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ESSAY: DANIEL A. BARBER

Hubbert's Peak, Eneropa, and the Visualization of Renewable Energy

AMO, *Map of Eneropa*, 2009.

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More Bio >>

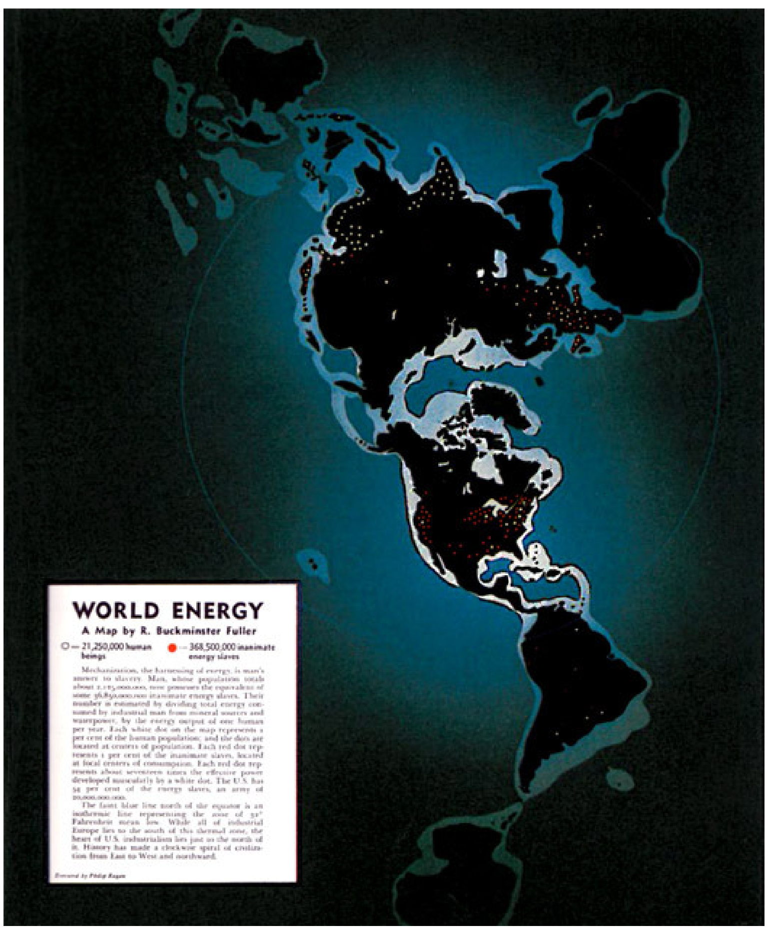
I.

In the summer of 2009, the research branch of the Office for Metropolitan Architecture, known as AMO, submitted a report to the European Climate Foundation titled "Eneropa." As part of the Foundation's *Roadmap 2050: A Practical Guide to a Prosperous, Carbon-Free Europe*, AMO had been commissioned to create the "graphic narrative" that would help communicate the extensive technical, economic and policy analyses performed by the Climate Foundation's consulting firms. AMO's contribution redraws the map of the continent according to method of energy generation: in northwest Europe there is "Geothermalia"; "Solaria" stretches across the Mediterranean south; the U.K. becomes the "Tidal States" and the Baltics become "Biomassburg"; North, West, East and Central "Hydropia" hug the mountain regions. Not only do the names and divisions on this new map toy with geopolitical histories — most potently in the CCSR (Carbon Capture and Storage Republics) written across the former CCCP/USSR; each region is also fancifully represented with the mechanisms of a new energy technology. A blanket of solar panels, for example, is strewn across the rooftops of Barcelona. As AMO partner Rainer de Graaf noted, Eneropa, by suggesting "the complete integration and synchronization of the EU's energy infrastructure," shows how "Europe can take maximum advantage of its geographic diversity towards a complementary system of energy provision ensuring energy security for future generations."

Given that it is the work of a leading architectural practitioner — and despite Koolhaas's and OMA/AMO's well-known predilection for irony — the Eneropa project warrants our attention for what it reveals about how the profession has responded to current pressures on our energy system. We can extract two points from Eneropa which are relevant to the history of energy in architecture, and which also underscore what is now at stake. First, over the last century or so, the design fields have become an important *discursive site* for debating and thinking about environmental complications, and about energy in particular. This is in part because these professions are concerned with the formal and physical practicalities of the built environment — such as global flows of materials and energy — and in part because of the strong disciplinary tradition of projecting a design concept into a future scenario. Architects have frequently been enlisted, as in Eneropa, to envision future conditions based on research from diverse fields — including economics, policy analysis, energy forecasting — and to think creatively about environmental change.

Second, Eneropa is of interest because of what it tells us about the *disposition* of images and ideas used by designers to represent environmental change. In presenting the project, de Graaf argued that, despite the redrawn political boundaries, "the most shocking part of [Eneropa] is how incredibly unshocking it is. Everything that moves is the same and still moves. Only the things that make the things move have all completely changed. It's a situation where everything changes and at the same time nothing changes." Even conceding some ironic self-positioning, De Graaf's explanation exemplifies a broader trend in architectural strategies that aim towards efficiency: that energy systems will, through carefully applied technological innovations, be reconstructed in such a way that we almost won't notice the difference. Daily life will stay the same: *nothing changes*. Or, still more pointedly, Eneropa suggests that in order for *the social fabric to remain intact*, dramatic changes are needed in *techno-scientific relations to the natural world*. One could look at any number of recent "green" buildings to see a similar emphasis on technological innovation as the primary means by which our environmental problems can be mitigated.

