in J. Byrne and D. Rich, eds. (1986)
The Politics of Energy Research and Development. New Brunswick, NJ:
Transaction Books. Vol. 3 in the
Energy Policy Studies Series.

In Search of the Abundant Energy Machine

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U.S. energy research and development policy has been remarkably consistent. While the political economy of energy has changed dramatically in recent decades and government energy programs have experienced significant budgetary fluctuations, national R&D policy has exhibited a nearly uniform technological preference. This consistency has resulted from the convergence of specific values and institutional conditions that have provided the framework for energy R&D policy over the past four decades. Among these, three have been of special significance. First, energy R&D has been inspired by and has sought to emulate the government's programs for weapons development during and after World War II. Second, the objective of R&D policy has been energy abundance rather than energy efficiency. Third, the evaluation of energy options and R&D allocations has been confined by a self-sealing logic of technical determinism.

Together, these values and institutional conditions constitute the normative architecture for U.S. energy R&D policy. That policy may be summarized as a search for an abundant energy machine: one which would sustain the availability of cheap energy supplies delivered by large-scale centralized institutions in a manner responsive to the demands of a high-consumption society. The prototype has been and remains nuclear power.

The Triumph of Technoscience

National R&D policy is a mid-twentieth century phenomenon. It was born out of wartime experience with weapons technology and nurtured by the postwar infusion of government resources in support of scientific and technological programs. Between the start of World

War II and the mid-1960s, the federal government spent nearly $175 billion on research and development activities. It was an event, Harvey Sapolsky points out, that was frequently taken to signal the passage of a major historical watershed. "The event's significance can be most closely compared to that of the Enclosure Acts, which transformed England into the first industrialized nation. The United States, because of the structural consequences of the government's conscious promotion of scientific and technological progress, is seen as moving beyond the societal stage of industrialization" (Sapolsky, 1975: 80). The precise nature of this transformation has been widely debated. A substantial portion of the science policy community has seemed convinced, however, that government activism in support of research and development is the leading indicator of a new era of scientific and technological prominence in social affairs. In this regard, Sanford Lakoff has pointed to the gradual evolution towards a Scientific Society: a society in which scientific understanding is both a principal measure and a key stimulus of progress. Science would become recognized as the "endless frontier," the "new property," offering incentives and opportunities to rival the stimulus historically afforded by open spaces and expanding markets. Scientists would emerge as an influential and enlightened new estate in the shaping of public affairs. Government would accept its responsibility as the patron of a scientific culture. In sum, knowledge would become power (Lakoff, 1964: 55-58; Bush, 1945; Price, 1965).

The vision of an emerging Scientific Society has offered a convenient frame of reference for interpreting the government's increased role in research and development. It does not, however, adequately identify the values and expectations that have shaped R&D policy over the past four decades. The investment of hundreds of billions of dollars in research and development is less indicative of an admiration and respect for science as a source of knowledge than an enthusiasm for large-scale technology as an instrument of national power and a confidence that with sufficient will and ample financial and organizational resources such technology can be delivered on demand. "The key intellectual commitment" according to Richard Nelson, "is the focus on a particular kind of resource-manpower with advanced formal training in the basic and applied sciences, and its employment in a particular kind of activity - organized research or development consciously aimed at achieving certain kinds of knowledge or technological capabilities" (1977: 58). Without doubt, the boundaries between basic and applied research and the interrelationship between science and technology are ambiguous and have been continuously debated. What is clear, however, is that the impetus and intent of government R&D policy has largely been to develop technologies to achieve specific national goals rather than provide general support for science. The guiding vision has been one of technological instrumentality on a grand scale: a search for the right machine.

