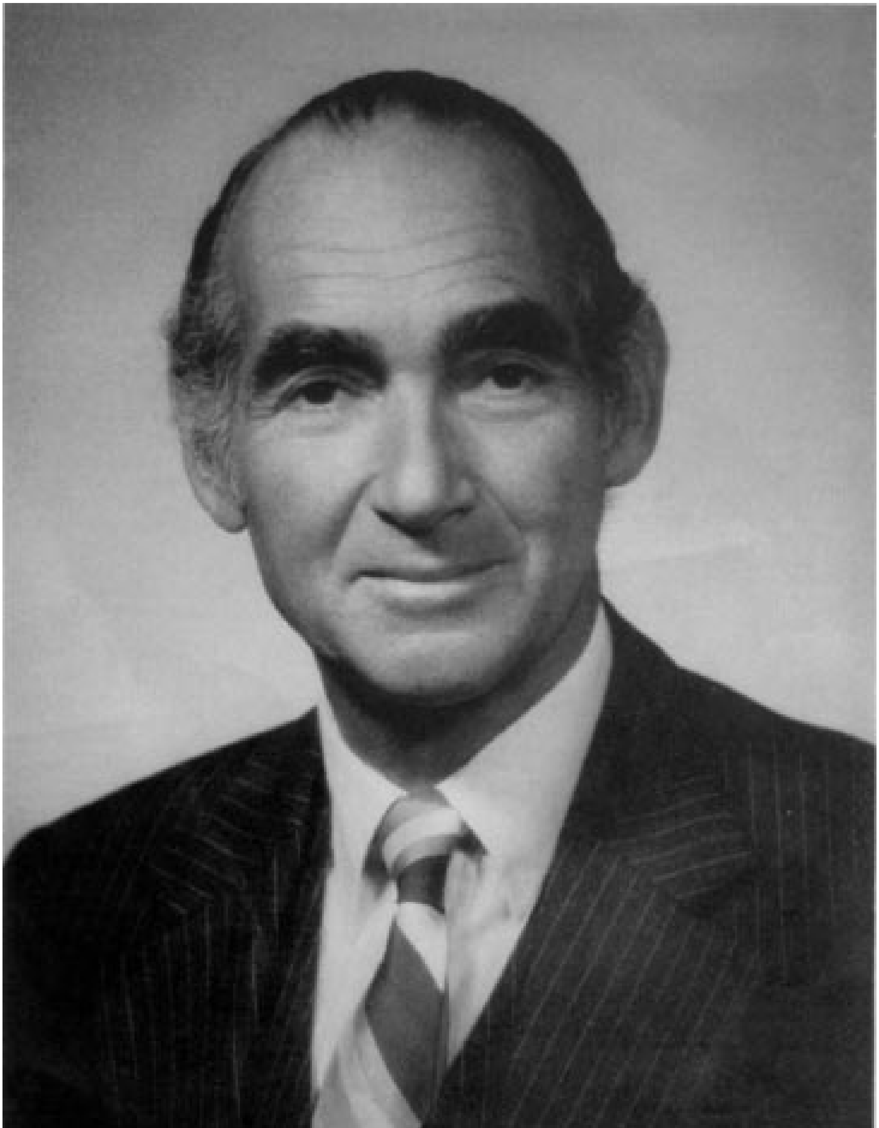

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THE EVOLUTION OF AN ENERGY CONTRARIAN

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ABSTRACT

An analysis of the forces that have shaped energy and energy-related environmental policies is presented through the eyes of an active participant in their evolution over the past 53 years. The problem of self-interest in taking energy and environmental policy positions is addressed candidly. The "energy crisis" is cited as an example. Its credibility depended on excessive demand projections, coupled with erroneous assessments of US and global hydrocarbon resources and of prospects for making these resources economically recoverable through technology advances. Many energy crisis proponents benefited from the misguided government response and from the large investments in uneconomic synthetic fuel technologies. Today, proponents of catastrophic anthropogenic climate change, again claiming scientific consensus, threaten to create even greater energy market distortions at large social and economic costs. The author traces his conversion to energy contrarian to the general failure of consensus and to his own misjudgments in these critical policy areas.

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THE DILEMMA OF SELF-INTEREST

In making this assessment of my 53-year journey through the energy world, I dwell a great deal on the difficulty of separating self-interest from principle when taking energy and environmental policy positions. For example, for more than half of this journey, while I was with the Institute of Gas Technology (IGT) in Chicago, whose main sources of revenue were research and development (R&D) contracts from the federal government and the gas industry, my primary mission was to sell technology. This goal was made relatively easy by the dramatic increase in funding for development and demonstration of processes for production of synthetic liquid and gaseous fuels from domestically abundant coal and oil shale during the 1950s, 1960s, and 1970s. I am now troubled by the fact that this costly effort was justified by flawed projections of future oil and gas demand and of economically recoverable domestic and global hydrocarbon resources, and the fact that I participated in these seemingly self-serving exercises. I also accepted many other tenets of what turned out to be a fictitious "energy crisis," caused largely by misguided government intervention in the energy market. Instead of critically examining these tenets as I would now, I published, spoke, and testified extensively on the urgent need to supplement domestic natural gas supplies with synthetic pipeline gas, and I succeeded in making IGT one of the largest contractors for R&D in this field. My able successor and long-time associate at IGT, Bernard S Lee, inherited this program and had to deal with its substantial contraction after the demise of the energy crisis. He was able to diversify into numerous new areas without sacrificing his personal commitment and that of IGT to advance further the art of coal gasification, a rather prescient move, as I discuss later on, in view of the growing global importance of clean coal technologies for power generation and other purposes.

After the Gas Research Institute (GRI) became the gas industry's R&D, planning, management, and financing organization in 1977, and I its founding president, my new mission was to buy technology, rather than sell it, and to ensure that GRI served the interest of gas consumers by making technology choices prudently on the basis of rigorous cost vs benefit analyses. My associates and I did not take long to adopt Roger W Sant's "least cost energy service strategy" as the paradigm governing GRI's selection of R&D projects (1; see also 2).[1] The basic premise was that all energy investments, including research, development, and demonstration (R,D&D) investments, should be aimed at delivering useful energy services—heating, cooling, lighting, refrigeration, shaft horsepower, passenger- and ton-miles, etc—to the ultimate consumer at fully internalized least cost. This goal drastically changed GRI's top priorities from coal and oil shale conversion to pipeline-quality gas, and from other economically doomed options for synthesizing methane, to enhanced recovery of natural gas and to cost-effective end-use efficiency improvements. This approach also forced us to fund only those new gas technologies that offered consumers a better option than energy services provided by electricity, oil, coal, or renewables, a rather altruistic posture for an organization serving an industry dedicated to increasing the market share of natural gas.