Which raises the question: What other dispositions are available, relative to the relationship between architecture, energy and environmental change? To some extent, AMO's approach to complex environmental problems has been placed in historical perspective through recent examinations of the experimental practices of the 1970s. Here as well, architectural proposals and projects operated as a discursive arena for wide-ranging explorations of emergent environmental knowledge. In houses made of earth and detritus; in the premise of systems autonomy and self-reliance; and in the interest in participatory design and community development, the design fields were key participants in '70s debates about environmental change. [1] And — in contrast to the AMO project — many designers of the period saw in technological innovations a new impetus for social transformations: for new ways of living, and for new individual and collective parameters for engaging with the resource base. [2] The countercultural diposition, in short, was that anticipated energy scarcity could be managed through new forms of social organization. [3] If Eneropa is based upon the assumption of technological dynamism, much of the work of the '70s is rooted in a faith in socio-cultural dynamism.



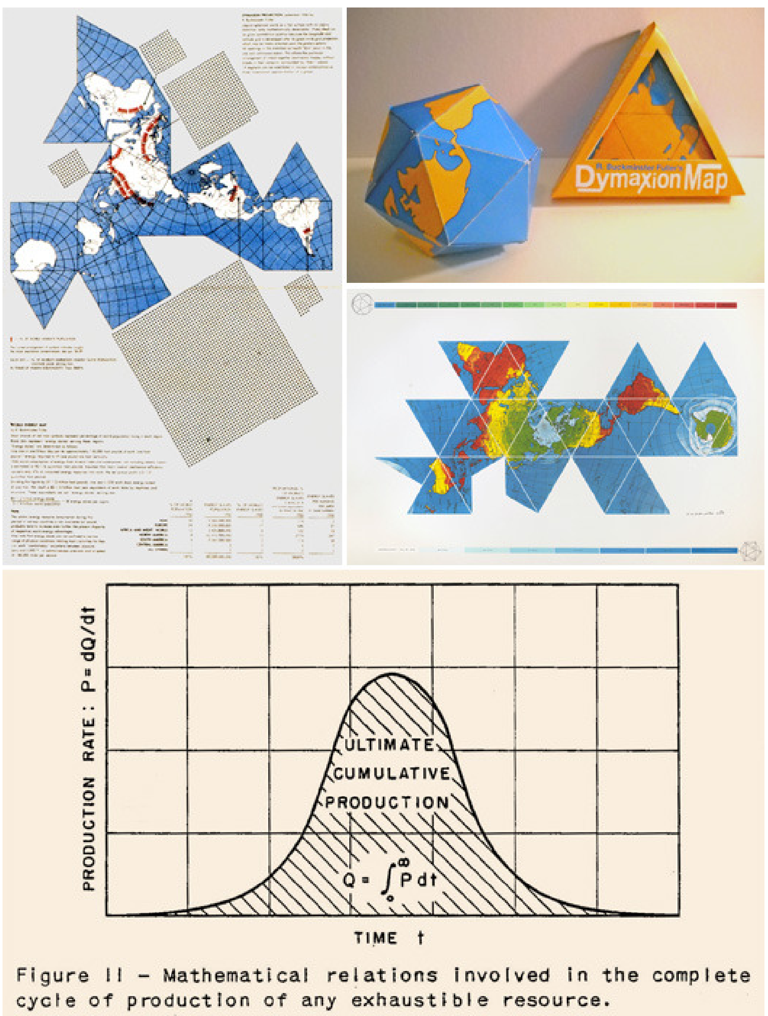
R. Buckminster Fuller, "World Energy," in *Fortune*, February 1940.

II.

My interest here, then, is to describe how historical patterns of visualizing energy can be read as evidence of broader cultural dispositions towards environmental change. In particular, given my premise that the design disciplines constitute an important site for discussing energy futures, we can begin to construct a deeper history of the creative visualization of renewable resources, and can read the various visual materials —maps, charts, systems diagrams and house designs, among others — as attempts to reveal the complicated nexus of social formations, resource availability and technological possibility.

The energy maps of R. Buckminster Fuller, for example, can be understood as a significant precursor to AMO's Eneropa. From 1936 to 1942, Fuller served as the "science and technology" consultant to *Fortune*, and in this capacity he produced a number of maps illustrating global energy uses and supplies. The "World Energy" map of 1940 operated as an early proposal for reading the ecological footprint of social and industrial activities: Fuller placed population distribution (in white dots) relative to what he termed "inanimate energy slaves" (in red dots) to indicate that energy use per capita correlated to uneven cultural, political and geographic conditions. [4] The map also suggested that the amount of energy being used far exceeded regionally available resources, and further that the United States, and in particular the East Coast, was the most egregious offender.

