaller in the kitchen and living areas used during the day.[44] The double-paned glass on the collector again sat in front of a thin air cavity, now faced on the other side by a black metal sheet to increase heat absorption. Solar radiation heated the air in this collection space and blew it into the "heat bins" below, where the salts liquefied and stored the heat. As the interior cooled, the salts recrystallized, and their heat was released. Traditional registers distributed the warmed air throughout the house.

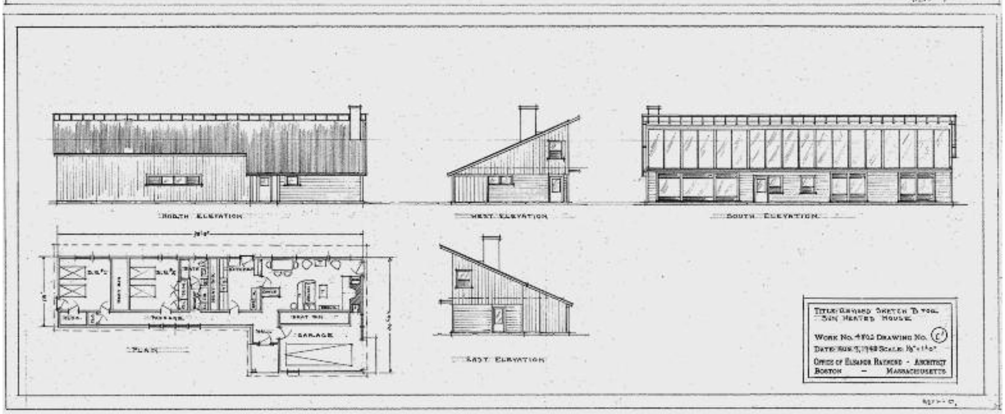
These refinements to the phase-change system, dependent upon the integration of the technological proposal into the architectural treatment of the house, greatly increased performance. As before, however, many problems arose. The biggest issue was that the intense heat in the collector led to the panel sealant drying out and thus to persistent leaks—both of water getting in and of heat getting out.[45] A combination of Telkes's advocacy and Peabody's financial resources allowed for these problems to be, for a time, withstood. Every summer, the whole system was rebuilt—the salts were replaced, and the glass panel was disassembled, recaulked, and put back in place.[46] Fortunately, the tenants of the house were cousins of Telkes and, as Peabody notes

Below: Eleanor Raymond. "Sun Heated House" (first scheme), February 26, 1948, and "Sun Heated House" (second scheme), August 9, 1948. Courtesy the Frances Loeb Library, Harvard Graduate School of Design.

Opposite, top: The Dover Sun House system schematic. From *Life*, May 2, 1949.

Opposite, bottom: Amelia Peabody (in hat), Maria Telkes, and MIT engineering faculty at the party celebrating the opening of the Dover Sun House, March 20, 1949. Courtesy the Department of Archives and Special Collections, Arizona State University Libraries.





in a 1952 letter to Raymond, were "frequently heroic" in withstanding "bitter temperatures."[47] But in the spring of 1954, after a particularly difficult winter, Peabody finally gave up. "We have proven that solar living is possible," she told the *Boston Globe*, "though it is not very comfortable. . . . The experiment is over."[48]

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Before any of these complications were understood—before most of them had developed—the house opened to great acclaim in March 1949. It recevied accolades in the professional and popular press, from *Heating and Ventilating News* to *Architectural Record* to *The Saturday Evening Post* and *Fortune*.[49] The formal awkwardness of the house was accepted, even celebrated, as a symbol of its utility amid the continued concern over energy sources. When Raymond was made a fellow of the American Institute of Architects in 1950, the Dover house was cited as one of her most important accomplishments.[50] In 1952, Telkes was given the first annual "Society of Women Engineers Achievement Award" based on the perceived success of the house.[51] A 1949 cover story in *Popular Science* claimed the house held "the key to economies in home heating and [in] the world's fuel supply," and, as the article continued, "while a house cannot compete in drama with the towering cloud of death that rose over Hiroshima, the sun furnace may be the more important portent of the two."[52] A hyperbolic statement, to be sure, but one not out of place amid the concerns of the period. From its opening until the early 1950s, the Dover Sun House was widely celebrated as a working demonstration of the potential of "income" energy sources to reorganize social patterns and priorities—as evidence of how "useful sun machines" could provide new and unexpected ways of living in the future.

The careful integration of architecture and technology in the Dover Sun House also made it an important cultural event. Much as with other demonstration houses of the late 1940s, including Breuer's "House in the Museum Garden" at New York's Museum of Modern Art (MoMA) and the prefabricated

WORLD'S FIRST SUN-HEATED HOME

A NEW HOUSE IN DOVER, MASS. HAS BEEN COMFORTABLY WARM ALL WINTER WITHOUT A FURNACE

Lustron houses shown across the Northeast, visitors flocked to the Dover house to expand their sense of what sort of life might be available to them now that wartime restrictions had ended.[53] The house can similarly be seen in the context of contemporaneous explorations of the use of glass to mediate the experience of nature—as proposed in very different ways in Philip Johnson's Glass House of 1949, Paolo Soleri's Desert House of 1950, and R. Buckminster Fuller's proposals for glass-enclosed domes, all of which were featured in the catalogue for the 1953 MoMA exhibition Built in USA: Post-war Architecture.[54] All of these houses were received in public discourse as productive challenges to familiar perceptions of how a house should look and how one would live differently in the future. Furthermore, Fuller's experiments, Arthur Drexler wrote, "would be equipped with portable mechanical packages for heat," and Johnson's famous house had its roots not only in his well-documented attention to Mies van der Rohe but also in his proposal for a passive solar house published in *Ladies Home Journal* in 1946 and exhibited at MoMA later that year.[55] The MoMA exhibition even proposed that the basic design principles of passive solar heating would "soon emerge as the dominant post-war plan type."[56]

In the context of these architectural developments and the postwar concern over resources, the Dover Sun House articulated a new resonance for architectural-technological choices and outlined a new role for the field in contributing to the formation of the world to come. The house's insertion into the resource discussion was both as a creative, if ultimately ineffective, response to the technological demands of resource pressures and as a catalyst to open up these debates to more fully consider the viability of other alternatives. In the fall of 1949, for example, Telkes participated in the United Nations Scientific Conference on the Conservation and Utilization of Resources (UNSCCUR), one of the first gatherings of scientists, policy makers, and technologists to discuss global environmental conditions. Telkes's paper "Space Heating with Solar Energy" summarized a number of contemporaneous solar house experiments and then described the "experimental house" in Dover.[57] The *New York Times* reported that, after seeing Telkes's presentation, U.S. Interior Secretary Julius Krug "placed solar energy high on the list of possibilities that might have a tremendous bearing on the resources of the country," and talk emerged of Telkes and Ayres leading a full-scale study of solar energy as an early project of the then-in-formation National Science Foundation.[58]