More generally, the insights I gained in switching from being a seller to a buyer of energy technology led to my skepticism of forecasts of energy and related environmental crises that usually serve the hidden and not-so-hidden agendas of the forecasters. After all, the major business of government is crisis management, so it is quite natural for government, and the science and technology establishments that depend on its largess, to create crises where none exist. Now that the United Nations has assumed the role of global environmental and population crisis manager, there are even fewer checks and balances. Nor are industrial interests averse to promoting, or at least acceding to, alarmist views in order to gain subsidies, tax breaks, and other comparative advantages for their particular solution to whatever energy and environmental problem has the attention of policymakers. In my view, the latest and potentially most harmful of these manufactured crises is the scientifically highly questionable threat of anthropogenic global climate change.

Early Contrarian Positions and the Influence of Mentors

In what has since become a pattern of affinity for contrarian positions, I turned into an early believer in the abundance of economically recoverable Lower-48 natural gas resources and especially of so-called unconventional resources, which were waiting to be unlocked by new exploration, development, and production technologies. This occurred soon after passage of two pieces of

[1]Roger Sant was Assistant Administrator for Energy Conservation of the Federal Energy Administration from 1974–1976 before he became director of the Energy Productivity Center. He was one of the charter members and guiding spirits of GRI's Advisory Council that strongly endorsed the ratepayer benefits focus of GRI's R&D strategy.

legislation in 1978—The Power Plant and Industrial Fuel Use Act and the Natural Gas Policy Act—which quite mistakenly presumed that growing shortages could only be avoided by restrictions on natural gas use and by huge price incentives for "new" and "high-cost" gas to offset equally counterproductive price ceilings on "old" gas. This legislation was largely responsible for the 26% decline in US gas consumption between 1973 and 1986, as prices paid by consumers rose by 20% per year over much of this period. Of course, as someone who had moved into R&D management, energy policy analysis, and the Washington circuit after 17 years at the lab bench and in the pilot plant, I depended on others for scientific support. Of greatest assistance was the renowned petroleum geologist, William L Fisher. He is the former director of the Bureau of Economic Geology at the University of Texas in Austin and was one of the earliest and most effective proponents of technological solutions to perceived hydrocarbon scarcity problems (3). However, I received no support from any traditional geologists in my even more contrarian foray into the abiogenic (i.e. primordial) origin of much of the earth's methane resources; here, I was under the tutelage of Thomas Gold, the leading and unrepentant advocate of this theory, who still counts me as a disciple (4).

Clearly, bias based on self-interest is not the only motivating factor in choosing positions on energy issues. In my case, the impact of intellectually powerful mentors, some of whom I have already mentioned, was of equal importance. This mentoring started with Paul Weber at Georgia Tech who taught a course entitled "Gas and Fuel" in 1943, which I took as part of my undergraduate chemical engineering curriculum. I can trace to this experience my lifelong commitment to the energy field and to energy abundance as the engine of human economic and social progress.[2] Equally influential were my mentors at what is now Mobil Corporation during my three years (1944–1947) of basic training in the oil business; at Brooklyn Polytechnic Institute (now Polytechnic University), where I earned a Masters degree in chemical engineering while working for Mobil; at IGT, during my 31 years (1947–1978) there; and at the Illinois Institute of Technology (IIT), with which IGT was affiliated until 1988 and with which I had an overlapping 48-year relationship. These mentors included many

[2] An alternative explanation might be that being born in Vienna between 1920 and 1924 predisposed one to energy and environmental policy analysis regardless of future academic specialization. Examples of those with this apparent predisposition include not only Tommy Gold, an astronomer who, in addition to his contrarian views on the origin of hydrocarbons, is also a leading critic of the stratospheric ozone depletion orthodoxy, but also S Fred Singer, a geophysicist who was probably the first public figure to debunk the oil crisis and who is now a leading critic of the global warming hysteria; and John H Lichtblau, an economist who has been a long-time critic of constraints on US oil imports as head of the Petroleum Industry Research Foundation, Inc. and Petroleum Industry Research Associates, Inc.

prominent individuals, such as the then-dean of the chemical engineering profession, Donald F Othmer, at Brooklyn Polytech; John T Rettaliata, president of IIT; and others too numerous to list here.

The Three Fifths of My Journey Through the Energy World Spent at the Institute of Gas Technology

My main objectives after joining the IGT in 1947 were to finish quickly my Ph.D. in chemical engineering at IIT, to expand and diversify IGT's contract R&D program, to gain visibility as a technological spokesman for the US gas industry, and in that capacity, still unencumbered by any least-cost energy service considerations, to advocate the use of more gas from whatever source as superior to electricity in meeting growing energy requirements. IGT allowed me to achieve peer recognition for my contributions to such diverse fields as town gas manufacture, pyrolysis and hydrogenolysis of petroleum fractions to produce natural gas substitutes and petrochemicals, coal and oil shale gasification, hydrocarbon resource assessment, molten carbonate fuel cells, and liquefied natural gas storage and utilization, as well as for my somewhat premature advocacy of the "hydrogen economy" concept (5). Graduate students in ample supply were available to conduct readily publishable basic research in these areas and to lay the foundations for applied programs of interest to government and industrial sponsors.

I rose rapidly through the ranks of IGT, briefly served as acting director in 1955 and 1956, was named director in 1961 and, in 1974, had my title changed to president during an interregnum at IIT when I no longer reported to the president of IIT but directly to IGT's board of trustees. Under my stewardship, IGT maintained its strong affiliation with IIT, on whose campus it had been headquartered since its founding in 1941. This affiliation assured that IGT would be able to continue its dual function as a research institute and an academic department of gas technology and, later, gas engineering. Students at IIT to whom IGT granted fellowships and scholarships could earn Masters and Ph.D. degrees, or they could pursue a gas technology option in various undergraduate engineering disciplines.