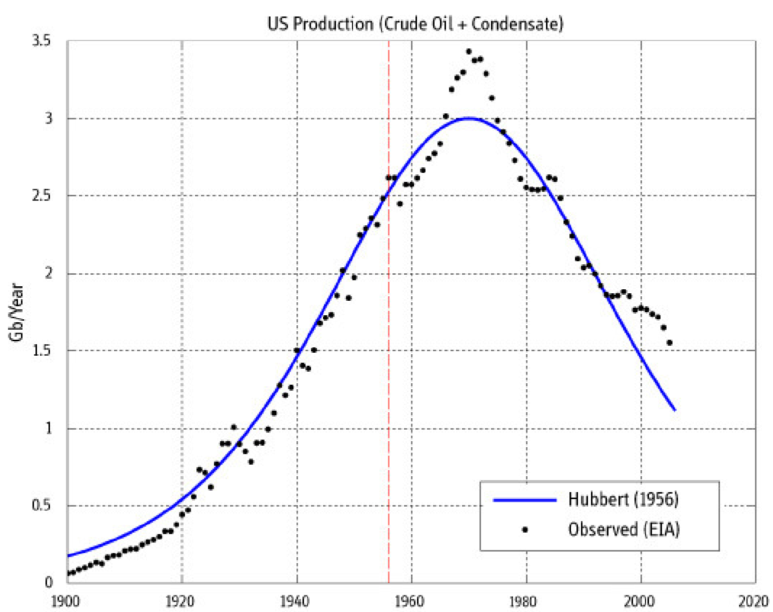
Even more compelling than the maps themselves, Fuller's images are symptomatic of a broad-based concern about how to provide adequate energy in the postwar decades. While the period after World War II is often seen as one of endless abundance, it was in fact a time of intense debate. Immediately after the war, the global energy system was in disarray. [5] Policy makers, economists, corporate researchers and others in the U.S. were concerned about declining output from domestic oil and coal reserves that had been depleted by military mobilization. The extent of Middle East oil fields was not yet widely known — and for political and technological reasons, their output was not yet available to American markets. [6] Fuller's concern about the geopolitical dynamics of energy contributed to a much wider inquiry into how to reconstruct the global economy so as to mitigate the uneven distribution of resources, to optimize emergent technologies, and to negotiate complex geopolitical tensions. Along with Fuller, many analysts saw a window of opportunity to reconsider the global dynamic between energy, technology and social systems. [7] Prominent research projects and government reports explored how to prepare for different futures with varying degrees of energy availability. The initial goal was to gather relevant data and visualize trends in supply.



Top left: R. Buckminster Fuller, "Conservation of Resources" Dymaxion Map, in *Life Magazine*, September 1943. Top right: Informational piece about Fuller designed by Elysse Van Fleet, 2010; and Fuller, et al., *Dymaxion Air-Ocean World*, with land and water temperatures, 1961. Bottom: Hubbert's Peak, from M. King Hubbert, "Nuclear Energy and the Fossil Fuels," presented at a meeting of the American Petroleum Institute, 1956.

Thus in the postwar years a new field emerged: energy forecasting, focused on analyzing current and historical data to predict the needs and supplies of the future. [8] Today the best known of these forecasters is M. King Hubbert, a research scientist who worked at the Shell Oil Company, in Houston, from 1943 to 1964. Hubbert first presented his theory of "peak oil" (also known as Hubbert's Peak) in a 1949 paper "Energy and the Fossil Fuels," published in *Science*. Extrapolating from the slow decline of production in the southwestern U.S., Hubbert proposed that it was possible to predict with some precision the moment at which the cost of energy extraction would exceed the market value of the energy thus extracted. By determining the "mathematical relations involved in the complete cycle of production of any exhaustible resource," he was also able to generalize about resource patterns, and to predict future availability. [9] Hubbert's bell curves indicated that the decline in "economic availability" of a resource would be gradual, and would more or less mirror its rise, thereby allowing time to prepare for energy transitions.

While Hubbert's characteristic curve ended with an arrow pointing down, and was rooted in the expectation of depletion, his rhetoric was optimistic. In the postwar reconsideration of energy, technology and social possibilities, the focus was not on imminent collapse of the energy regime but rather on how to estimate, on a long time scale, the number of years available for research into other sources. Which is to say the apparent decline of fossil fuel availability was seen, by Hubbert and others, as an opportunity to develop new sources and to encourage new ways of living. Indeed, in 1948 Hubbert referred to the current moment as a "pip" in "human affairs"; he saw reliance on fossil fuels as a historical aberration and the postwar complications as a spur to explore more reliable means of energy generation. Thus, while the lines on Hubbert's charts may have appeared apocalyptic, with their steep downward trajectories, what was really at stake were the specific angles of the trajectories, and the social and technological innovations through which the period of prosperity could be extended. [10]

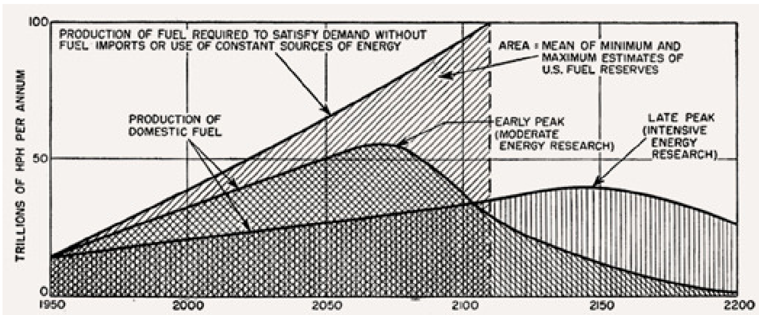


Comparison of Hubbert's curve with observed data from the U.S. Energy Information Administration. [Graph by S. Foucher, 2007]

These days Hubbert's research is widely known — to a large extent because his predictions that the U.S. would reach "peak oil" in the early 1970s are seen by some to have been borne out; but the most prominent energy forecaster of the period was Eugene Ayres. A scientist employed by the Gulf Research and Development Company, Ayres was an expert on oil exploration methods; he was also a strong advocate of alternative energies, and, even more than Hubbert, viewed the eventual decline of fossil fuels as an impetus to research new systems. Asked to address the American Petroleum Institute at its annual meeting in 1948, Ayres presented a paper on "Major Sources of Energy," which was soon photocopied and distributed to all Institute members, including many in government. [11]

"Major Sources of Energy" had three themes: first, an analysis of global resources; second, an assessment of the economics of resource extraction that differentiated between non-renewable and renewable sources; and third, an argument that a shift to renewable resources should be understood as a moral obligation even before it became an economic necessity. On the first point, Ayres presented one of the most comprehensive data analyses of global resources to date, summarizing the research on predicted depletion and paying careful attention to shifts in orders of magnitude as expected global population increases caused demand to rise. [12] He analyzed fossil fuels and other mineral sources, including uranium, on the basis of both extractive efficiencies and relationships to end use, and was forthright about his misgivings that these fuels would suffice to meet future needs.