The house was also featured in a 1951 Truman administration report called *Resources for Freedom*. By this time petroleum exploration in the Middle East and Venezuela, and the adjustment of the relevant tariff structure, had led to imported oil flowing freely into the United States.[59] The start of the Korean War, however, again focused attention on the fragility of the global resource system. The commission organized to produce *Resources for Freedom* sought to outline means to integrate resource policy, economic policy, and foreign policy. The commission analyzed "the combined material requirements and supplies of the entire free non-Communist world," as well as the government policies and corporate practices affecting them. The resultant document proposes adjustments to international trade agreements and targeted government subsidies that would provide for the "common welfare, common growth, and common security of these countries."[60] The intense militarization of the U.S. presence abroad occasioned by the Korean War—and perpetuated more generally by concerns over apparent Communist aggression—was thus reflected in concerns over how this expanded territory could be managed in terms of, as the report states, "the interdependence of moral and material values."[61]

While the larger report assesses an array of materials, the focus of the widely distributed summary is energy. Research into "alternative energy," as it was already termed, was seen as especially significant: by funding solar energy projects for sun-rich developing economies in the global south, the summary proposes, the oil and other resources held in those countries could be imported into the United States, simultaneously increasing the standard of living there and in countries at risk of falling under Soviet influence.[62] Because of this strategic approach, the *Resources for Freedom* summary claims "the direct utilization of solar energy . . . was the most important contribution technology can make to the solution of the materials problem."[63]

Rather quickly, then, a number of historical contingencies transformed the trajectory of phase-change solar heating from a strained technological experiment to an opportunity for rethinking the geopolitical dimension of energy systems. Telkes, increasingly isolated at MIT, developed a number of funding proposals that clarified these new possibilities.[64] One of the first was a 1951 proposal for a "Solar Energy Research Institute" at Arthur D. Little, Inc., an early pioneer in contracted services and operations research models as they migrated from government to private industry after the war.[65] The proposal was to develop a coordinating organization through which technologists could "collaborate with industry" for developing "solar energy utilizing devices, engines, or processes."[66] The project was seen as participating in the "technological leadership of the United States" as it was being "extended to underdeveloped countries. . . . Most of these countries," Telkes writes, "do not have fuel and power for industrial development." She proposes that "as a first step, solar distillation could supply fresh water from sea water or from saline wells, thereby increasing the possibilities of agricultural development. As a second step, solar heating and power production may inaugurate their industrial development" and leave the way open for additional investment. Finally, Telkes concludes, "These underdeveloped countries cannot be expected to do anything in the development of solar energy. *Research and development in this field must come from* [the] *technological leadership of the United States*."[67]

With the "Solar Energy Research Institute" proposal, Telkes was participating in the broader integration of resource concerns into programs of "technical assistance." Such programs emphasized the "interrelatedness of social, cultural, political, and technical-economic change." The "invention of technical assistance" was part of the postwar reconfiguration of global cooperation initiated in the first UN General Assembly, which clarified the UN's "non-political functions."[68] At the same time, the United States provided the operational leadership and funding for these programs, especially after Truman's "Point Four" proposal in early 1949 and the subsequent "Act for International Development" of 1950.[69]

Here, as with many other issues, however, the situation changed after the 1952 election of Dwight Eisenhower—and in subtle but significant ways. Eisenhower claimed a laissez-faire approach to technological innovation and a general reduction of government spending. However, he saw in technical assistance projects a cost-effective mechanism to influence both political transformation and economic growth. This led to a shift of funding from direct foreign aid programs to technical assistance operations, many of which were led by the U.S. Foreign Operations Administration formed by Eisenhower in 1953.[70] Eisenhower's policies also led to a dramatic increase in collaboration with the UN, the Ford Foundation, the Rockefeller Foundation, and other entities, often at the agency level, as a way to reap the benefits of assistance regimes without shouldering the responsibility.[71]

One of the best-known examples of the Eisenhower administration's investment in technical assistance was the "Atoms for Peace" program of 1953. Responding to the Soviet Union's attainment of hydrogen bomb technology, the program proposed a "world-wide investigation into the most effective peacetime uses of fissionable material" and sought to develop means to export nuclear technology and materials to developing economies.[72] Though the program was effective on rhetorical terms in the ensuing diplomatic dynamics of the arms race, it quickly became clear that the technical challenges to sharing and securing nuclear technology were prohibitive.[73]

In light of the failure of the Atoms for Peace proposal, the flexibility and user-friendly potential of solar technology and its seeming appropriateness to the low-tech needs of the "underdeveloped," sun-rich regions of the global south made it appear even more useful to the administration's economic and political goals. A confidential memorandum circulated by the Office of Defense Mobilization in late 1954 proposes that, in order to "further the exploration of new and imaginative ideas which provide opportunity for cooperative international effort and the lessening of suspicion and tensions among nations . . . it is felt that consideration should be given to a World Solar Energy Project."[74] The memo cites the discussion of solar energy at UNSCCUR and in *Resources for Freedom*, as well as numerous other experiments in solar energy applications. The phase-change process in particular, the report asserts, was proof that "there is sufficient technical challenge in this area to provide a firm foundation for an international project which could symbolize the will of all nations to join hands in a program for their common betterment."[75]

While the "World Solar Energy Project" was not developed as policy, it was nonetheless largely instantiated through small-scale and disparate applications of phase-change materials and other solar technologies developed in the realm of government- and foundation-supported technical assistance ventures in support of the Eisenhower administration's economic and foreign policy goals. The proliferation of solar-based systems and objects developed for these programs, and the array of corporate, government, and nonprofit foundation support that engendered them, was remarkably dynamic. Here again, Telkes was a leading figure. In a proposal to the College of Engineering at New York University in 1953, she listed the areas of solar research in which she had generated interest, including: solar ovens; solar desalination units; solar pumps to carry water uphill; storage and transportation of heat-sensitive goods—including blood and other medical supplies—in regions without reliable refrigeration; agricultural frost protection; and the strategic solar heating of oil pipelines to help oil flow more quickly to its destination.[76] Based on this proposal, Telkes was offered a job at NYU in 1953 and formed the Solar Energy Research Laboratory there in 1955.[77]

One of the most successful of the solar technological objects proposed by Telkes was the phase-change solar oven she developed "for use in fuel-short regions such as India and the Near-East."[78]

Exhibition of solar ovens, furnaces, and water distillation devices organized by Telkes's Solar Energy Research Laboratory at New York University and the Association for Applied Solar Energy, outside Ahmedabad, India, 1956. Courtesy the Department of Archives and Special Collections, Arizona State University Libraries.