Turning a rather minor research organization into an internationally recognized leader in development of new gas supply and end-use technologies and of new concepts for enhancing the role of gas in the global energy system was quite an exhilarating experience. During my 17 years running IGT, its staff grew from about 110 to 600, and its budget from a little over $1 million to $33 million (6). To accommodate this growth, we built a second building, and I bought a third, adjoining one from IIT, to give us 200,000 square ft of contiguous space on the IIT campus. We also acquired large pilot plant facilities located nearby, on the site of a former manufactured gas plant of Peoples Gas Light and Coke Company. IGT's academic, continuing, and industrial education programs and information services also experienced substantial growth. Numerous IGT alumni who had earned advanced degrees in the early years under IGT's industry-financed fellowship program became executives in the US gas industry and served as a loyal cadre of influential supporters. In 1965, IGT formed a for-profit consulting and technology commercialization subsidiary, the Gas Developments Corporation, Inc. (GDC), that licensed IGT-owned patents and established a large, blue-ribbon international energy consulting practice. At that time, creation of such a subsidiary by a not-for-profit membership institute was still rather novel.

In spite of growing administrative duties after I became head of IGT, and later of GDC, I continued to publish strenuously and travelled the globe to speak at international meetings. In 1968, I even helped to start the International Conferences on Liquefied Natural Gas (LNG). An interesting outgrowth of IGT's involvement in creating what is now a thriving international LNG business that fuels much of the Pacific Rim was a project to advance the image of natural gas by beating the land speed record with an LNG-powered rocket car: the Blue Flame. I only promoted and raised the money for this project; the hard work on design, construction, and shake-down was done under the direction of my long-term associate at IGT and GRI, Dean R Dietrich, and the vehicle was operated by the well-known race car driver Gary Gabelich. The project overran its budget at least threefold and was beset with technical problems. However, on October 23, 1970, the Blue Flame did finally set a decisive new land speed record at the Bonneville, Utah, Salt Flats: 622.407 miles per hour, a mark that stood for 13 years. Thanks to positive media coverage, we were equally successful in achieving our public relations objectives.

The 1970s were also a time of commuting to Algeria, where IGT had set up two facilities for training the technicians and engineers who were to operate the liquefaction facilities for export of Algerian LNG to Europe and the United States. These trips provided convenient stopovers in England and on the Continent to develop and maintain professional contacts and to squeeze in vacations. One of the highlights of my activities in Algeria was helping organize the 4th International Conference on LNG in 1974. It was quite a logistical challenge to bring hundreds of delegates from all over the world to Algiers (IGT chartered two Boeing 707s for the US delegation), to provide them with accommodations befitting their rank, to assign chauffeur-driven limousines of the appropriate length to the numerous VIPs, and even to organize golf games for American CEOs (after chasing the snakes off the greens and fairways at the somewhat dilapidated surviving club in postrevolutionary Algiers). But, with the help of

Sonatrach, the Algerian oil and gas company, all the plans came off very well, including an evening in the well-preserved ruins of the nearby Roman colonial and vacation town of Tipaza, lit by Algerian Army searchlights, with Tuareg tribesmen on camels shooting muskets for entertainment and the traditional Meshwi dinner of roast lamb eaten off spits with one's fingers.

Unfortunately, importation of LNG into the United States to supplement domestic and Canadian natural gas supplies proved to be uneconomic except in very special situations. This resulted in stranded investments in mothballed receiving terminals, including one for which I bore some responsibility. It was one of several reminders of my failure to anticipate the huge price and technology elasticity of gas supply and demand.

The Problems of Mainstream Thinking During the Energy Crisis Years—and Some of the Benefits

My years at IGT clearly demonstrate that being an energy maven whose views conformed largely to mainstream thinking during the 1950s, 1960s and most of the 70s had its rewards. Unfortunately, this conformity also colored my work in energy forecasting and my advisory functions in Washington, where I assumed the direct linkage between economic growth and energy consumption would continue indefinitely. As a result of the well-known herd instinct of energy forecasters, projections of US energy consumption in the late 1960s and early 1970s showed astronomical growth. In a 1972 report by the National Petroleum Council's Committee on the US Energy Outlook, on whose Gas Subcommittee I served, primary energy consumption in 1985 was projected to reach 125 quadrillion (10^{15}) Btu, or 125 quads, compared to what turned out to be an actual requirement of only 74 quads. Gas demand in 1985, even under relatively conservative assumptions, was projected to reach 30 quads, a level well in excess of what is now forecast for 2010. Projections of US oil demand were equally far off the mark. In some scenarios considered quite reasonable at the time, oil imports projected for 1985 approached or exceeded what turned out to be the actual total oil consumption in that year. Even the analytically more sophisticated Project Independence, developed by the Federal Energy Administration in the wake of the 1973/1974 oil embargo, suffered from this tendency to overestimate future primary energy needs and oil import requirements.

No wonder, then, that there was broad technical and political support for the creation of a huge US synthetic fuels production capability. After this support collapsed when the energy crisis proved to be a mirage, and after the Synthetic Fuels Corporation was scuttled, the lone surviving monument of that era was the Great Plains Coal Gasification Plant in Beulah, North Dakota, which was a great technical success but an economic failure. Unless a recent decision by an Administrative Law Judge of the Federal Energy Regulatory Commission (FERC) shuts it down, this plant will continue to produce overpriced pipeline gas at well above design capacity, and it will remain a financial burden to the pipelines that committed to buy its output, and to their customers. Needless to say, I was one of its architects. It is worth remembering that the ambitious synfuels commercialization program was hard to bring to a close: Even in September 1976, the program was defeated in the House by only a one-vote margin, 193 to 192.

I was not among those who justified their support of synfuels development by underestimating the hydrocarbon resource base. My error was to overestimate demand. In quite contrarian modeling efforts during the late 1960s and early 1970s, my coworkers and I projected the economically recoverable US natural gas resource base to be substantially larger than what was the consensus at that time. As early as 1968, with another of my mentors, Martin A Elliott, who was director of IGT from 1956 to 1961, I projected an ultimately economically recoverable US gas resource base of 1740 trillion cubic ft (Tcf), not far below current estimates (7). Such a resource base was adequate, even for the greatly overstated future consumption, provided that government policies that artificially constrained exploration, development, and production were modified (8). At that time, the Federal Power Commission put in place regulations that kept prices at the natural gas fields unnaturally low, nominally to protect consumers. In 1973, just before the start of the energy crisis, the average wellhead price was only 22 cents per thousand cubic ft (Mcf) or, roughly, 22 cents per million Btu. The low price, rather predictably, inhibited reserve additions and caused a shortage of cheap, interstate natural gas, as demand skyrocketed to a level not reached since then.