Ayres's most influential innovation was to contrast this pessimistic assessment of fossil fuels with the endless possibilities then anticipated from explorations in wind, solar and water energy. He argued for a distinction between "capital" sources — in essence, those resources buried deep in the ground such as coal and oil — and "income" sources, such as solar and wind, which, once harnessed by new technologies, would provide boundless energy. Income sources, Ayres proposed, would offer a return on investment that was categorically different from capital sources: technological innovations would lead not to an increase in time-to-depletion — i.e., a slight extension of the declining curve — but rather would enable reliable sources indefinitely — an arrow pointing ever upwards. [13] The "host of technologists working constantly on problems of power production, transmission, and utilization," he wrote, "should focus their efforts on income sources." [14] Many heeded Ayres's injunction: government and corporate entities began to assess their research programs with attention to the capital-income distinction, and numerous research projects were launched to explore wind, solar and geothermal power. [15]



Eugene Ayres, "Some Possibilities In Our Future Energy Picture," *Energy Sources — the Wealth of the World*, 1952.

Though economic benefits were the chief measure of the capital/income distinction, Ayres was explicit as well about the implications for the future of civilization. As his third theme, Ayres argued that the development of renewable resources was nothing less than the philosophical baseline for the application of human intelligence to the challenge of energy supply and demand. He asserted that technological engagement with income sources would indicate a triumph of human ingenuity far beyond the laborious and destructive extraction of stored carbon. Echoing Hubbert, Ayres wrote: "This tiny period of earth's life, 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." [16] Like Hubbert, Ayres valued renewable resources not only for their potential to mitigate imminent crises but also for their long-term potential to enhance the quality of civilization. [17]

In the end, the historical significance of the analyses of Hubbert, Ayres, et al., was not so much for their specific projections — calculated, as we now know, with inadequate data about the extent of global fossil fuel reserves — but rather for their insistence that the postwar alarm about decreasing capital resources was a call to strengthen the economic and social institutions related to energy provision. The mid-century discourse hummed with this notion that scarcity — and the need to explore income sources — was at heart a test of human civilization. It was marked by a profound sense of hope — hope that some combination of technological ingenuity and social adaptation would lead not only to new routes beyond depletion, but also to unforeseen benefits for social and cultural production. [18]

III.

As in the case of Eneropa, decades later, so too in the mid-century years architecture was widely seen as an exciting realm in which to play out various conceptions of the energy future. What would a society look like in which energy from the sun, wind and sea were endlessly available? "The eventual depletion of fossil fuel," Ayres wrote, in a 1951 article exploring innovations in solar house heating, "will not be disastrous. On the contrary, for our children's children the dreams of our architects and engineers will come true — communities of people who live in comfort without combustion." [19] Not surprisingly, the interest in architecture was pragmatic — the use of solar energy for house heating, both passive and active, was a readily available application of income sources. But it was also relevant to the growth of the postwar suburbs — not only by reinforcing the leitmotif of the self-reliant household but also by emphasizing the importance of the open plot configuration, which allowed for control over solar orientation and thus for maximized absorption of radiation. [20]

During and right after the war, hundreds of solar houses were built across the United States, most using passive radiation to reduce heating load. Typically these designs featured a narrow plan and an all-glass façade, in order to allow solar rays to penetrate deep into the house in the winter, and also a carefully designed overhang, in order to deflect the summer heat. Cement floors and masonry partitions operated as thermal storage, absorbing daytime heat for release at night. This "solar house principle" was celebrated in industry journals such as *Architectural Forum* and *Progressive Architecture*, popularized in the *Ladies Home Journal* and other consumer magazines, and exhibited at the Museum of Modern Art in 1946. [21] A series of solar houses based on active technology was developed by researchers at MIT between 1947 and 1959, and a competition to design a solar house was held in 1959; the competition was sponsored by the Stanford Research Institute and the Association for Applied Solar Energy, and the jury included Pietro Belluschi, Thomas Creighton (editor of *Progressive Architecture*) and Nathaniel Owings of SOM. Across these various venues, solar houses were designed by leading architects such as Louis Kahn, Philip Johnson, Carl Koch, Serge Chermayeff, Vernon de Mars, Paolo Soleri, Marcel Breuer, and TAC; meanwhile the general appellation "solar house" was used in the popular press for virtually any building with a glazed southern facade.

Top: MIT Solar House III, 1948; in *The Saturday Evening Post*, September 1949. Middle left: Ray Pioch, "Sun Furnace in Your Attic," *Popular Science*, March 1949. Middle right: Maria Telkes and Eleanor Raymond, Dover Sun House, 1948; in *Life Magazine*, April 1949. Bottom: George Fred Keck, house in *Ladies Home Journal*, July 1944.