The phase-change oven was first tested at a Navajo Indian reservation in Arizona in 1954, and versions were later exhibited in India as part of a Department of Commerce tour of delegates in 1955, at the 1956 Brussels World Fair, and at the 1957 International Trade Fair in Salonika, Greece. In 1955, a demonstration of the solar oven was made to the Foreign Operations Administration and the State Department.[79] In 1957, under Telkes's direction, the Food and Agriculture Organization of the UN organized a "one-day course" on assembling solar ovens. UN field tests were made in Thailand, Egypt, India, Trinidad, and Rome, and solar ovens were widely distributed and used in the late 1950s.[80]

Telkes's lab also experimented with desalination techniques. The lab developed a number of models: a "flat tilted solar still . . . that can be operated at the sea shore with sea water" as well as a "roof-type" still that trapped heat in a glass- or plastic-enclosed volume and collected distilled water along the sides. A later "ten-stage multiple-effect atmospheric still" produced six times more water than previous experiments, and also produced table salt—a useful sun machine indeed.[81] Later improvements included "automatic controls . . . that regulate the flow of water, admitting more salt water when the sun shines brightly."[82] Telkes's projects had numerous applications relevant to economic development and health improvement, including solar desalination plants to increase agricultural productivity and "municipal solar distilling plants" which Telkes proposed to the governments of Curaçao and Cuba. From 1955 onward, Telkes was a frequent "water quality" consultant to UN technical missions.[83]

A number of phase-change solar houses were also built, including one at the U.S. Department of Commerce's trade fair outside Casablanca, Morocco, in 1957 that experimented with solar cooling.[84] Solar technologies became central to the new forms of economic development knowledge and to the dissemination of American influence—both as a means to

improve economic opportunities and to help secure the political affiliation of unallied nations as the Cold War was heating up.

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Much as the story of the Dover Sun House is about how it was made to work, "propped up" by excessive investment, continuous maintenance, and aggressive advocacy, the technological possibilities of the phase-change system and of solar energy more generally were constructed and reconfigured in multiple attempts to maintain relevance amid a brief historical moment of a receptive political discourse.[85] The vicissitudes of the phase-change process provide evidence that all technologies develop in relationship to contingent cultural and political factors—a point further clarified by the fact that phase-change materials are today a familiar element in the sustainable architect's toolkit.[86] This same principle of historical contingency needs to be applied to the foil of midcentury solar experiments: the multifaceted project to construct a global infrastructure of oil. Oil was also propped up by numerous geopolitical forces in the period. Securing a reliable flow of oil into the United States involved a combination of military threats, careful diplomacy, and new techniques in political forms of clandestine infiltration—this last illustrated most dramatically in the 1953 CIA-organized coup in petroleum-rich Iran.[87] Making oil available and affordable in the U.S. and Europe was itself a massive technological and political project, with a range of social and environmental effects. A minor consequence of this effort was the reduced utility of solar energy in the global coordination of energy systems.

Thus, while the Dover house had some significant effects, it did not, in the end, help to resolve midcentury concerns over energy sources. The historic significance of phase-change tech-

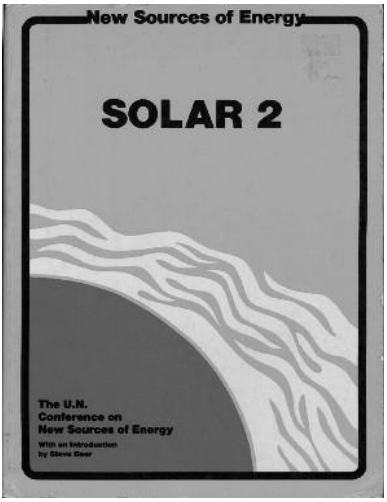
Opposite, left: Maria Telkes and Stella Andrassy. Hot-box type clay-coated phase-change solar oven, 1955. Shown during a demonstration of the oven to the U.S. Foreign Operations Administration. Courtesy the Department of Archives and Special Collections, Arizona State University Libraries.

Opposite, right: George O. Löf. Folding-umbrella-type portable solar kitchen. Shown in use in Pakistan, 1956.

Below: John I. Yellott and the Association for Applied Solar Energy. Casablanca Solar House, U.S. Department of Commerce International Trade Fair, Casablanca, Morocco, 1957. The demonstration house used a Telkes-designed phase-change chemical system for both heating and cooling. Courtesy the Department of Archives and Special Collections, Arizona State University Libraries.

Top: Cover of the 1978 reprint of *Solar 2: The U.N. Conference on New Sources of Energy*, which detailed the solar energy discussions at the United Nations Conference on New Sources of Energy: Solar Energy, Wind Power, and Geothermal Energy held in Rome in 1961.

Bottom: View of the Sun at Work exposition at the World Symposium on Applied Solar Energy, Phoenix, AZ, 1955. Courtesy the Department of Archives and Special Collections, Arizona State University Libraries.



nology in the 1950s was less in finding effective means to disentangle the complications of anticipated resource scarcity and more in defining new realms for technological and creative intervention. Architectural and applied science research in environmental technology was less potent for its explicit effects on the energy system and more for its capacity to facilitate new forms of social collectivity.[88] The instrumentalism of Banham's "fact of utility" is thereby recast to provide a window onto how technological interventions, rather than resolving social and environmental complications, served to restructure collective visions of the future.

The reception of the Dover house was in this sense embedded in a much more broadly conceived "World Solar Energy Project": an attempt to offer an alternative form of political organization focused on the relationship between technology, culture, and environmental change. New funding streams, organizational infrastructures, and social movements arose in response to the apparent promise of midcentury solar energy experimentation. Beyond direct means of technical assistance, philanthropic and corporate research funds increasingly focused on facilitating a cultural and scientific discourse concerned with how to measure and manage environmental change. Conferences on alternative energy research were held to direct technological knowledge and professional practice. A conference at the University of Wisconsin in 1954, for example, sponsored by the National Science Foundation, introduced significant new technologies such as early p-n junction photovoltaic cells and the French engineer Felix Trombe's solar furnace.[89] The Stanford Research Institute and a think tank called Resources for the Future, which had developed in response to the initial enthusiasm about the

Resources for Freedom report, organized the World Symposium on Applied Solar Energy in Phoenix in 1955. Here, the existing solar research was summarized and, in the form of an exposition called "The Sun at Work," presented to industry as opportunities for investment.[90] Telkes, working with the Association for Applied Solar Energy that grew out of this conference, organized related symposia at NYU in 1956 and 1959.