The orientation towards research and development that arose out of the federal weapons research programs during World War II has not changed substantially over the succeeding four decades. The wartime experience, particularly the Manhattan project, established the policy link between public investment in R&D and the maintenance of national security. The vast majority of postwar investments in R&D have been intended to maintain and extend that policy link. In effect, R&D policy has been an adjunct of national security policy. Thus, Sapolsky points out that 85 percent of federal support for research and development activities in the quarter century since the war were devoted to programs to meet an external challenge (1975: 85). This condition and its implications are nowhere more apparent than in the case of energy research and development. The government role in energy R&D arose directly out of military interests, was expanded in response to the Cold War, gained urgency over the last decade to combat a perceived foreign challenge to reliable and cheap energy supplies, and continues to be conceived as a policy to protect American interests in a period of "global insecurity" (Yergin and Hildebrand, 1983).

In the decades following World War II, energy R&D was nuclear R&D. As Hewlett and Dierenfield point out, "the federal role in developing energy technologies other than nuclear in the 1950s and 1960s was minuscule" (1983: xii). The military significance of nuclear energy research and development has meant that it has enjoyed a substantial portion of the total federal R&D budget with, until recently, little necessity of substantive justification. Henry Lambright notes that at "the outset of the 1970s, 86 percent of all federal energy R&D funds that had been spent since World War II had gone to [the Atomic Energy Commission]" (1976: 33). Massive investment in nuclear technologies took place during decades when, as Nelson notes, there was no perception of energy crisis, or even of impending hard times regarding the price and availability of conventional fuel"; "the 1965 study *Energy R&D and National Progress,* which was undertaken with the express purpose of identifying sources of concern, reached the conclusion that significant shortages of conventional fuels, or sharply rising costs of extraction, were not likely in this century" (1977: 116). After the oil embargo of 1973-74 abruptly changed the energy forecast, support for nuclear research and development continued to dominate the government's energy R&D budget. Such dominance cannot be explained by nuclear's contribution to meeting U.S. energy needs now or in the foreseeable future. Indeed, firewood supplied more energy in 1980 than all civilian nuclear sources (Guerra, 1981: 20). Over the past five years, nuclear's contributions as an energy source have remained minor. Despite this, nuclear technologies continue to receive by far the largest share of government support for energy R&D. Approximately 70 percent of the Department of Energy's budget is now devoted to nuclear programs, with 40 percent dedicated to military applications (Congressional Budget Office, 1984: 31-40). This fact constitutes dramatic evidence of the military mindset that has continued to shape U.S. R&D policy in general and energy policy in particular. To paraphrase Sapolsky, the direction of energy R&D policy might best be labeled "the ballistic missile solution" to the energy crisis.

The Manhattan Project set the pattern for energy R&D programs in the decades ahead. Christopher Hill has suggested that one manifestation of that pattern has been the enormous influence granted physicists over the direction of government-sponsored R&D because of their successes in the development of weapons technologies. One result has been to promote the physicists' vision of "what constitutes good research as the touchstone of quality in other fields" and to encourage the perpetuation of high energy physics as an almost singular model for effective R&D (1985: 11). Experience in a domain of research and development which is certainly distinctive, if not unique, and which is most notable for its development of nuclear weapons, has emerged and persisted as the standard for determining the suitable subject matter and styles of federal R&D support. Energy R&D has always been dominated by the direct inheritance of nuclear power research and nuclear scientists. Even non-nuclear R&D has been characterized by periodic efforts to develop the right machine in the image of nuclear technologies (Rhodes, 1983). This situation has also resulted in a peculiar but common fascination with technological exotica and a parallel proclivity to regard the exotic as practical. As Barry Commoner has pointed out, there has been a curious inversion of expectations that has frequently accompanied the evaluation of energy alternatives in the R&D community. While solar energy, "the oldest energy source exploited by human society...was usually regarded as an impractical, exotic product," nuclear power, which is "the product of advanced science, and certainly an exotic way to boil water...was regarded as an unchallengeable, practical reality" (1979: 32).

While wartime experience served to establish nuclear physics as the substantive model for government R&D, its most significant influence lay elsewhere. As Don Price has argued, the most important discovery of wartime R&D was not scientific nor even technological in the sense of the actual "technical secrets" involved in radar and the atomic bomb. Rather, the key achievements were organizational, managerial and technocratic: the central lessons to be learned were in "the administrative system and set of operating policies that produced such technological feats" (quoted in Lambright, 1976: 23). What was seen as possible and replicable was the mobilization of manpower and money for the successful management of technological innovation on a scale that had few historical precedents. The chief lesson was that big achievements require big organizations to develop big technologies. The success of government R&D was thus seen as tied to technological and institutional scale.