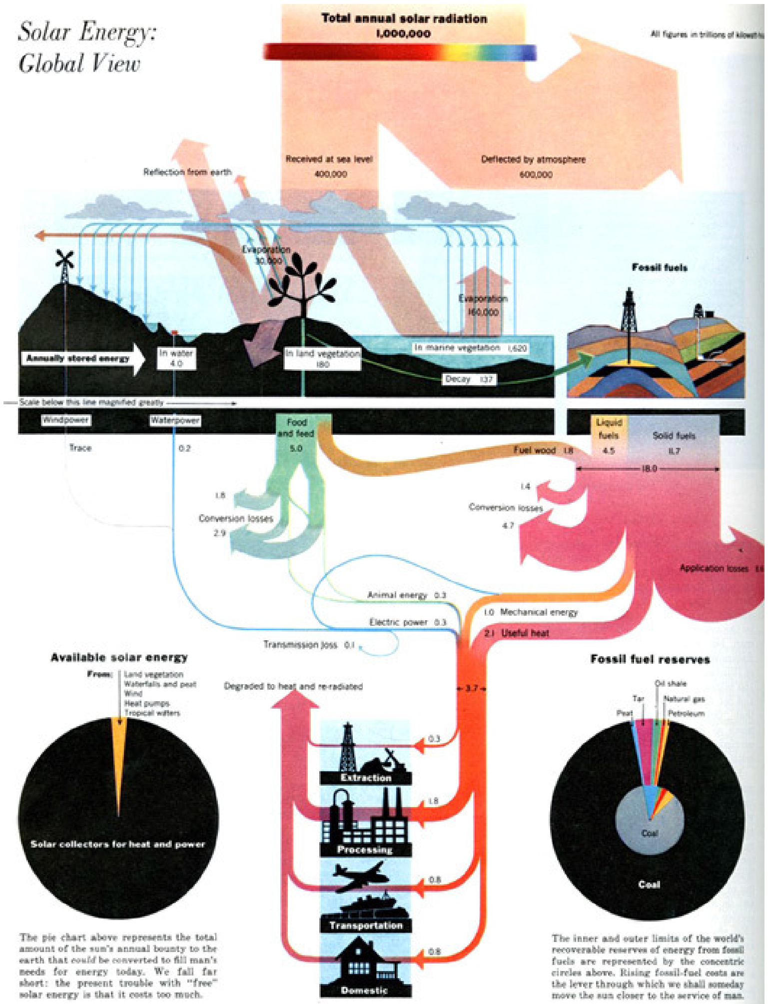
Though they struggled to balance innovation and cost, and in some cases strained to articulate an architectural vision conducive to maximizing solar radiation, solar houses nonetheless came to embody the prospect of a new and wide-open future — a future in which the growth of economies did not rely on the depletion of resources, but rather was rooted in the interconnected ambitions of energy efficient designs, changing social values, and new arrangements of the population across the national landscape. A 1949 article in *Popular Science* celebrated some of these houses, and proclaimed that while advances in solar technology "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." [22] The cover of the magazine showed a family happily enjoying a winter afternoon in the living room while the sun — clean, free, efficient — heats the house. Based on one of the MIT experiments, this image suggested that the emerging territorial, material and formal organization exemplified by the single-family suburban dwelling could mitigate the specter of energy scarcity without any need for dramatic adjustments in life patterns. To be sure, the featured house was far from ordinary. On the one hand, it seemed to indicate, as in Eneropa, that life under a different energy regime would continue as before; on the other hand, with its prominent "sun furnace in the attic," the new dwelling strongly implied that if the "dreams of our architects," as Ayres had put it, were to be fulfilled, then the transformation towards energy efficient design would need to infuse cultural and political discourse.

IV.

These solar houses, however, were not especially effective — the sun furnace illustrated in *Popular Science* only worked for about four years, and it demanded continual maintenance. And, as Ayres noted in 1952, this first wave of solar experimentation was "overwhelmed by the flood of oil now coming out of the ground" in the Middle East and Venezuela. [23] Diplomatic and military efforts, aided by the nascent Central Intelligence Agency, had secured access to foreign petroleum for the U.S. and its allies, and as a result the angles of the declining trajectory of fossil fuel availability, while still pointing down, seemed to extend endlessly into the future.

Still more significant for the present discussion is the *image* economy that began to circulate as alternative energy was further developed. Although the practical advantages of the solar house were to some extent nullified by the newly discovered oil, what did persist was the conviction that the exploration of income energy was as much a moral imperative as an economic necessity. An article in *Fortune* in September 1953, with a lengthy quote from Ayres as an epigraph, made this clear. Written by Eric Hodgins, an editor at the magazine, "Power from the Sun" surveyed recent solar experimentation; to spark interest in income technologies, it looked not only at developments in house heating and in the direct conversion of solar energy to electricity but also at innovations in using solar energy to produce cultured algae as a cheap food source, to render salt water potable, and to power irrigation pumps.

Hodgins's article also signaled a change in the visual presentation of energy futures. In a full-page graphic entitled "Solar Energy: Global View," the illustrators at *Fortune* created an ambivalent image of the potential of solar radiation. Although the illustration indicated the importance of the sun's rays for planetary life, Hodgins intimated that *direct use* of the sun for daily human needs was compromised by a "strange socio-industrial lethargy." "The future world that does capture solar energy," he wrote, "is not likely to be a straight-line projection of our present highly urbanized US factory-system economy." [24] Among other ramifications, Hodgins was interested in how solar technologies could be used to manage U.S. influence in the developing world; or more precisely, he saw the developing world as a site for energy experiments which, he predicted, would ultimately help save the industrialized economies from themselves.