Unesco and the Ford Foundation sponsored "Wind and Solar Energy," a conference in New Delhi in 1954 that focused in part on refining a global analytic method for assessing the energy needs of a given community in order to determine "the possibility of satisfying [those needs] by an integration of solar, wind, and waste vegetable matter as sources."[91] This conference was the organizational precedent to the 1961 "United Nations Conference on New Sources of Energy: Solar Energy, Wind Power, and Geothermal Energy" in Rome. The Rome conference was, in turn, a touchstone for solar architects of the 1970s—the sessions on solar energy were reprinted in 1978, with an introduction by prolific technologist Steve Baer.[92] The Rome conference, in conjunction with the 1968 Unesco conference on the "Use and Conservation of the Biosphere" held in Paris, was also an important precedent to the discussion of energy at the 1972 "Conference on the Human Environment" in Stockholm, which saw the formation of the UN Environment Program and is often regarded as the beginning of the global managerial regime we now call "sustainable development."[93] This historical trace could be continued to encompass the Brandt Commission report of 1980, the Brundtland Commission report of 1987, and on to the Rio Earth Summit in 1992 and the yearly meetings of the International Panel on Climate Change since 1998 that have continued as a prominent vehicle for environmental advocacy up to the present.[94]

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The interest in solar energy at midcentury thus holds the potential to rescript much of the history of postwar environmentalism, both relative to architecture and more generally. The point here is not simply to applaud the formation of these organizational bodies and their attendant regulatory regimes—in many cases this global managerial approach can be seen to have shut down, rather than opened up, possibilities for rethinking future prospects.[95] As Nancy suggests, the worlds formed through ecotechnological experimentation are not inevitably productive of the new forms of life that appear to be increasingly necessary in the face of environmental degradation, in the face of the political incapacity to encounter climate change, and in the face of the professional challenges to architecture and other fields as they struggle to resist the momentum behind simply proceeding with "business as usual."[96] Banham's exhortation for architects to shed their "professional garments" in order to "run with technology" has long since been exceeded, as the imperative for technological innovation has redefined, if not in fact overwhelmed, the design professions. Much as the bureaucratic realm of global environmental management has come to be indistinguishable from the neoliberal discourse on endless economic growth, so has the promise of architectural ecotechnologies often collapsed into, rather than an opportunity for new forms of life, a form of "technical legitimization for promoting conventional solutions."[97]

At stake instead is a new framework for the historical and critical evaluation of the complex relationship between architecture, technology, and environmentalism. The World Solar Energy Project renders visible the tight interconnection between architectural experimentation and the gathering of new publics—collective social bodies newly concerned with the multifaceted and multifarious dynamics of the global ecological system. Experimentation in solar house heating, among other examples in the architectural history of the postwar period, demonstrates the potential of the design disciplines to contribute to the constitution of new social conditions, to new relationships toward materials and energy resources, to debates over political and economic organization, and toward new forms of life, for better or worse. Expanding our historical understanding of architecture to include these ecotechnological experiments also points to the need to persistently interrogate the presumed promise of technological innovation, and to hold such claims for innovation to a different set of criteria, that of facilitating that cultural potential for environmental change.

Notes

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1. Eugene Ayres with Charles Scarlott, *Energy Sources: The Wealth of the World* (New York: McGraw Hill, 1952), 282.

2. "What Is Happening to Modern Architecture?" *Museum of Modern Art Bulletin* 15, no. 3 (Spring 1948): 13.

3. See John Neuhart et al., eds., *Eames Design: The Work of Charles and Ray Eames* (New York: Abrams, 1989), 178. On Alcoa's architectural promotions, see Annmarie Brennan, "Forecast," in *Coldwar/Hothouses*, ed. Annmarie Brennan et al. (New York: Princeton Architectural Press, 2004), 55–90.

4. "A Twirling Toy Run by Sun: Gadget Is Forerunner of Future Solar Power Machine," *Life*, 24 March 1958, 22–24.

5. As Shelia Jasanoff indicates, "modern environmentalism includes at its core a widely acknowledged, if only imperfectly realized, ethical imperative to renegotiate human beings' relationship with nature in light of new scientific understanding." Sheila Jasanoff, "Image and Imagination: The Formation of Global Environmental Consciousness," in *Changing the Atmosphere: Expert Knowledge and Environmental Governance*, ed. Clark A. Miller and Paul N. Edwards (Cambridge: MIT Press, 2001), 309–338.

6. Reyner Banham, *Theory and Design in the First Machine Age* (New York: Praeger, 1960), 330. See also Reyner Banham, "The Machine Aesthetic," *Architectural Review* 117 (April 1955): 225; and Lewis Mumford, "The Case against Modern Architecture," *Architectural Record* 82, no. 4 (April 1962): 155–162.

7. Reyner Banham, "Convenient Bodies and Handy Hooks: Functional Considerations in the Criticism of Art and Architecture," in *The History, Theory and Criticism of Architecture: Papers from the 1964 AIA-ACSA Teacher Seminar*, ed. Marcus Whiffen (Bloomfield Hills, MI: Cranbrook Press, 1965), 92. See also Banham's 1960 "Stocktaking" series in *Architectural Review*, especially the third article on "The Science Side," featuring experts on "Weapons Systems," "Computers," and "Human Sciences." Reyner Banham, "Architecture after 1960," *Architectural Review* 127, no. 755 (January, 1960): 10; Reyner Banham, "1960 Stocktaking," *Architectural Review* 127, no. 756 (February 1960): 93–100; and Reyner Banham, "The Science Side," *Architectural Review* 127, no. 757 (March 1960): 183–190. In the series, Banham makes repeated reference to Charles Eames's "Discourse" at the Royal Institute of British Architects in 1959, in which Eames, as Banham writes, "introduced the concept of operational lore into architectural thought, and made with it a plea for the acceptance of scientific attitudes of mind." Banham, "1960 Stocktaking,"

100. The Eameses' sun toy was published in the February 1959 issue of *Architectural Review*, where Banham was by then literary editor. See "The Exploring Eye: Sun Mill," *Architectural Review* 125, no. 745 (February 1959): 105–107 (with foldout).

8. Samuel P. Hays, *A History of Environmental Politics since 1945* (Pittsburgh: University of Pittsburgh Press, 2000), 2.