Energy R&D has been dominated by large-scale programs that offer the promise of technological spectaculars, that involve billions of dollars in expenditures and casts of thousands, and that can only be managed effectively by large techno-bureaucracies, or what Lambright calls the "technoscience agencies" (1976). The institutional and technical dimensions of these scale conditions are reinforcing. On the one hand, the organizational manpower and funding patterns of large-scale R&D institutions can only be successfully accommodated to technological programs on a comparably monumental scale. On the other hand, large-scale technology programs would overwhelm the capacities of all but the largest "technoscience" institutions. Thus, for example, in the wake of the Arab oil embargo, arguments in support of the creation of a consolidated energy agency were predicated on the belief that only an overarching institution with ample and sustained funding could provide the direction for significant progress in energy research and development. The commonly identified models for such an institution were the established, mission-oriented technoscience agencies - the Atomic Energy Commission, NASA, and the Department of Defense.

Organizational and technological scale requirements have led to the rise of R&D systems whose sheer size and weight create institutional inertia. Such inertia determines the substantive focus of research and development and that focus in turn becomes progressively impervious to change. As Lambright puts it, "it is much easier to talk about redirecting R&D than it is to accomplish such a feat" (1976: 165). The nuclear program developed by the AEC is a prototype of a grand-scale technology program promoted and managed by a set of institutional arrangements that are insulated from review or change. In 1974, the bulk of this system was incorporated in the new Energy Research and Development Administration (ERDA). Part of the rationale was for this incorporation was the expectation that the well-established AEC infrastructure would provide the new agency with the scientific and technical talent, facilities and network of relationships to carry out its mission. As Hewlett and Dierenfield point out, ERDA inherited "the national system of government laboratories, university and private research institutions, engineering firms, equipment manufacturers, and electric utilities both public and private...[as well as]...the contract forms and other arrangements which the commission had devised over the years to define the role of the federal government and the place of industry in nuclear research and development" (1983: 52). Predictably, the scale and inertia of the AEC legacy largely dictated the direction of subsequent energy R&D policy. Built into ERDA and subsequently DOE was the AEC's institutionalized commitment to what constituted the right machine and how it was to be obtained. As Gregory Daneke has characterized it, "[e]nergy organization began as a tangent to the nuclear weapons development following the Second World War, and weapons remain DOE's stock and trade" (1984: 311). Advocates of alternatives to nuclear energy have found themselves overwhelmed by the magnitude of the nuclear program and the strength of its institutional support. At the same time, the institutional and technological characteristics of the nuclear program shaped the ways in which any alternative R&D programs were to be pursued.

The pattern of funding over the past decade clearly manifests this bias in energy R&D. Support for nuclear technologies continued to dominate the R&D budget. Programs for nonnuclear alternatives, such as the solar power tower experiments and the Synfuels program, were often fashioned to replicate the organizational scale and technological characteristics of nuclear R&D. Throughout the decade, support for R&D on energy efficiency options was dwarfed by investments in technologies designed to increase energy supplies. Even in the period of the late 1970s when the Carter administration and the Congress increased support for conservation and solar options, the United States was, as David Morell points out, "still basically pursuing a fuels supply policy, not one focused on energy conservation" (1981: 10). Over the past five years even rhetorical support for alternatives to large-scale production-oriented technologies has abated.

Energy R&D policy epitomizes government as a nonlearning system (Schon, 1971). The content and implications of policy have been systematically shielded from public evaluation. For decades, the commitment to nuclear technologies was officially exempted from open scrutiny. The magnitude and stability of this largely uncontested commitment resulted in a mobilization of technological bias that gradually became institutionalized as the most distinctive feature of the energy R&D policy environment. As a result, energy R&D policy has been to a significant extent a derivative policy; a by-product of institutional and technological inertia promoted and protected on grounds of national security and adapted to the needs of both the technoscience agencies and large-scale centralized systems of energy production and distribution. In this respect, the overall direction of energy R&D policy has been sustained by a pattern of nondecision making that is rationalized by the purported costs of any deviation from the current path.