Our 1968 model also projected 450 billion barrels of ultimately economically recoverable US crude oil, even prior to the development of the large Alaskan resources. This was a dramatic break with the doomsday forecasts of early exhaustion of much more limited US oil resources, typified by the simplistic models of MK Hubbert that dominated the thinking of most analysts (9). Another contrarian IGT modeling effort in 1974 projected far higher world oil productive capacity than the prevailing consensus and what turned out to be actual requirements (10).

Perhaps I am being too apologetic for having advocated the expenditure of several billion dollars on uneconomic supplemental gas projects and synthetic fuels R,D&D. A lot of new technology was created that is being put to good use. The integration of coal gasification with combined-cycle turbine power generation, for example, has resulted in highly efficient and super-clean coal conversion technology that, in my opinion, is destined to become the dominant global source of new baseload capacity, pending revival of the nuclear option. The potential of this technology was first demonstrated by the Electric Power Research Institute (EPRI) and has benefited greatly from advances in coal gasification made by Shell, Texaco, IGT, and others. These coal gasification processes now also satisfy a growing need for synthesis gas in the production of chemicals and fertilizers in places where natural gas is not readily available.

Of course, natural gas–fueled combined-cycle technology—i.e. an aero-derivative combustion turbine in tandem with a heat recovery boiler and a steam turbine—is already revolutionizing global power generation. I am proud to have been an early proponent (11). Compared to a heatrate of about 10,500 Btu per kWh for conventional steam-electric plants, the latest combined-cycle plants have heatrates of 6300–6700 Btu per kWh, corresponding to lower heating value thermal efficiencies of 57–60%.[3] In addition, the installed cost of such plants has dropped to less than half that of modern coal-fired plants which, at current natural gas prices, makes them capable of producing clean, base-load power for 3–4 cents per kWh.

I have already mentioned the thriving international LNG business. This industry is based on much new technology for liquefaction, cryogenic storage, and tankers. LNG has revolutionized energy consumption patterns in the Pacific Rim and may now do so in Southeast Asia and even in the Caribbean. In the United States, cryogenically stored LNG is being used to meet needle peaks, and conversion of mothballed LNG import terminals to expand this capability is under active consideration. US imports of LNG from Algeria are continuing on a limited scale at competitive costs, thanks to low net-back prices and the use of largely depreciated liquefaction and terminal facilities and tankers. In addition, exports of LNG from Alaska to the Pacific Rim, where natural gas still commands a premium over oil, are likely to increase.

Energy Abundance as the Engine of Social and Economic Progress

At no time during my evolution into an energy contrarian and advocate of least-cost energy services did I recant my belief in energy abundance as the engine of economic and social progress. In my long battle against those who wanted to use the fictitious energy crisis as the pretense for drastically reducing energy consumption, I published numerous papers and studies that demonstrated that,

[3]Combustion turbine efficiencies are normally quoted in terms of the lower heating value of the fuel; i.e. assuming the combustion products carbon dioxide and water are in gaseous form. Heatrates are normally quoted in terms of the higher heating value; i.e. assuming that the water produced is in liquid form. For natural gas, the difference is about 11%.

for the whole universe of national economies, primary energy consumption was well correlated with gross national or gross domestic product (GNP or GDP) per capita and with just about every other measure of economic and social well-being. I also explored reasons for the observed deviations from this trend line, which form a band of data points whose width is equivalent to roughly a fourfold variance in the ratio of primary energy consumption to GNP or GDP (E/G). Among the reasons for this variance, which implies that the same nominal level of economic well-being can be achieved over a wide range of this ratio, I identified distortions in G arising from inherent uncertainties in the correction of monetary exchange rates for purchasing power parity and distortions in E arising from a lack of uniformity in the statistical treatment of energy data.

Moreover, as most national economies develop, their E/G shows a typical pattern: increasing during the early and relatively inefficient stages of industrialization, then leveling off, and then gradually declining towards some lower bound. The relative positions of various countries along this common development path are responsible for much of the variance in E/G. The value of E/G in the United States peaked soon after World War I and has fallen by more than a factor of two since then, while the share of primary energy converted to electricity rose from 10 to 36%.

Furthermore, at the same stage of industrialization, E/G does vary from country to country, depending on such elements of its energy infrastructure as availability of indigenous resources, degree of electrification, relative dependence on personal and public transport for mobility, and energy pricing and taxation policies. The E/G ratio is also affected by climate, overall population density, degree of urbanization, and the relative contributions to economic activity of heavy and light manufacturing, services, extractive industries, agriculture, imports, and exports.

My persistence in stressing these fundamentals governing energy-economic interrelationships naturally led to repeated confrontations with those who asserted that the wide (although narrowing) divergences in E/G between, say, Switzerland and Japan on one hand, and the United States and Canada on the other, were evidence of energy waste. Japan, in particular, has been adept at moving overseas the most energy-intensive sectors of its economy, such as the manufacture of primary aluminum, while keeping at home mostly high-value-added sectors. This strategy has allowed Japan to claim leadership in energy productivity and in reductions of CO_2 emissions. I have consistently maintained that the societal benefits of abundance of readily available and affordable energy services and personal mobility, such as improvements in the economic and social status of women and erosions of class distinctions, are not captured by such facile comparisons. In the West, neither the shrinkage of the huge servant class nor the emancipation of women could have occurred without the energy revolution that has made possible dishwashers, washer/dryers, vacuum cleaners, microwave ovens, convenience foods, and two-car families.

We are still a long way from the lower limit of E/G. The "ultimate" level of E/G theoretically achievable by a mature industrialized or postindustrial economy will change over time, owing to advances in technology, changes in environmental standards, and many other factors. Energy productivity continues to increase even without a stimulus from rising real energy prices or from expectations of a future rise in real prices because of competitive pressures that accelerate these technology advances and because of ongoing electrification. In Organization for Economic Cooperation and Development (OECD) countries, the annual percent increase in primary energy consumption is currently only half the annual percent increase in inflation-corrected GDP growth. The critical weakness in my earlier forecasts of US energy requirements was my failure to recognize that the relative stability of the E/G ratio during the 1950s, 1960s, and early 1970s was not something fundamental, but an artifact of falling real energy prices that made the substitution of energy for labor and capital perfectly rational.