9. See Anthony Vidler, "Toward a Theory of Environmental Program," *October* 106 (Fall 2003): 59–74; and Felicity D. Scott, "Afterword: No End(s) in Sight," in *Neo-Avant Garde and Postmodern: Postwar Architecture in Britain and Beyond*, ed. Mark Crinson and Claire Zimmerman (New Haven: Yale University Press, 2010), 387–401.

10. Much later, Banham would reflect this premise of technological utility through *Arts and Architecture*'s Case Study House program, in which the Eameses were prominent participants. See Reyner Banham, "Klarheit, Ehrlichkeit, Einfachkeit . . . and Wit Too! The Case Study Houses in the World's Eyes," in *Blueprints for Modern Living: The History and Legacy of the Case Study Houses*, ed. Elizabeth A.T. Smith (Los Angeles: The Museum of Contemporary Art, 1989), 183–196.

11. See, for example, Jane Drew and Maxwell Fry, *Tropical Architecture in the Humid Zones* (Huntington, NY: Kreiger, 1956); and Victor Olgyay, *Design with Climate: Bioclimatic Approach to Architectural Regionalism* (Princeton, NJ: Princeton University Press, 1963).

12. Jean-Luc Nancy, "A Note on the Term: Biopolitics," in *The Creation of the World or Globalization*, trans. François Raffoul and David Pettigrew (Albany: State University of New York Press, 2007), 95 (emphasis in original).

13. Nancy, "A Note on the Term," 94.

14. See Ken Butti and John Perlin, *A Golden Thread: 2500 Years of Solar Architecture and Technology* (New York: Van Nostrand Reinhold, 1980); and Frank T. Kryza, *The Power of Light: The Epic Story of Man's Quest to Harness the Sun* (New York: McGraw Hill, 2003).

15. Langdon Winner, "Do Artifacts Have Politics?" *Daedalus* 109, no. 1 (Winter 1980): 125. The theme of the issue was "Modern Technology: Problem or Opportunity?" For a contemporary iteration of this same formulation, see Alexis C. Madrigal, *Powering the Dream: The History and Promise of Green Technology* (New York: Da Capo Press, 2011).

16. Telkes joined the Massachusetts Institute of Technology research staff in June 1939 after working for twelve years at the Cleveland Clinic Foundation and then, starting in 1937, at Westinghouse, where she experimented with different alloys for direct conversion of solar energy to electricity through thermocouples. "Data of Maria Telkes," in box 17, Papers of Hoyt C. Hottel (MC 544), Institute Archives and Special Collections, MIT Libraries, Cambridge, Massachusetts (hereinafter referred to as Hottel Papers).

17. This "all-solar" aspect was indicated in many of the press reports referenced below, as well as in Katharine Van Etten Lyford, "Solar Magic in Your Home," in *The Journal of the Boston BPW (Business and Professional Women's Club)* (December 1949): 368–370, 379.

18. "World's First Sun-Heated Home," *Life*, 2 May 1949, 90, 93.

19. See, for example, Timothy Mitchell, *Carbon Democracy: Political Power in the Age of Oil* (New York: Routledge, 2011); and the special issue on "Oil in American History," *American History* 99, no. 1 (June 2012). An early iteration is David Painter, *Oil and the American Century: The Political Economy of US Foreign Oil Policy, 1941–1954* (Baltimore: Johns Hopkins University Press, 1986).

20. Harold Ickes, "We're Running Out of Oil!" *American Magazine*, December

1943, 38.

21. See Harold Barnett, *Energy Uses and Supplies, 1939, 1947, 1965* (Washington, DC: U.S. Department of the Interior, 1948).

22. Palmer Putnam, *Power from the Wind* (New York: Van Nostrand, 1948); and Richard H.K. Vietor, *Energy Policy in America since 1945: A Study of Business Government Relations* (New York: Cambridge University Press, 1984). The latter details Truman administration experiments with liquefying shale.

23. Fairfield Osborn, *Our Plundered Planet* (New York: Grosset and Dunlap, 1948); and William Vogt, *Road to Survival* (New York: W. Sloane, 1948). See also Thomas Robertson, "Total War and Total Environment: Fairfield Osborn, William Vogt and the Birth of Global Ecology," *Environmental History* 17 (April 2012): 336–364.

24. These texts and the discussions that surrounded them are a precursor to the neo-Malthusianism of the 1970s. See Donatella Meadows et al., *Limits to Growth: A Report for the Club of Rome's Project on the Predicament of Mankind* (New York: Universe Books, 1971).

25. "Family Utopia: The Dreams of 1946," *Life*, 25 November 1946, 58–59. See also Beatriz Colomina, *Domesticity at War* (Cambridge: MIT Press, 2007); and Greg Castillo, *Cold War on the Home Front: The Soft Power of Midcentury Design* (Minneapolis: University of Minnesota Press, 2010).

26. Andrew Shanken, *194X: Architecture, Planning and Consumer Culture on the Home Front* (Cambridge: MIT Press, 2009), 69.

27. Esther McCoy, "*Arts and Architecture* Case Study Houses," in *Blueprints for Modern Living*, ed. Smith, 21.

28. The best known of these analysts today is M. King Hubbert, whose theory of "Hubbert's Peak," or peak oil, was optimistic about the coming age of "water power and solar radiation." M. King Hubbert, "Energy from Fossil Fuels," *Science* 109, no. 2823 (4 February 1949), 103–109.

29. Eugene Ayres, "Major Sources of Energy," in *Addresses and Reports Delivered at the Twenty-Eighth Annual Meeting* (New York: American Petroleum Institute, 1948), 109–144.

30. Eugene Ayres, "Windows," *Scientific American*, February 1951, 65.

31. See "A Portfolio of Modern Houses: George Fred Keck, Architect," *Architectural Forum* 82, no. 9 (September 1942): 75–79; and Daniel A. Barber, "Tomorrow's House: Passive Solar Housing in the 1940s," *Technology and Culture* 55, no. 1 (forthcoming).

32. Maria Telkes, "Solar House: Solar Heat Collection through South Windows and Flat Plate Collectors in Relation to the Heat Load in Cambridge," October 1945, 12, in box 71, Papers of Maria Telkes, Solar Energy Collection, Arizona State University Archives and Special Collections (hereinafter referred to as Telkes Papers); and Maria Telkes, "Solar Heat Storage," 7 February 1947, in box 71, Telkes Papers.

33. Telkes, "Solar House," 15.

34. "File Memo on Solar Energy Project: Domestic Dwelling Project," in box 27, Hottel Papers. Initial plans called for building multiple buildings to more effectively explore the architectural components of these variables.