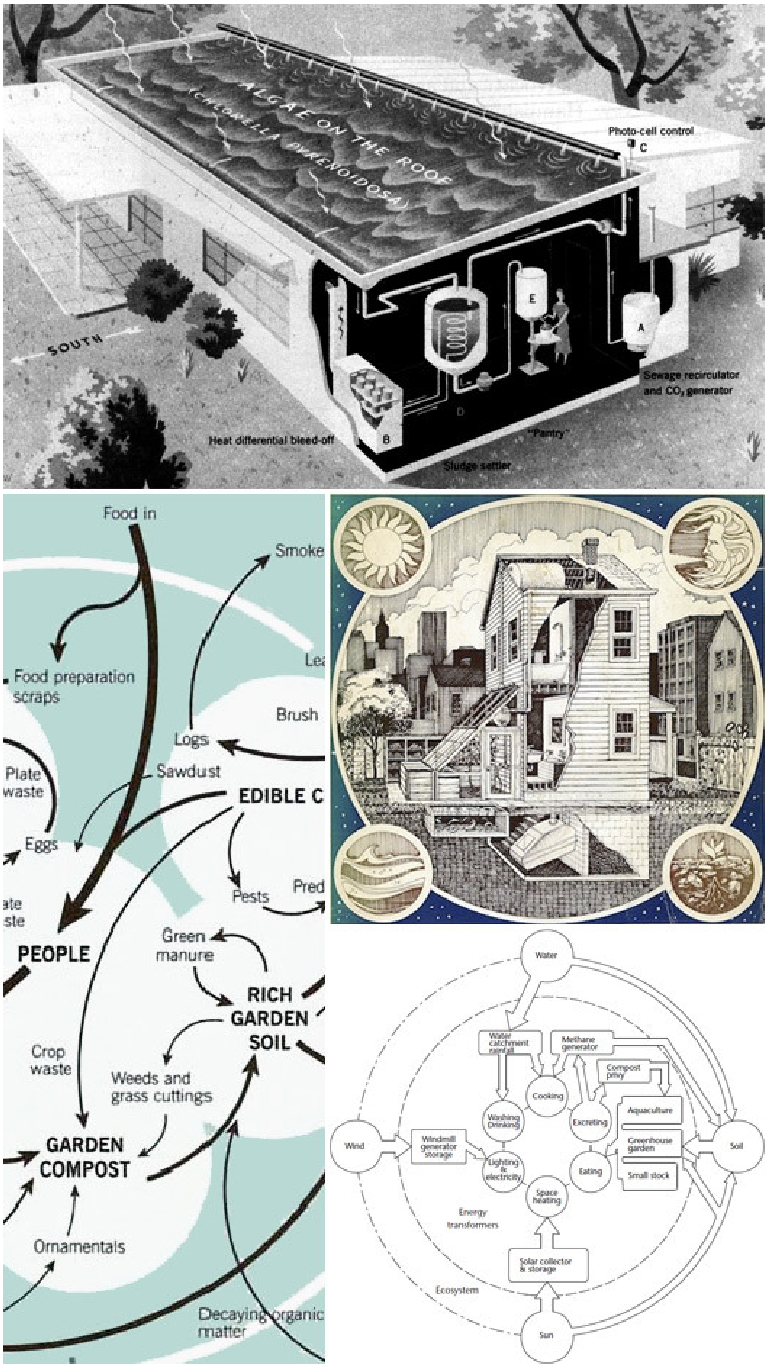


Max Gschwind, "Solar Energy: Global View," illustration from Erik Hodgins, "Power from the Sun," *Fortune*, September 1953.

Hodgins was familiar with these energy experiments, and with their implications for economic development policy. From 1951 to '52, he had served on Harry S. Truman's President's Resource Policy Commission, which worked to analyze "the combined material requirements and supplies of the entire free non-Communist world," as well as the relevant government policies and corporate practices. [25] The commission's report, *Resources for Freedom*, was edited by Hodgins and published in five volumes in February 1952. Exemplifying the broad interest in alternative energy before the consolidation of the oil infrastructure, the report proposed that "direct utilization of solar energy" was "the most important contribution technology can make to the solution of the materials problem"; Hodgins and the other commissioners saw this "utilization" as necessarily global, and inflected by the evolving relationship between political alliances and economic growth in the industrializing world. [26]

The single-family house remained a key element of these reconceived energy futures, even as the promise of those futures was being re-interpreted across an uneven global economic landscape. In an offset panel on the fourth page of Hodgins's "Power from the Sun" article, there was a drawing of a simple bar-shaped house — similar to the solar houses mentioned above, with south-facing windows and an extended roof overhang — which was captioned "A Not So Utopian Future." While the basic principles of solar heating were implicit, the point was to demonstrate that the house also "utilizes solar radiation to grow its own food, in the form of algae on its roof, on the assumption that the day is coming when population will make wheat fields and cattle ranges luxuries of the dear dead past"; other benefits, such as water re-use and methane as a power source, were also illustrated. [27] In other words, the house was a stand-alone support system for a family of four, in a fashion that prefigured much of the survivalist ecology of the 1970s — from Sim van der Ryn's Integral Urban House to John and Nancy Jack Todd's Bioshelters, to the New Alchemy Institute's Ark and Brenda and Robert Vales' Autonomous House — and that treated the building as a closed system, with waste being recycled as input for other systems. [28]

The arrow of civilization's future was here pointed in many directions. Hodgins's "Not So Utopian Future" placed the visualization strategies we have been reviewing in a revealing light. Not only are the physical dynamics of solar energy rooted in a cyclical pattern; so too are the technological processes of a self-contained living environment: waste becomes nourishment, "developing" countries of the south offer solutions to the "overdeveloped" countries in the north. Then and now, attempts to further exploit fossil fuels only serve to delay an inevitable turn to a more dynamic system — extending the curve of decline, before we must, collectively, find other ways of living. While the exploration of the closed system — as the basis for global, national and domestic energy economies — was further developed by architects in the 1970s, its connection to this larger cycle of historical growth or decline has largely been lost. As in Eneropa, the visualization of systems-based economies of energy use and supply have mostly eschewed the larger social and cultural opportunities, opting instead for technological solutions that claim little relevance to social change.