My Encounter with Alvin Weinberg and the Club of Rome

An encounter with a major figure in the energy world that affected me profoundly occurred just before the start of the official US energy crisis in 1973, with the onset of the Arab oil embargo. This encounter was with Alvin M Weinberg, whose autobiographical essay, "From Technological Fixer to Think-Tanker," was published in Volume 19 of this journal. I wrote an article that gives a more complete account of my relationship with Alvin (in celebration of his 70th birthday), which was published in *Nuclear Science and Engineering* (12). The following summary of our joint experience with the Club of Rome is condensed from that article (pp. 348–349):[4]

> I had, of course, known of Alvin Weinberg for many years, but actually met him first at the Hotel Michelangelo in Rome on March 13, 1973, after two members of the Club of Rome—Dennis Gabor, the Nobel Prize–winning physicist at Imperial College of Science and Technology, and Umberto Colombo, then still with Montedison S.p.A.— recruited us and a number of food and natural resource specialists to join a "Working Party" of the Club in order to restudy the gloomy scenarios developed in *The Limits to Growth* (13). The Club of Rome was an influential and very loosely organized group of businessmen, scientists, educators, sociologists, and economists from about 25 countries who became alarmed by the rapid economic and population growth in the two decades following World War II and the likely impact of such continued rapid growth on the environment and the

[4]Copyright 1985 by the American Nuclear Society, LaGrange Park, Illinois.

> rate of depletion of nonrenewable natural resources. The driving force for the formation of the Club of Rome in 1968 was the conviction of its founder and leader, Aurelio Peccei, that man, in his impetuous drive for progress, was overreaching his dominance of the planet and wreaking a global "problematique." Peccei always took great pains to explain that the project that started at the Massachusetts Institute of Technology (MIT) in July 1970, and led to publication of *The Limits to Growth* only 18 months later, was a study made for the Club of Rome, not by the Club of Rome. In spite of these denials, the Club of Rome became closely identified with the zero-growth movement and even served as its symbol. One of the most frequently recurring and substantive criticisms of the MIT study was that the model did not adequately account for the future impacts of science and technology. It was argued that, if properly stimulated, these would help to solve the problem of the scarcity of natural resources. Alvin and I, along with Umberto Columbo, were to handle energy and energy-related issues. Remember that this was 1973, quite late in the era for those of us who, soon after World War II, became alarmed by the ultimate outcome of the rapidly growing dependence of industrialized and industrializing countries on natural hydrocarbon fuels. Even then, most resource economists were still preoccupied with food and population problems and looming shortages of various critical raw materials such as phosphorus.

I have difficulty establishing the exact point at which my views on the economic, social, and environmental benefits of energy abundance—which I would now redefine as the abundance of useful energy services provided through least-cost strategies—required me to confront the antienergy, antigrowth elites, and assorted neo-Malthusians. I believe the final impetus came as a result of our efforts to rescue the Club of Rome from its zero-growth image in 1973. Alvin Weinberg stated our position most succinctly (12, p. 351):

> The Club of Rome technological orientation and spirit can be regarded as neo-Malthusian: the Earth is finite, and there will come a time, if the world's population does not stabilize, when mankind will exhaust the world's non-renewable resources. Opposed to this is the view of the neo-Ricardians: that the world's resources are essentially infinite, but that we shall gradually be obliged, through the working of the marketplace, to exploit ever more expensive materials, or find substitutes, either functional or material. The extreme neo-Ricardian view is the one expressed by Herman Kahn—to a lesser degree it is also held by most economists who have criticized the Club of Rome and by many technologists.
>
> My own views have been strongly neo-Ricardian. For each of the major requirements of mankind—food, mineral resources, energy—I had been aware of resources or possibilities of technology or of substitution which would make the overshoot and collapse scenario quite unlikely, at least insofar as this scenario depends on the limitation of resources per se.

In regard to energy, Alvin shared my belief in the close linkage between energy abundance and social and economic progress. At that time, quite understandably, we disagreed about what would be the principal energy carrier of the future: Alvin advocated electricity (from fission), whereas I, still believing that direct electrification was too capital intensive, preferred gaseous fuels; initially,

Table 1 Life of world fossil fuel resources at various demand growth rates[a]

Annual growth rate %	Date when remaining reserve production ratio drops to 10 years[b]		
	A	B	C
4	2003	2047	2064
3	2008	2064	2087
2	2015	2094	2127

[a]Based on 1974 year-end estimates.
[b]A: Proved reserves (0.737–0.814 trillion tce); B: Total remaining recoverable resources (5.39 trillion tce); C: Effective doubling of B resources by use of non-fossil sources. tce = metric tons of coal equivalent; 1 tce = 27.778 million Btu.

methane from various sources and, eventually, hydrogen produced from a mix of nuclear power and high-tech renewable sources. Later, I radically readjusted my thinking, and I now consider electrification to be an economic imperative (14). My current view is that most stationary energy uses will require electricity, and hydrogen will serve as a supplemental energy transport and storage medium and as the dominant surface and air transportation fuel.

The Evolution of the "Hydrogen Economy" Concept

In 1973, I was still very much in my alarmist mode. I believed that global fossil fuels and low-cost uranium would be depleted well before the end of the twenty-first century, because I assumed a 5% per year increase in world energy requirements. Even in 1976, when my views on the need for energy consumption growth had moderated considerably, I presented the chart shown in Table 1 at the 13th World Gas Conference in London (15).

Since then, advances in technology have substantially increased the proved reserves of oil and natural gas and the economically recoverable resources of all fossil fuels. These advances have also greatly increased energy end-use efficiency and reduced the environmental impacts of the entire energy system. Thus, the urgency to achieve sustainability has lessened considerably (16). Certainly, the driver is no longer fear of imminent resource exhaustion or excessive increases in energy prices.