35. Telkes, "Solar House," 7.

36. George R. Harrison, "Report on the Solar Energy Project under the Godfrey L. Cabot Fund," 25 May 1953, 7, in box 43, MIT Office of the President Records, Solar Energy Fund (AC 4), Institute Archives and Special Collections, MIT Libraries, Cambridge, MA. The director of the fund, Hoyt Hottel, would later complain, "Dr. Telkes has, since her separation from our subcommittee activity [in 1947] been highly critical of the MIT program. She makes an excel-

lent impression on people who do not have to work with her, and has a wide circle of influential acquaintances impressed with her enthusiasm for solar heating and her apparent intelligence." Hottel to Harrison, 29 April 1953, 5, in box 15, Hottel Papers.

37. Hoyt Hottel, memorandum, "Solar Meeting—July 23 and August 4, 1947," 5 August 1947, in box 27, Hottel Papers; and memorandum from Anderson to Dietz, Hottel, Telkes, and Witherell, 27 November 1946, in box 27, Hottel Papers.

38. Telkes concluded her 1945 report on solar heat storage in *Heating and Ventilating* in May 1947 by proposing, "the architectural design of the house should harmonize with the [panel] shape factor, heat load, and solar energy absorbing requirements." Maria Telkes, "Solar House Heating: A Problem of Heat Storage," *Heating and Ventilating* 44, no. 5 (May 1947): 12–17; 17.

39. Eleanor Raymond, *Early Domestic Architecture of Pennsylvania* (New York: Helburn, 1931). See also Kevin D. Murphy, "The Vernacular Moment: Eleanor Raymond, Walter Gropius, and New England Modernism between the Wars," *Journal of the Society of Architectural Historians* 70, no. 3 (September 2011): 308–329; and Nancy Beth Gurskin, "Building Context: The Personal and Professional Life of Eleanor Raymond, Architect (1887–1989)" (Ph.D. diss., Boston University, 1998), 157–160.

40. According to Gurskin, Raymond and Peabody met at the Cambridge School of Architecture and Landscape Architecture for Women, where Raymond was a guest critic and Peabody a student. One of Raymond's early modern designs was an art studio for Peabody, built in 1933. She built sixteen commissions for Peabody from 1933 to 1972. Gurskin, 232.

41. Raymond to Telkes, 25 July 1947, in box 79, Telkes Papers. See also Telkes to Raymond, 20 June 1947, in "Dover Sun House" folder, Eleanor Raymond Collection, Frances Loeb Library Special Collections, Harvard Graduate School of Design (hereinafter referred to as Raymond Collection).

42. Maria Telkes, "Sun Wall Chemical Heat Storage," n.d., n.p., in Raymond Collection.

43. Eleanor Raymond, "Architectural Problems in the Solar Heated House at Dover, Massachusetts," in *Space Heating with Solar Energy: Proceedings of a Course-Symposium Held at the Massachusetts Institute of Technology, August 21–26, 1950*, ed. Richard W. Hamilton (Cambridge: MIT/Bemis Foundation, 1954), 97.

44. Maria Telkes and Eleanor Raymond, "Storing Solar Heat in Chemicals—A Report on the Dover House," in *Heating and Ventilating*, November 1949, 79.

45. Raymond to Peabody, 11 December 1950, in Raymond Collection; and T.P. Walsh, Manager, Pittsburgh Plate Glass, to Raymond, 13 April 1953, in Raymond Collection.

46. Maria Telkes, "Confidential Report for Eleanor Raymond: Summer Cooling of the Dover House," 28 September 1948, in Raymond Collection. See also "Heat Wave Tests the Solar House," *New York Times*, 31 July 1949, 9.

47. Peabody to Raymond, n.d. [1952], in Raymond Papers; and memorandum from Mr. Monroe to Raymond, "Confirming Yesterday's Decisions," 23 June 1954, in Raymond Collection. See also Lester Grant, "Sun Heated Home Ready for Test through Winter near Boston," *New York Herald Tribune*, 16 September 1948, 1, 17; and A. Nemethy, "Heated by the Sun," *American Artisan*, August 1949, n.p.

48. Frances Burns, "Sun-Heated House Gets Real Furnace," *Boston Globe*, 17 February 1954. See also Gurskin, 170. Burns's article suggests that the problem was living space and not heating effectiveness: the "new, conventional

furnace was installed," she writes, "because the tenants wanted upstairs rooms finished for use."

49. See, for example, John Kobler, "Like Living in Macy's Window," *Saturday Evening Post*, 24 September 1949, 154–161; "Test House Heated Only by Solar Heat," *Architectural Record*, March 1949, 136–137; Waldemar Laempffert, "Tapping the Mightiest of Power Plants," *New York Times*, 2 April 1950, 19, 33–34, 36–37, 39; Eric Hoidgins, "Power from the Sun," *Fortune*, September 1953, 130–135, 184–194; "Storing Solar Heat in Chemicals—A Report on the Dover House," *Heating and Ventilating News*, November 1949, 79–86.

50. Gurskin, 155; and Doris Cole, *Eleanor Raymond, Architect* (Philadelphia: Art Alliance Press, 1981), 111.

51. "Centennial Awards Luncheon," in *Centennial of Engineering: History and Proceedings of Symposia* (Chicago: Museum of Science and Industry, 1953), 26.

52. Hartley E. Howe, "A Furnace in Your Attic," *Popular Science*, March 1949, 112.

53. See Robert A. Poteete, "Sun's Rays Heat House for Second Winter," *New York Herald Tribune*, 25 April 1950, 11. See also Beatriz Colomina, "The Exhibitionist House," in *At the End of the Century: One Hundred Years of Architecture*, ed. Richard Koshalek and Elizabeth A.T. Smith (Los Angeles: The Museum of Contemporary Art, 1998), 126–155.

54. Henry-Russell Hitchcock and Arthur Drexler, *Built in USA: Post-War Architecture*, exh. cat. (New York: Museum of Modern Art, 1953).

55. Arthur Drexler, "Post-war Architecture," in *Built in USA*, 37. Johnson's solar house was the subject of Richard Pratt, "As Simple as That," *Ladies Home Journal* 62, no. 7 (July 1945): 118, and was featured, as were a number of houses from the journal, in the exhibition Tomorrow's Small House: Models and Plans at MoMA, May 29–September 30, 1945, and in Elizabeth Mock and Richard Pratt, *Tomorrow's Small House: Models and Plans*, exh. cat. (New York: Museum of Modern Art, 1945).