Top: Antonio Petruccelli, "A Not So Utopian Future," illustration from Erik Hodgins, "Power from the Sun," *Fortune*, September 1953. Bottom left: Center for Alternative Technology, *Life Cycle Diagram*, c. 1977 (redrawn 2007), detail. Bottom right: Sim van der Ryn, et al., *The Integral Urban House*, 1977, cover and illustration "Energy Flow in a Closed Habitat."

Currently, informed opinion differs widely regarding the extent of economically feasible fossil fuel reserves. Many agree that Hubbert's prediction — that the United States would reach peak oil in the early 1970s — has come to pass; nonetheless, the potential of new extraction technologies has extended the downward slope of the bell curve ever farther into the future. Deep-sea drilling in the Gulf of Mexico and off the coast of southern Brazil has opened up new reserves to exploit; widespread fracking is influencing the technological and geopolitical debates about energy independence. But these innovations have given rise to other concerns — today sophisticated forecasters attempt more aggressively than ever to integrate the economic costs and benefits of an energy source with its potential to cause environmental degradation. Concern about climate change has led to new matrices for evaluating the relative benefits of any particular energy system.

But still, we might recall that six decades ago Eric Hodgins ended his *Fortune* article with an echo of Ayres's and Hubbert's determined optimism: "There is more than one way of saving ourselves from the future." Today, design experimentation aims to render the arrow of resource decline ever more dynamic — not only through exploiting new energy sources or using existing supplies more efficiently, but also through inserting an integrative socio-technological dimension into the overall project of environmental building design, one concerned not only with advancing technological possibility but also with facilitating social movements that can encourage new ways of living.

Editors' Note

"Hubbert's Peak, Eneropa and the Visualization of Renewable Energy" is adapted from a chapter in *Architecture and Energy: Performance and Style*, edited by William Braham and Daniel Willis, published this month by Routledge. It appears here with the permission of the publisher, editors and author.

For related content on Places, see also Accidents Will Happen: Lessons on Honey, Smoked Pig Fat, Atomic Disaster and the Half-Life of Truth, by Steven Boyd Saum; Visualizing the Ends of Oil, and Illuminating the Petrochemical Landscape, by Mark Feldman; Thirsty City, by Austin Troy; Colstrip, Montana, by David T. Hanson; and New Fuel for an Old Narrative: Notes on the BP Oil Disaster, by Richard Campanella.

Notes

1. A survey of these strategies has been collected in a recent exhibition and catalogue organized by the Canadian Centre for Architecture: see G. Borasi and M. Zardini, eds., *Sorry, Out of Gas: Architecture's Response to the 1973 Oil Crisis* (Montreal: Canadian Centre for Architecture, and Montova, Italy: Corraini Edizioni, 2007). Many other recent publications have begun to consider the experimentation of the 1970s in conditioning current interest in architecture and energy.

2. On the mid-century scientific discourse concerning harmony, chaos and other states of ecological change, see M. G. Barbour, "Ecological Fragmentation in the Fifties," in W. Cronon, ed., *Uncommon Ground: Rethinking the Human Place in Nature* (New York: Norton, 1996), 233-256. For the premise of natural limits, see D. 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); for a discussion of the roots of these issues in the discussions of the 1950s, see T. Robertson, "Total War and Total Environment: Fairfield Osborn, William Vogt and the Birth of Global Ecology," *Environmental History* 17, April 2012, 336-364.

3. For an example of integrations of technological and social possibility, see G. Boyle and P. Harper, *Radical Technology: Food, Shelter, Tools, Materials, Energy* (New York: Pantheon, 1976). On broader terms, Amory Lovin's *Soft Energy Paths* argues against nuclear power in part on the premise that it limits possibilities of social change in the future. See A. Lovins, *Soft Energy Paths: Towards a Durable Peace* (New York: Harper, 1977).

4. "World Energy: A Map by R. Buckminster Fuller [executed by Philip Ragan]" *Fortune* 21:2, February 1940, 7. Fuller's interest in visualizing the dynamic between energy and population was an inspiration for the famous dymaxion map, a more aggressive attempt to "bring home" to *Fortune*'s readers the impact their behaviors can have on the broader resource condition.

5. Recently, historians have begun to reassess the postwar period with energy concerns in mind. The most effective rethinking is T. Mitchell, *Carbon Democracy: Political Power in the Age of Oil* (New York: Routledge, 2011); see especially chapter 5: "Fuel Economy," 109-144. Postwar energy politics are also a primary concern in J.R. McNeill and C. R. Unger, eds., *Environmental Histories of the Cold War* (New York: Cambridge University Press, 2010). See also the foundational work of David Painter, especially D. Painter, *Oil and the American Century: The Political Economy of US Foreign Oil Policy, 1941-1954* (Baltimore: Johns Hopkins University Press, 1986).

6. Of the seven billion barrels of oil used by the allies from 1942 to 1945, six billion came from the United States, mostly from the Gulf Coast. See H. Ickes, "War and Our Vanishing Resources," *American Magazine*, Dec. 1945, 18-23; C. D. Goodwin, "The Truman Administration: Towards a National Energy Policy" in Goodwin, ed., *Energy Policy in Perspective: Today's Problems, Yesterday's Solutions* (Washington: The Brookings Institution, 1981), 1-63; and A. E. Eckes, Jr., *The United States and the Global Struggle for Minerals* (Austin: University of Texas Press, 1979), 120.