Energy Myths and Megapower

The search for the abundant energy machine has been reinforced by a deeply rooted belief that energy consumption is an essential facet of social progress. As Amory Lovins has argued, underlying the contemporary evaluation of energy alternatives is the belief that "the more energy we use, the better off we are" (1977: 4). The source of this belief may be traced to what George Basalla calls the energy-civilization equation: a prevalent if often implicit assumption in Western societies over the past two hundred years that high and growing energy consumption is essential not only for physical comfort, economic well-being, and military strength, but for social, moral and intellectual achievement as well - in short, for the progress of civilization (1980: 40). In the U.S., the energy-civilization equation has seemingly been validated by recent historical experience in which growth in national wealth and energy consumption were apparently synchronous. From the vantage point of such experience, Barbara Ward has noted, a nation's wealth and its energy use are frequently two ways of saying the same thing (1977).

In the context of the energy-civilization equation, it is easy to understand why the energy events of the 1970s were seen to pose a crisis. It is also possible to recognize why policy proposals for energy conservation have frequently been greeted with skepticism. As Morell has pointed out, supply-oriented energy policies have been seen as "compatible with basic American myths and values, while conservation is seen as antithetical" (1981: 12). Reduced energy use, Basalla explains, generates apocalyptic visions of an American society in a downward slide from progress.

> We foresee a doomed civilization with tractors paralyzed in the fields, abandoned automobiles rusting on weed-choked freeways, factories as quiet as tombs, and our haggard descendants facing a life of everlasting drudgery...A retreat from rising energy consumption under those circumstances means far more than the minor discomfort of living in a warmer house in the summer and a cooler one in the winter, or driving a smaller car less frequently and more slowly. As less energy is available per capita the nation is thought to lose its standing among the world's civilizations (1980: 39,40).

Portrayals of conservation as nothing less than the progenitor of a New Dark Age have been moderated in recent years. It is no longer taken for granted that reduced energy consumption portends rapid economic collapse. Nonetheless, conservation continues to be undervalued as an energy alternative. The persistence of this condition, despite ample evidence of conservation's viability as an energy option, can be regarded as a measure of the strength of the energy-civilization myth. Precisely because it is a myth, it is largely impervious to the facts. It hardly matters that North Americans use nearly twice as much energy as the not exactly impoverished West Germans, and they in turn, about twice as much as the far from destitute New Zealanders (Ward, 1977); or that conservation has been responsible for meeting 70 percent of the new energy needs of the U.S. since the embargo (Lovins, 1983); or even that projections indicate that conservation is our least-cost supply alternative to the end of this century with a highly competitive price of $7 to $8 per barrel of oil equivalent saved (California Energy Commission, 1981). U.S. energy policies have consistently treated conservation as capable of, at best, a short-term, transient contribution along the main path to a new era of energy abundance delivered by a combination of market adjustments and large-scale technological breakthroughs. Thus, the 1983 and 1984 Reagan administration's budget proposals called for eliminating virtually all support for energy conservation R&D, while doubling funding for nuclear reactor research (Shapley et al., 1983). In the search for the abundant energy machine, conservation has been no match for megapower.

The energy-civilization equation is not the only myth that has guided our understanding of energy prospects and possibilities. Indeed, mythology has pervaded our expectations about energy. Since the industrial revolution, energy has frequently been portrayed as the essential catalyst of social organization and progress with, at times, heroic if not spiritual attributes. Odum and Odum, for example, proclaim energy as "the source and control of all things, all value and all the actions of human beings and nature" (1976: 1). Seen in this way, it is not surprising that energy sources have conventionally been invested with mythical qualities such that each new energy option has historically been characterized by a cycle of utopian aspirations followed by dashed hopes leading to a new generation of proposed energy utopias. As Basalla points out:

> [a]ny newly discovered source of energy is assumed without faults, infinitely abundant, and to have the potential to affect utopian changes in society. These myths persist until a new energy source is developed to the point that its drawbacks become apparent and the failure to establish a utopian society must be reluctantly admitted...At this point, one might suppose that society would emerge from its difficulties sadder but wiser and treat the next new energy source differently. Unfortunately this is not the case. The latest form of energy is not handled in a more restrained fashion. Instead, the recently discarded energy myths are resurrected and bestowed upon the newcomer. And so the cycle continues, with only the myths remaining unaltered while various sources of energy enter and leave the public spotlight (1982: 27-28).