56. Mock and Pratt, 6. See also David Smiley, "Making the Modified Modern," *Perspecta* 32 (2001): 39–54; and Barber, "Tomorrow's House."

57. Maria Telkes, "Space Heating with Solar Energy," in *Proceedings of the United Nations Scientific Conference on the Conservation and Utilization of Resources: Volume III* (Lake Success, NY: United Nations Department of Economic Affairs, 1950), 215–218. Telkes's claims were supported by an Israeli scientist who reported the increased thermal capacity of walls that had been built with Dead Sea salt, a compound chemically similar to some that Telkes had been testing (217).

58. A.M. Rosenthal, "U.S. Seeks to Harness Sun, May Ask Big Fund, Krug Says," *New York Times*, 27 August 1949, 1, 4; and Ayres to Telkes, 10 September 1949, in box 10, Telkes Papers.

59. Painter, 186.

60. President's Materials Policy Commission, *Resources for Freedom: Summary of Volume I of a Report to the President* (Washington, DC: U.S. Government Printing Office, 1952), 2–4.

61. *Resources for Freedom*, 2.

62. The term *alternative energy* was used to introduce a symposium on solar energy research at the University of Wisconsin in 1954. See Farrington Daniels and John Duffie, eds., *Solar Energy Research* (Madison: University of Wisconsin Press, 1955), 13.

63. *Resources for Freedom*, 54. As the *New York Times* summarized, "the problem of materials—at least under a free enterprise system—is essentially a

problem of technology." "Commission Releases Report on Materials," *New York Times*, 6 June 1952. See also Editorial, *Wall Street Journal*, 9 June 1952.

64. After UNSCCUR, Telkes's first attempt to get further funding involved an application to the Bemis Foundation—an independent foundation housed at the MIT School of Architecture and Planning—and the Housing and Home Financing Agency's (HHFA) division of housing research. Raymond was indicated as a consulting architect. Institutional obstacles at MIT—including a lack of support from the Solar Energy Fund—prevented the proposal from even being submitted to HHFA. See Maria Telkes, "Tentative Research Proposal, Prepared on the Basis of a Suggested Outline by the Housing and Home Finance Agency Division of Housing Research," 5 June 1950, in box 1, Telkes Papers.

65. Maria Telkes, "Proposal for the Organization of an Institute for Scientific Research and Development in the Use of Solar Energy (Solar Energy Research Institute)," 18 September 1951, 5, in box 1, Telkes Papers. See also A.W. Fisher Jr., "Economic Aspects of Algae as a Potential Fuel," in *Solar Energy Research*, ed. Daniels and Duffie, 185–189, which describes a project on algae growth being supported by Arthur D. Little.

66. Telkes, "Proposal," 9.

67. Telkes, "Proposal," 5 (emphasis in original).

68. Ruben P. Mendez, "United Nations Development Programme," personal website of Charles Lerche, http://www.javvo.com/colerche/UNDP_000.htm. See also the discussion of technical assistance in Paul N. Edwards, "Meteorology as Infrastructural Globalism," *Osiris* 21 (2006): 241–244. Telkes's position was in line with a broader reconfiguration of the ends of scientific research after the war, much of which centered on Roosevelt's and Truman's scientific adviser Vannevar Bush—whom Telkes befriended when the two were both at MIT in the early 1940s. See, for example, Vannevar Bush, *Science: The Endless Frontier: A Report to the President* (Washington, DC: U.S. Government Printing Office, 1945); and Vannevar Bush, *Modern Arms and Free Men: A Discussion of the Role of Science in Preserving Democracy* (London: W. Heinemann, 1950).

69. Frank Fisher, *Technocracy and the Politics of Expertise* (London: Sage, 1990), 57.

70. Robert E. Wood, *From Marshall Plan to Debt Crisis: Foreign Aid and Development Choices in the World Economy* (Berkeley and Los Angeles: University of California Press, 1985), 114. Wood refers to this as "strategic non-lending." See also W.W. Rostow, *Eisenhower, Kennedy and Foreign Aid* (Austin: University of Texas Press, 1985), 90. In 1955 the Foreign Operations Administration became the International Cooperation Administration and a branch of the State Department. Technical assistance elements were written into the Baghdad Pact and the Mutual Defense Pact, both signed in 1955.

71. See Dwight MacDonald, *The Ford Foundation: The Men and the Millions* (1954; New Brunswick, NJ: Transaction Publishers, 1989), which notes the tenfold increase in the capital of the Ford Foundation in the early 1950s. See also Harvey Strum, "Eisenhower's Energy Policy," *The Public Historian* 6, no. 2 (Spring 1984): 38.

72. Dwight D. Eisenhower, "'Atoms for Peace' Address before the General Assembly of the United Nations on Peaceful Uses of Atomic Energy, New York City, December 8th, 1953," Dwight D. Eisenhower Presidential Library and Museum, www.eisenhower.utexas.edu/all_about_ike/speeches/atoms_for_peace.pdf.

73. See Ira Chernus, *Eisenhower's Atoms for Peace* (College Station: Texas A&M University Press, 2002); and John Krige, "Atoms for Peace, Scientific Internationalism, and Scientific Intelligence," in *Global Power Knowledge:*

Science and Technology in International Affairs, ed. John Krige and Kai-Henrik Barth (Chicago: University of Chicago Press, 2006), 17.

74. David Z. Beckler, "Memorandum on World Solar Energy Project" from the Executive Office of the President, Office of Defense Mobilization, 18 June 1954, in box 44, Hottel Papers. Beckler was a special assistant to the president and scientific liaison.

75. Beckler, "Memorandum," 4. The memorandum proposes that the U.S. support a UN solar energy program for the following six reasons, all of which pertain to the elaboration of solar energy as an ideal form of technical assistance: first, "it would continue to identify the United States with world peace and prosperity," especially if the United States formed such a program before the USSR did; second, "it would initiate work in a field where large and small nations are on equal footing, where there is no monopoly of energy resources, and where there are no direct military applications"; third, "it would fall within the technical capabilities of most countries"; fourth, an international solar energy laboratory would provide a "working demonstration of peaceful international cooperation"; fifth, "the under-developed areas of the world are blessed with the largest amounts of solar energy"; and sixth, "the unique possibilities of solar energy in further satisfying man's need for food, clothing, and shelter present a goal which the entire world could be expected to pursue with vigor and enthusiasm" (4).

76. Maria Telkes, "Projects Suggested to New York University," 8 May 1953, 2–5, in box 75, Telkes Papers.

77. *Annual Report: NYU College of Engineering* (1955), 16, in box 75, Telkes Papers.