7. See A. Barry, "Technological Zones," *The European Journal of Social Theory* 9:2, 2006, 239-253.

8. One of the first postwar forecasts was produced by a Harvard PhD student in economics working at the Department of the Interior. See H. Barnett, *Energy Uses and Supplies, 1939, 1947, 1965* (Washington: U.S. Department of the Interior, 1948). Barnett would later co-write an influential text resisting the basic premise of resource scarcity: H. Barnett and C. Morse, *Scarcity and Growth: The Economics of Natural Resource Availability* (Baltimore: Johns Hopkins University Press and Resources for the Future, 1963).

9. M. K. Hubbert, "Energy from Fossil Fuels," *Science*, Feb. 1949; see also A. Lovins, et al., *Winning the Oil Endgame* (Snowmass, CO: The Rocky Mountain Institute, 2004).

10. Much of this work from the 1940s and '50s was summarized in M. K. Hubbert, "Exponential Growth as a Transient Phenomenon in Human History," *Other Issues*, 1976, 75-87. By this time Hubbert had achieved some renown, as his prediction that domestic oil reserves would reach their "peak" around 1970 appeared to have been accurate.

11. Ayres's paper was the basis for E. Ayers and C. A. Scarlott, *Energy Sources: The Wealth of the World* (New York: McGraw-Hill, 1952).

12. E. Ayres, "Major Sources of Energy" (Washington: American Petroleum Institute, 1948).

13. E. Ayres, "International Fuel Economy" in *Annals of the American Academy of Political and Social Sciences*, vol. 281: "The Future of our Natural Resources" (May 1952): 73-78; 75.

14. Ayres, "Major Sources," 112.

15. A number of relevant research projects are mentioned in R.H.K. Vietor, *Energy Policy in America since 1945: A Study of Business Government Relations* (New York: Cambridge University Press, 1984). Vietor foucses on attempts to extract liquid fuel from coal and shale, but he describes as well the broader interest in alternatives. It is worth noting that until the 1960s, nuclear energy was also considered an "alternative source" and was subject, as has been well documented, to intense efforts to develop its commercial viability. See B. Podobnik, *Global Energy Shifts: Fostering Sustainability in a Turbulent Age* (Philadelphia: Temple University Press, 2006).

The capital/income distinction was also a major preoccupation of a three-week long conference sponsored by the United Nations, called the UN Scientific Conference on the Conservation and Utilization of Resources, held in the fall of 1949. See *Proceedings: United Nations Conference for the Conservation and Utilization of Resources* (5 volumes) (Lake Success, NY: UN Department of Economic Affairs, 1949). For a discussion of Ayres' influence, see C. N. Gibboney, "The United Nations Scientific Conference for the Conservation and Utilization of Resources," *Science* 110:2869, Dec, 1949, 675-678.

16. Ayers and Scarlott, *Energy Sources*, 279.

17. Ayres, "Major Sources," 109.

18. Such peripheral benefits were also a major basis for interest in solar energy in the 1970s, as summarized in a well-known essay by Langdon Winner from 1980. He proposed that the energy benefits of solar power were secondary to the social benefits of decentralization, and the "salutary institutions [that decentralization] is likely to permit in other areas of public life." See L. Winner, "Do Artifacts Have Politics?" *Daedalus* 1:9, Winter 1980, 121-136.

19. E. Ayres, "Windows," *Scientific American*, February 1951, 60-65; 65.

20. On the confluence of architecture, energy and the suburbs, see Christine Macy and Sarah Bonnemaison, *Architecture and Nature: Creating the American Landscape* (New York: Routledge, 2003).

21. D. Barber, "The Solar House Principle: Architectural Experimentation and Infrastructural Engagement in the US, ca. 1946," *Delft Architectural Studies on Housing*, 7 (2012), 18-32.

22. H. E. Howe, "Sun Furnace in Your Attic," *Popular Science*, March 1949, 107-112; 112.

23. Ayres, "International Fuel Economy," 74.

24. Eric Hodgins, "Power from the Sun," *Fortune*, 43:9, September 1953: 130-135, 184-188, 190-194. Ayres was referred to as "brilliant and learned" and taken to be the last word on the subject of solar energy's potential. Hodgins was also the author of *Mr. Blandings Builds his Dream House* (1946), a satire of a New York couple attempting to work with an architect on their weekend house, which was turned into a popular movie in 1948.

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

26. *Resources for Freedom*: Summary, 54.

27. This "not so utopian future" was based on an article from the June 1953 issue of the British journal *Research*; Hodgins quoted extensively from the article, in which the author, a German scientist named Hans Gaffron, described his vision: "The algae cultivated on the flat roof of a somewhat extended ranch house could provide all of the protein and some of the carbohydrate for the family living below … this house should have a roof slightly inclined to the south. A steady stream about two-inches thick of a deep green algal suspension would be pumped over the roof. The carbon dioxide needed to charge the suspension might be derived from the burning of the family's garbage." Hodgins, "Power from the Sun," 134-135.

28. See Sim van der Ryn, *Integral Urban House* (San Francisco: Sierra Club Books, 1979); John and Nancy Todd, *Bioshelters, Ocean Arks, City Farming: Ecology as the Basis for Design* (San Francisco: Sierra Club Books, 1984), which summarizes the Todd's work with the New Alchemy group; Brenda and Robert

Vale, *Autonomous House: Design and Planning for Self-Sufficiency* (London: Thames and Hudson, 1975) and the collection of interviews in *What do We Use For Lifeboats When the Ship Goes Down?* (New York: Harper and Row, 1976).

29. Hodgins, "Power from the Sun," 194.