An acceleration of the transition to a sustainable global energy system would only be needed if the 700 billion to 2 trillion metric tons of carbon that might be liberated from the 4–5 trillion tons contained in the technically recoverable fossil fuel resources between now and 2100 can be shown to have a significant detrimental effect on global climate. Because of my earlier expectation that this transition had to be accomplished well before the end of the twenty-first century due to fossil fuel resource constraints, I used the platform provided me by the Club of Rome to advocate the "hydrogen economy." I cited the following advantages of hydrogen over electricity as a secondary energy source (17):

> As fossil fuel and low-cost uranium resources are depleted, they will be replaced first by breeder reactor-based electricity. However, instead of converting to more and more direct use of electricity, hydrogen should be considered as a major secondary energy source because of its many advantages. It has superior convertibility to other energy forms and to organic chemicals and portable fuels. It is also essentially nonpolluting. Further, hydrogen has much lower transmission and distribution costs than electricity, it can be stored as a gas or in liquefied form, and its normal mode of transport is in belowground pipelines rather than overhead systems. Existing technology would still require power generation from nuclear energy and electrolysis to generate the hydrogen, but there are promising prospects for conversion cycles using nuclear heat directly to decompose water at temperatures achievable in nuclear reactors.

Today, I believe that hydrogen is destined to become a supplement to, not a substitute for, electricity. Hydrogen will serve primarily as a transportation fuel and energy storage medium. The high and still rising efficiencies of electrotechnologies such as heat pumps; electric motors; and induction, microwave, and infrared heaters, in combination with the higher efficiencies and lower investment costs achievable when nuclear and high-tech renewable technologies are used to generate electric power rather than hydrogen, argue for electrification as the rational and sustainable least-cost strategy for stationary energy applications, even when rising costs of power transmission and distribution are taken into account. Factors determining the details of the future energy system include the ability of natural gas and oil to hold market share in end-use applications and the ability of fossil fuel–fired electric power generation to maintain its cost advantage over renewable and nuclear options under growing environmental constraints.

One source of hydrogen in a sustainable energy system would be electrolysis of water with off-peak nuclear power. Electricity generation from such renewable sources as solar and wind energy, and direct water decomposition by various chemical cycles driven by solar or nuclear heat, are also likely to play a role. The easy and efficient convertibility of electricity to hydrogen, and of hydrogen to electricity by means of fuel cells, in combination with the good storability of hydrogen, will be of special value in the event that neither nuclear fission nor nuclear fusion becomes the mainstay of the global energy system and primary reliance is placed on intermittent solar or solar-derivative sources. I generally oppose production of relatively cheap hydrogen from fossil fuels as an interim measure, especially from natural gas, which is already an environmentally desirable fuel with high hydrogen content. Such production would reduce overall thermal efficiency and increase overall CO_2 emissions compared to direct use of natural gas. The only exceptions would be unusually high-efficiency applications, such as fuel cells for vehicles or distributed power generation.

Helping Make Energy Policy in Washington

My serious involvement in the Washington energy policy circuit started in 1963, when I was appointed to several industry advisory committees of the Interdepartmental Energy Study of the Office of Science and Technology and to the Technical Advisory Committee of the Office of Coal Research. One of the highlights was being asked to help in the preparation of President Nixon's energy message of June, 1971, the first such message by a US president. The pace for energy policy wonks picked up considerably with the appointment of our country's first "energy czar," Governor John A Love, who became head of the White House Energy Policy Office in June, 1973. His chief of staff was the then very young William T McCormick Jr., now Chairman and CEO of CMS Energy, with whom I have maintained a close relationship ever since, throughout his meteoric rise in the energy world. At that time, the White House Energy R&D Advisory Council was established, and I became one of its members.

Our activities took on greater significance following the oil embargo attempt by the Organization of Arab Petroleum Exporting Countries that began in October, 1973. I use the term "attempt" advisedly, because the embargo was quite ineffective, as evidenced by rather stable US oil import levels: 6.3 million barrels per day in 1973, 6.1 in 1974, and 6.1 again in 1975. The gasoline lines and other dislocations were primarily the consequence of misguided federal and state interventions in refinery operations, inventory management, and product distribution.

These events also led to a continuing relationship with Alvin Weinberg, who had become a Washington energy policy insider after our Club of Rome experience. The following account is again taken in part from the article in *Nuclear Science and Engineering* (12, p. 354). In 1974, William E Simon, our second energy czar, asked Alvin to form the Energy Research and Development Office (ERDO), which initially reported to the Federal Energy Office (FEO), the predecessor of the Federal Energy Administration (FEA). ERDO evolved (at least alphabetically) into ERDA—the Energy Research and Development Administration—which, in January, 1975, became the transitional agency between the Atomic Energy Commission (AEC) and the Department of Energy (DOE). One of ERDO's primary responsibilities was to assist AEC Chairman Dixy Lee Ray in formulating a five-year, integrated energy R&D program, the so-called 10 billion dollar exercise assigned to her by President Nixon in June, 1973 (which turned into 11 billion, as I recall). This “exercise,” and Senator Henry M (Scoop) Jackson’s earlier effort in March, 1973 to increase nonnuclear energy R&D, eventually led to the legislation that broadened federal energy-related R&D. Moving beyond the AEC’s exclusively fission- and fusion-based, supply-oriented program, and the much smaller coal-based supply R&D program of the Office of Coal Research of the Department of the Interior, ERDA was designed as a complete and balanced program. ERDA started quickly and successfully in 1975, under Administrator Robert C Seamans Jr. and his deputy, Robert W Fri. Its outstanding performance and output over the two short years of its existence speak well for their leadership and for the groundwork that Alvin Weinberg and his ERDO team laid during those exciting days. ERDO also played a peripheral role in the genesis of FEA’s major energy policy exercise—Project Independence—completed in November, 1974.

During William Simon’s and then John Sawhill’s tenures as energy czar, I worked as a one-day-a-week consultant for Alvin and his small staff, and I became involved in numerous other energy policy activities, such as the Department of Commerce’s Technical Advisory Board Panel on the “Project Independence Blueprint” and the Federal Power Commission’s Gas Policy Advisory Council. Our status was evidenced by the opulent quarters we occupied in the Old Executive Office Building. As the crisis waned, we were moved to the more spartan New Executive Office Building and lost our privilege of belonging to the White House Mess. The glamour and excitement of crisis management and the hospitable climate for costly technological solutions during those heady days stands in stark contrast to today’s sober reliance on market forces, which have restrained energy demand and enhanced energy supply beyond our wildest hopes. The experience, however, was excellent preparation for our later reincarnations as hard-headed businessmen, market-oriented academics, consultants, and R&D managers.