The energy utopia cycle has meant that the advantages of new energy sources tend to be overestimated while the costs are underestimated and the obstacles to exploitation often ignored. The cycle began with the replacement of wood, the earlier "fuel of civilization" by coal, America's first "black gold," during the "age of steam" in the 19th century. It was apparent in expectations that the petroleum age and its related technologies would bring forth an "era as distinct and creative as that brought by steam" and change the face of America's social and physical landscape so as to bring the amenities of urban life within reach of all (quoted in Still, 1974: 390). It continued, with the boundless prospects associated with the electricity revolution beginning in the late 19th century and extending throughout the 20th century. It was carried forward in the 1930s and 1940s when hydropower was touted as "white coal," "clean coal" and "super power" that could produce energy "in its finest, even spiritual form - electricity" (Basalla, 1982: 31). And, it has been dramatically extended in recent decades by the expectation that nuclear energy, the ultimate source of megapower, would provide the final solution to energy scarcity.

Indeed, nuclear-generated electricity continues to be pronounced as the natural energy implication of postindustrial progress.

The energy utopia cycle has meant that each new pretender to the status of energy prominence must offer not only the prospect of inexhaustible abundance but also the promise that it will usher in a new and beneficent social age. Thus, for example, recent advocacy of a solar energy future has frequently been framed around utopian visions of a Solar Age that purportedly confirms solar's indisputable superiority over other energy options. Recent literature contains guarantees that a solar energy transition will bring forth all of the following: the triumph of democracy; the accommodation to human scale; the achievement of local self-determination; the return to material simplicity and self-reliance; and the maintenance of ecological harmony. Some advocates go even further and proclaim that the Solar Age will fulfill the "ultimate moral imperative," by expressing mankind's recognition and reverence for its fixed natural endowment and by embodying a responsibility to preserve that endowment for future generations (Rifkin, 1980: 259-260).

While the claims made for a solar future are often dramatic, solar remains a minor contender for the role of reigning energy utopia. That title goes indisputably to the Electric Society, and for all the misgivings expressed over the last decade, the key to the electric society is still nuclear energy. What fossil fuels meant to the process of industrialization, electricity is now understood to mean for a postindustrial future. Indeed, it has generally be taken for granted that a postindustrial society is an electric society and that nuclear generated electric power is the ultimate high-technology path to postindustrial progress. The power of the electricity mystique has been such that it has hardly been diverted by the growing recognition of nuclear energy's cost and risks. From the vantage point of postindustrial progress, the transition to a nuclear electric society may be acknowledged as more costly than previously anticipated, but all alternatives to proceeding on course are considered even more costly. For example, Peter Navarro argues that "GNP cannot grow at a rate much higher than the rate of increase in electricity supply...utility capacity is the locomotive of the American economy" (1983: 93). Navarro further asserts that it will take at least $350 billion in capital investment within a ten-year period to keep that locomotive moving; "just to keep the lights on and the economy growing" (1983: 87). In the context of the electricity mystique such an investment is simply a necessary price of progress. Recent advertisements of the U.S. Committee on Energy Awareness (the lobbying arm of the nuclear utility industry) typify the reasoning that the Electric Society transcends economic evaluation. The American public is warned that "a healthy national economy needs a secure supply of electric energy" and that nuclear electricity is our best hope for the future. Indeed, a link is drawn between expanded production of nuclear power and conservation of domestic energy resources, leading the committee to dub nuclear "the conservation fuel." The question is thus posed: "In a competitive world market where abundant energy is a must, can America afford to fall behind in the very technology we pioneered?" In the search for the abundant energy machine, no price is too great.