78. *Annual Report* (1955), 17.

79. See John G. Harlan, Assistant Director, Office of Industrial Resources, Foreign Operations Administration, to Telkes, 20 April 1955, in box 12, Telkes Papers; and report from Telkes to Harold K. Work, Director of the Research Division at NYU College of Engineering, 27 April 1955, in box 12, Telkes Papers.

80. Telkes to A.J. Ronk, International Cooperation Administration, 2 June 1958, in box 24, Telkes Papers.

81. *Annual Report: NYU College of Engineering* (1957), 41, in box 75, Telkes Papers.

82. *Annual Report: NYU College of Engineering* (1958), 30, in box 75, Telkes Papers.

83. See Arthur Gagliotti, executive director of UNESCO, to Telkes, 28 January 1957, in box 22, Telkes Papers, asking her to take a position in Egypt focused on improving access to water.

84. The house's cooling system was based on a technique that Telkes had proposed for the Dover house. See Telkes, "Summer Cooling of the Dover House," n.p.

85. The phrase "propped up" was applied to the Dover house by the director of the MIT Solar Energy Fund, Hoyt Hottel, during the discussion of Telkes's presentation on the house at a conference at MIT in 1950. See Maria Telkes, "Performance of a Solar Heated House at Dover, Massachusetts," in *Space Heating with Solar Energy*, ed. Hamilton, 96.

86. That technological developments are "the product of heterogeneous contingency" is proposed in Wiebe E. Bijker and John Law, "General Introduction," in *Shaping Technology/Building Society: Studies in Technological Change*, ed. Wiebe E. Bijker and John Law (Cambridge: MIT Press, 1992), 3. On phase-change materials today, see, for example, K. Darkwa et al., "Phase-Change Drywall in a Passive Solar Building," *Applied Energy* 83, no. 5 (May 2006): 425–435.

87. See Mitchell, 144–145. See also Ervand Abrahamian, “The 1953 Coup in Iran,” *Science and Society* 65, no. 2 (2001): 185–215.

88. Andrew Barry, *Political Machines: Governing a Technological Society* (London: Continuum, 2001), 7.

89. Felix Trombe, “Development of Large Scale Solar Furnaces,” in *Solar Energy Research*, ed. Daniels and Duffie, 169–175.

90. *Proceedings of the World Symposium on Applied Solar Energy* (Menlo Park, CA: Stanford Research Institute, 1955).

91. Unesco, foreword to *Wind and Solar Energy: Proceedings of the New Delhi Symposium* (Paris: Unesco, 1956), 9. See also United Nations Department of Economic and Social Affairs, *New Sources of Energy and Economic Development: Solar Energy, Wind Energy, Tidal Energy, Geothermic Energy, and Thermal Energy of the Seas* (New York: United Nations Publications, 1957).

92. *Solar 2: Proceedings of the United Nations Conference on New Sources of Energy, with an Introduction by Steve Baer* (Seattle: Cloudburst Press, 1978). Steve Baer had designed his own solar house in 1971 and founded Zomeworks in the early 1970s. He wrote the *Dome Cookbook* and the *Zome Primer*, two popular handbooks for counterculture architects of the 1970s. According to Andrew Kirk, Baer ascribed his interest in solar energy to reading documents from the 1950s solar energy discourse described in the present article. See Andrew G. Kirk, *Counterculture Green: The Whole Earth Catalog and American Environmentalism* (Lawrence: University of Kansas Press, 2007), 151–153; Steve Baer, *Sunspots: Collected Facts and Solar Fiction* (Albuquerque, NM: Zomeworks, 1977); and Felicity D. Scott, *Architecture or Techno-Utopia: Politics after Modernism* (Cambridge: MIT Press, 2007), 157–175.

93. Unesco, *Use and Conservation of the Biosphere* (Paris: UNESCO, 1970). On Stockholm, see Peter Stone, *Did We Save the Earth at Stockholm?* (London: Earth Island, 1973); and Rene Dubos and Barbara Ward, *Only One Earth: The Care and Maintenance of a Small Planet* (New York: W.W. Norton, 1972). A more recent critical analysis can be found in Felicity D. Scott, “Woodstockholm,” in *Sensible Politics: The Visual Culture of Nongovernmental Activism*, ed. Meg McLagan and Yates McKee (New York: Zone Books, 2012), 397–427.

94. The Brandt Commission report was submitted to the House of Commons in the U.K. in 1980, and later published as the Brandt Commission, *Common Crisis North-South: Cooperation for World Recovery* (Cambridge: MIT Press, 1983). For the Bruntlandt report, see World Commission on Environment and Development, *Our Common Future* (New York: Oxford University Press, 1987); for the Earth Summit in Rio, see *The Global Partnership for Environment and Development: A Guide to Agenda 21* (Geneva: United Nations Conference on Environment and Development, 1992). The Intergovernmental Panel on Climate Change (IPCC) was established in 1988 and has submitted to date four “Assesment Reports,” with a fifth expected in 2014.

95. For an early analysis of the failings of this managerial premise, see Donald Worster, “The Shaky Ground of Sustainability,” in *Global Ecology: A New Arena for Political Conflict*, ed. Wolfgang Sachs (London: Zed Books, 1993), 132–145. See also Timothy Luke, “Environmentality as Green Governmentality,” in *Discourse of the Environment*, ed. Eric Darier (Malden, MA: Blackwell, 1999), 121–151. Broader analyses of the tensions between sustainability as a managerial regime and environmentalism as a social movement can be found in Joan Martinez-Alier, *The Environmentalism of the Poor: A Study of Ecological Conflicts and Valuation* (Northampton, MA: Edward Elgar, 2002). A related architectural case study is described in Panayiota Pyla, “Planetary Home and

Garden: Ekistics and Environmental-Development Politics," *Grey Room* 36 (Summer 2009): 6–35.

96. The phrase "business as usual" is used here in reference to one of the better known models for technological solutions to climate change in S. Pacala and R. Socolow, "Stabilization Wedges: Solving the Climate Problem for the Next 50 Years with Current Technologies," *Science* 305, no. 5686 (13 August 2004): 968–972. Pacala and Socolow's model was later updated and popularized in Al Gore's film *An Inconvenient Truth* (2006).

97. Mohsen Mostafavi, "Why Ecological Urbanism, Why Now?" in *Ecological Urbanism*, ed. Mohsen Mostafavi (Cambridge: Harvard University Graduate School of Design and Lars Muller, 2010), 17. Mostafavi uses this phrase in contrast to the opportunity to refocus the field toward the ecological potential of "speculative design innovations."