My real glory days in Washington followed my appointment to the prestigious General Advisory Committee (GAC) of ERDA by President Ford in 1975. The GAC was a carryover from the AEC and had perks far beyond those customary for government advisory bodies. With our top security clearances, we not only had access to all of the weapons laboratories, but also enjoyed the AEC/National Laboratory culture, which included having sherry before lunch. Unfortunately, my term and the terms of my colleagues on the GAC were cut short by the election of President Carter in 1976 and the formation of DOE in 1977. James R Schlesinger, the first Secretary of Energy, felt he could dispense with GAC oversight.

A major factor that brought about my disenchantment with synthetic fuels was what I learned from my GAC and ERDA colleagues, most notably Charles

J Hitch (the Chairman of GAC), Bob Seamans, and Bob Fri. ERDA developed a highly contrarian analytical tool for prioritizing energy R&D investments—the Market-Oriented Program Planning Study (MOPPS)—that showed, lo and behold, that the supply of such critical and supposedly rapidly depleting energy commodities as oil and natural gas was highly price elastic. We called into doubt all of the linear forecasting that did not provide for a price response and that predicted an inevitable energy crisis, and we highlighted the potentially disastrous impact of government intervention in energy markets. The Washington energy policy establishment was not amused. It suppressed the study, provoking a famous "ERDAgate" editorial in *The Wall Street Journal* (18). It took me a couple of years to apply to our GRI program this belated insight about the price and technology elasticity of supply and demand. However, even as early as May, 1975, I questioned the validity of inevitable oil and gas shortage scenarios in a paper I presented to the Third National Energy Forum in Washington, DC, entitled "Is the Synthetic Fuels Option Still Credible?" (19). Instead, I argued that, even after allowing for the end use–efficiency advantages of electricity, clean energy could be obtained from coal more cheaply in the form of synthetic methane than in the form of electricity. I also argued that the cost of nuclear power was likely to escalate and outstrip that of a variety of supplemental gas options.

Early in 1977, Jim Schlesinger, while still Assistant to President Carter, did me the honor of asking me to join his DOE team, but I was too deeply engaged in the formation of GRI and declined with considerable regret. In 1978, when GRI went into full operation, my involvement in Washington energy policy affairs abated. Although I still testified frequently before Congress on energy issues and served on several advisory bodies, I transferred many of my activities to a very effective GRI Washington office under the direction of David O Webb, whom I recruited from the Congressional relations arm of ERDA. He was instrumental in obtaining about $70 million annually of federal coordinated funding for GRI's R&D program and in maintaining excellent relations with Congressional staffs, DOE, the Federal Energy Regulatory Commission, and all the other constituencies whose good will was essential to the success of GRI. During these years, I became affiliated with The Aspen Institute and helped organize and finance its energy policy program.

My Growing Confrontation with Neo-Malthusians (After Some Early Errors in Judgment)[5]

In reviewing my publications and speeches over the past 50 years as part of this autobiographical exercise, I discovered with dismay that my position on

[5]Portions of this section are taken from Reference 20.

anthropogenic climate change went through a complete reversal. In my efforts to sell the hydrogen economy, I made the following statements that could have come straight from the Intergovernmental Panel on Climate Change (IPCC)—today's primary purveyor of what I consider alarmist thinking—in a paper presented at the 7th Biennial Mid-Pacific Energy Conference in May, 1971 (21, p. 14):

> Since the middle of the 19th century, we have been engaged in removing the organic carbon that has been buried in the Earth's crust over the last 500 million years at an ever increasing rate and burning it in the form of fossil fuels. This has already dumped enough carbon dioxide into the atmosphere to increase its concentration by about one-sixth to roughly three-hundredths percent by volume. If we burn all of the 4500 billion tons of fossil fuel carbon in the Earth's recoverable hydrocarbon and coal deposits, and half of the carbon dioxide produced is absorbed by the oceans, this would still leave enough to raise the atmosphere concentration more than four-fold, or to well over one-tenth percent by volume. The way we are going, this process will probably be completed before the end of the 21st century. Thus, we will have undone, in less than 300 years, what it took Mother Nature to accomplish in 500 million.
>
> However, we probably won't get away with this. Even only doubling the present carbon dioxide content of the atmosphere would raise the average global temperature by about 5 F, and doubling it again would probably have serious effects. Carbon dioxide is a good heat absorber which traps heat by preventing it from radiating back into space.

The numbers (whose source I do not remember), as well as the projected outcomes, are amazingly close to what is currently promoted as scientific consensus, with which I and my colleagues in the anti-alarmist camp now strenuously disagree (22). The 1971 paper, in every other way, exudes technological optimism. It attacks radical environmentalists in very much the same terms as I do now, charging that, in seeking to impede or stop the expansion of energy supply and use, they are disregarding potentially disastrous social and economic side effects. As was fashionable at the time, I equated the 1970 per capita US primary energy consumption of 335 million Btu to the work-equivalent of at least 200 slaves, and I suggested that the human race did not wish to regress to the energy famine it had endured until the middle of the nineteenth century. I noted that all the great ancient civilizations were based on animate power—some provided by animals, but much by human slaves—and that the neo-Luddite vision of a return to the simple life unencumbered by energy-intensive technologies without loss of human freedom was a fraud. To dramatize this point, I stated (21, p. 15):

> Upper-crust Romans were very comfortable, but only by enslaving much of the world's population which carried them around on their backs and trekked to the top of the Alps to bring them ice. And as far as pollution is concerned—from the beginning of history, nothing was filthier than human habitats until energy and technology rescued us quite recently. Except, of course, for that thin upper-crust who again had their slaves to keep things clean.

Since then, I have refined these points. I now recognize the role of technology in increasing energy productivity through cost-effective end-use efficiency improvements, in addition to its role in increasing economically recoverable fossil and fissile energy resources. I have also adopted the formulation of another of my mentors and role models, Chauncey Starr (whose autobiographical essay appeared in Volume 20 of this journal), that poverty is the most pernicious social and environmental pollutant. Clearly, only the continuing substitution, on a global scale, of commercial energy commodities and energy-intensive technologies for human and animal labor and primitive forms of renewable energy can eradicate poverty, as it has already eradicated slavery, serfdom, child labor, and the tradition of exploiting women as the cheapest animate energy source in industrial market economies. However, the claim for energy abundance as the material foundation of the unprecedented human progress of the past 150 years is not in any way meant to detract from other equally important philosophical and spiritual foundations laid during the Enlightenment and the political, social, and religious revolutions they spawned.