Technology and the Displacement of Politics

The energy-civilization equation and the myths of megapower reflect the dominant beliefs of a technocratic culture. The most significant of these is the belief that technology is the essential instrument of social progress and that the limits of technology are generally synonymous with the limits to progress. In this context, the fulfillment of U.S. energy needs has been conceived as a technological problem requiring a technological solution. It is this conception, even more than the specific interests served by technoscience, which has shaped the politics of energy R&D and constrained evaluation of energy prospects and possibilities. The search for an abundant energy machine has thus been sustained by a self-sealing logic that presumes technology to be the pacing element of social change and that defines progress as a succession of technofixes.

In some respects, the technocratic logic that has guided the politics of energy R&D may be seen as both justifiable and prudent. In Western societies, technological advance has indeed been a measure of social progress for at least two centuries. Moreover, there is an undeniable truth in the notion that ignorance of and nonadaption to the technological requisites of modern society will only court disaster. As Langdon Winner points out, "certain technical means stand at the very basis of human survival. Failure to provide for them is to invite discomfort, suffering and even death" (1977: 102). Beyond this, it must be admitted that the challenges of modern society typically arise in the context of technological change and that meeting such challenges entails a need to directly address their technological implications. Surely the energy crisis is such a challenge; to ignore its technical dimensions or the role of technology in its outcome would be, at best, foolhardy. An R&D policy that addresses the technological character of energy choice and seeks to expand the possibilities for choice may thus be judged essential. Indeed, the basic rationale for government R&D policy cannot be reasonably separated from recognition of the society's need to meet the technological challenges of the modern era.

The reasons cited to justify the technocratic logic guiding R&D policy also signal its threat. Precisely because technology can be recognized as essential to social existence, it is possible in contemporary society for it to be regarded as a type of moral standard. Technique, through its association with survival and comfort, furnishes root meanings of good and bad, necessary and unnecessary, appropriate and inappropriate (Ellul, 1964). Indeed, we regularly judge our social options according to various attributes of the technical means for bringing them about; "the rule of technological circumstances in the modern era does in fact supplant other ways of building, maintaining, choosing, acting and enforcing, which are more commonly considered political" (Winner, 1977: 237). In this sense, technology offers not merely a means for fulfilling an end but also a framework of moral and political judgments that defines social needs and possibilities. It is distinctive of a technological civilization that such moral and political judgments tend to be shielded from open evaluation precisely because they are framed in the context of technological instrumentality. Political choice is sealed *within* technical choice and as a result insulated from external standards of value and performance. Not just any political culture will do. As Ellul has argued, technique embodies its own rationale and demands to be evaluated on its own terms.

> [I]ndependently of the objectives that man pretends to assign to any given technical means, that means always conceals in itself a finality which cannot be evaded. And if there is a competition between this intrinsic finality and an extrinsic end proposed by man, it is always the intrinsic finality which carries the day...If we make use of technique, we must accept the specificity and autonomy of its ends, and the totality of its rules...Technique does not accept the existence of rules outside itself, or of any norm. Still less will it accept any judgment upon it. As a consequence, no matter where it penetrates, what it does is permitted, lawful, justified (1964: 141, 142).

The technological preemption of moral and political choice typifies the politics of energy R&D during the past four decades. Again, no case is more instructive than the promotion and development of nuclear power.

That nuclear power is essential to social progress and in this sense good for society was decided before its practicality as an energy source was determined and before the technical means to control it existed. Nuclear power did not surface to fill an immediate social need. No credible economic or energy reasons compelled the use of nuclear power. This is not to suggest that economic and other factors did not affect or even stimulate technological innovations in nuclear power. Rather, the point is that technology generally and nuclear technology specifically has, through its political standing in Western civilization, acted upon economic life as much or more than it has been acted upon. As Winner notes, the recognition of a moral and political character in technology does not deny the existence of economic or other forces. "It merely suggests that such factors may not be the overwhelmingly decisive ones. There is a sphere of vital concern that one misses if every question is reduced to categories of economics" (1977: 236).

In the case of nuclear power, economic justification was irrelevant to its initial promotion. Nuclear power was not the invention of enterprise; there was no market demand for it and there was no economic supply of it available prior to its institutionalization. As an energy source, nuclear power was not technologically available and could not be demonstrated when the U.S. undertook its promotion. An institutional framework for promoting nuclear power was initiated with the Manhattan Project, which brought together three of the most powerful institutions in American society - the military, large industry and technoscience - to create nuclear bombs. This apparatus was then authorized in 1946 by the U.S. Congress to deliver the peaceful atom, eleven years before the idea could be technologically expressed and seventeen years before the successful demonstration of the first turnkey plant. In effect, this society set about to discover and affirm the advantages of nuclear power and to discount its costs without any knowledge of its economic practicality and before the technical means to deliver it existed. The social desirability and technical viability of nuclear power were evaluated *in the context of its active promotion* and not the other way around.

The promotion of nuclear power can only be explained in the context of technocratic norms and aspirations. Nuclear power exemplifies the modern vision of human progress. Nuclear power was and to a significant extent continues to be seen as the natural and inevitable fulfillment of the technological promise; by dreams of reason, humanity discovers the secret of energy by which all technological invention is possible and upon which human progress fundamentally depends. Through nuclear power, we would have the endless energy to create. While the computer, the laser and other modern inventions impart a sense of social awe, they are derivative of the energy secret. They do not offer limitless energy but depend upon it. In this way, the promise of nuclear power is inseparable from the promise of technological civilization itself. As one nuclear advocate has put it, nuclear power is the essential foundation for carrying forward the advances of the past two hundred years; "nuclear is the only nonfossil energy source that will be available to us in sufficient amounts to support our current civilization and to fuel progress for the foreseeable future" (Agnew, 1983: 1). Cost is inconsequential when civilization is at stake. To deny ourselves access to the energy secret is to forego progress. The enthusiasm for nuclear power, the institutional resources dedicated to its development, and the resistance to any deviation from the nuclear commitment can only be understood in the context of a ruling ideology of technological optimization.

So long as the aspirations of technological civilization define nuclear's promise, external indicators of performance are irrelevant. In this sense, nuclear power has been demanded to meet the requirements of an established technological path and, however precarious its performance may be by other standards, it is valued as a response to the systemic needs of that path. That is why the active promotion of nuclear power in the 1950s, despite its lack of availability, was deemed not only pragmatic but inevitable. It was anticipated and affirmed because it could be recognized as a logical extension of current technical and institutional arrangements for the production and use of energy. It was recognized as a practical option during the last 40 years in the same sense that, as Ellul suggests, the interconnection of electrical networks was:

> Electrical networks may remain for some time independent of one another. But this situation cannot last when it is found that independence gives rise to general costs of no inconsiderable magnitude, difficulties in arranging the courses of the lines, and even practical difficulties in electrical technique. The interconnection of electrical networks is demanded by all technical men (1964: 237).

In the context of such recognized system demands, matters of social purpose become recast as matters of efficient technical practice. As Winner has pointed out, "the technological society tends to arrange all situations of choice, judgment and decisions in such a way that only instrumental concerns have any true impact. In these situations questions of 'how' tend to overpower and retailor questions of 'why' so that the two matters become, for all practical purposes, indistinguishable" (1977: 232-233).

For four decades the central question of energy choice has been defined as instrumental rather than purposive: essentially, how to perpetuate the "rapid expansion of centralized high technologies to increase supplies of energy, especially in the form of electricity" (Lovins, 1977: 25). The basic issues have been framed in terms of the technological requirements of the existing energy path. Two types of technical requirements have been dominant. First, the technology must be compatible with the scale and centralization of existing energy production and distribution; it must meet the condition of connectivity with prevailing technical and institutional arrangements. Second, it must be suited to the delivery of energy in a form currently forecast as essential to continued progress along the existing technological path; it must meet an Electric Society's definition of technical efficiency. Within the technological paradigm, it is virtually undeniable that nuclear power, and possibly *only* nuclear power, may meet both of these requirements. Once this judgment is made, the only remaining question is, how can we make the nuclear energy machine work?

To a significant extent, energy R&D policy has been framed around this question. The commitment to nuclear power has been treated as practically irreversible. The growing catalogue of nuclear's liabilities has grudgingly been admitted, but it has not led to a fundamental alteration of our technological path. Instead, we have engaged in a process which Winner calls "reverse adaptation" whereby "a series of transformations engendered by the introduction of technological means eventually leads to transformation of ends"; "ends are adapted to suit the means available" (1977: 238). Thus, for example, the declining economic fortunes of the nuclear industry are not to be regarded as an indictment of nuclear economics but, rather, a compelling justification for increased capital investment. Similarly, issues of nuclear proliferation, nuclear waste disposal, and nuclear safety are acknowledged to be serious, but we must recognize that all progress has unanticipated consequences. These consequences must now be treated as simply a new generation of technological challenges requiring an even greater investment of resources in finding technological solutions. In the spirit of such contemporary challenges, breeder reactor technology is held out as a *solution,* incredibly enough, to the threat of nuclear proliferation. Similarly, technical rationality dictates that the waste disposal problem is to be resolved, for example, by transporting the Shippingport reactor core by barge down the

Atlantic coast, through the Panama Canal, and up the Pacific coast to the Hanford reservation in Washington. And the sensible approach to safety issues is to cap the accident liability of the utility industry until publicly supported nuclear R&D - which, logically, must be increased - yields acceptable answers; under such a blaming-the-victim strategy, the public must pay for addressing the threat to public safety posed by the technological choices of the utility industry. In sum, we may conclude that the Electric Society is more costly and dangerous than previously imagined, but we dare not risk an alternative. To reason otherwise would be to raise suspicion about the stability of our technological civilization. In fact, to reason in any other way would be to admit technological defeat.

The search for the nuclear energy machine demonstrates the compulsive quality of technological choice. As Ellul has said, technique accepts no permanent limits: it "is autonomous and recognizes as barriers only the temporary limits of its action"; "it is driven onward by itself, by its character of self-augmentation" (1964: 142). Once launched upon a technological path, obstacles can only be evaluated as new challenges to be overcome by enhancing our commitment; technique provides its own moral and political justification. Recognizing this should draw our attention to Amory Lovins' warning that we stand at a crossroads of energy choice and that without decisive action our options will slip away. As he has argued the differences between the hard path we are on and the soft path that is available "may seem abstract, but they are sharp, imminent, and practical" (1977: 59). Those differences are, most importantly, social, political and ethical. "Crucially at stake," according to Winner, "are choices that concern the essential character of energy regimes: how large they will be, what energy sources they will employ, how they will be designed, how and by whom they will be run, and how they will affect the structure and texture of human life" (1982: 275). These matters cannot be evaluated if technical imperatives are accepted as surrogates for moral and political judgment. Unfortunately, the primary and most disconcerting legacy of four decades of energy R&D policy is the acceptance of such imperatives.

R&D Policy and Energy Regimes

While not usually analyzed as such, energy R&D policy has been an instrument of the current American energy regime. That regime is dominated by economic and political institutions which are militaristic, highly centralized, technocratic, and dedicated to the preservation of a culture of energy abundance. The objective of this regime has been an energy future governed by large-scale technical systems. This is evidenced most strikingly by the overwhelming and virtually uncontested R&D support given to nuclear power. To a significant extent, energy policy in general and R&D policy in particular is now driven by the inertia of the nuclear commitment. This commitment has been reinforced by a prevailing mythology that equates energy use with civilization and defines social progress as the achievement of the Electric Society.

Under the current regime, opportunities for conservation and the use of renewable energy will be undervalued. R&D policy will continue to search for the abundant nuclear energy machine. Only those technical solutions consonant with existing energy institutions will be judged as feasible. The inversion of technical means and social ends will persist, not because it is desirable, just or freely chosen, but because it is deemed necessary.

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