I believe I first used the term anti-energy, anti-growth elitists in a talk at the Illinois Institute of Technology Centennial Conference on Science, Technology, and Allocation of Global Resources, on September 27, 1990. I used this term primarily to capture the peculiar affinity of urban and academic intellectuals and their media and political allies for energy policy options that would erode one of the most positive characteristics of US society: its lack of a rigid class structure (23). In spite of overwhelming evidence that the availability of commercial, nonrenewable energy commodities fueling labor-saving manufacturing, agricultural, and transportation technologies has liberated an ever-increasing portion of humanity from untold millennia of misery, deprivation, and exploitation by a small ruling class, these influential elites continue to insist that growing energy consumption is the root of all evil and must be reigned in by all possible means.

The most repugnant symbol of energy abundance for these elites, who are obviously troubled by an increasingly classless and upwardly mobile society, is mass ownership of personal automobiles powered by the internal combustion engine, the main contributor to physical mobility. In the United States, the ingenuity of Henry Ford and the fortuitous contemporaneous development of the petroleum industry led to an affordable, mass-produced automobile and cheap, readily available transportation fuel. The resulting personal mobility is by far the most significant US contribution to the restructuring of human society. It hampers central control and overcomes the constraints and indignities of public transportation. This mobility also enhances political and cultural freedom, labor productivity, and social and economic mobility.

This unprecedented degree of physical mobility, however, has made national parks and wilderness areas accessible to the general public and has allowed ordinary people to live in the countryside. Therefore, the fact that the personal automobile has become the bête noire of elites offended by the resulting invasion of their sanctuaries should come as no surprise. Their allies in government invariably focus on personal transport when they want to expand regulation or increase taxation. Ever tighter corporate average fuel economy (CAFE) standards, increases in federal excise taxes on gasoline to OECD levels, speed limits below levels required for highway safety, taxpayer subsidies for uneconomic and inefficient fixed-rail public transportation systems, traffic lane restrictions for single-occupant vehicles and, not so long ago, standby gasoline rationing plans to compound the artificial shortages caused by clumsy government intervention, are all examples of command-and-control policies favored by those who wish to reduce the physical mobility that has shaped American society and culture and that is being eagerly copied throughout the world.

I often wonder what motivates these elites, who consider themselves guardians of the public interest and champions of the disadvantaged, to oppose energy abundance instead of embracing it with unbridled enthusiasm. Why have they become partisans in the latest anti-energy, anti-progress cause: saving the world from the specter of global warming? Part of the reason may be their hostility towards the energy industry. But, as I discuss in more detail below, the drastic actions they advocate to reduce the emissions of the so-called greenhouse-effect gases that are inherent in the utilization of fossil fuels could cause resource misallocations at least an order of magnitude greater than those triggered by the largely fictitious energy crisis of the 1970s and early 1980s. Such actions would also postpone indefinitely the fulfillment of the aspirations of the developing world to improve its living standards; aspirations that can only be met by using massive quantities of coal, oil, and natural gas and by allocating all available land resources to food production. Near the end of this essay I say more about my campaign against excessive measures to respond to the alarm about global warming.

The Organization of the Gas Research Institute

With a few of my trusted IGT colleagues, I incorporated GRI on July 8, 1976, as an Illinois not-for-profit corporation. We had the nominal backing of an ad hoc committee appointed by the boards of two of the gas industry's major trade associations: the American Gas Association (A.G.A.), representing primarily the interests of local distribution companies; and the Interstate Natural Gas Association of America (INGAA), representing the interests of interstate pipelines.

Nevertheless, our initiative was somewhat of a coup, executed with great urgency. Although the regulatory climate in mid-1976 was ripe for the creation of an independent R&D planning, management, and financing organization for the entire US gas industry, the initial intent of A.G.A. was to retain these functions and to create its own version of GRI. During the years just prior to 1976, A.G.A. believed that it should assume the responsibility for raising the volume of cooperative gas R,D&D well above its then rather pitiful level of about $20 million per year. A.G.A. had in mind something closer to $150 million, the level already attained by EPRI, which had been formed in 1972. Of A.G.A.'s $20 million R&D budget, nearly half was for so-called utility research, relating largely to the priorities of gas distributors; a small amount was devoted to pipeline research; and $10 million per year was dedicated to a cooperative coal gasification R&D program, cofunded with $20 million from the Office of Coal Research, which was an agency of the Department of the Interior, then by ERDA, and finally by DOE. (IGT was a major contractor of this gasification program.)

After a somewhat rocky start that involved a great deal of maneuvering by me and my IGT team to obtain the support of key gas industry constituencies, A.G.A. had a change of heart. Under the leadership of its new president, George H (Bud) Lawrence, it fully backed GRI and turned the management of its R&D program over to GRI. During 1978, when GRI had only $9.5 million of its own funding, A.G.A. continued to seek financial support for GRI. A.G.A. also became GRI's advocate in regulatory proceedings. Perhaps even more important was the early backing of GRI by INGAA, as I explain below when I describe GRI's innovative funding mechanism.

GRI began to function as an independent organization in March, 1977, with a skeleton staff largely recruited from former officers and employees of IGT. I remained president of both IGT and GRI until August, 1978. Three members of my original management team courageously left the security of their IGT positions long before the future of GRI was assured: Robert B Rosenberg, Dean R Dietrich, and Ronald O Decker. My strongest industry backer and indispensable partner in the creation of GRI was WJ (Jack) Bowen, GRI's founding chairman and a highly respected figure in the gas industry and its trade associations. During the critical formative period for GRI, Jack was instrumental in organizing the ad hoc committee of A.G.A. and INGAA that presented the broad principles of GRI's governance and funding to their boards and to the board of IGT in 1976. At that time, Jack was chairman, president, and CEO of Transco Companies, Inc., one of the major interstate pipeline systems. Thanks to his persuasiveness, the principles were accepted, an interim Board of GRI was appointed (made up of equal numbers of pipeline and distribution company representatives, with me as interim president), and IGT agreed to provide interim staffing. During my tenure, however, GRI never gained the full support of the trade associations of gas producers and of industrial gas consumers that often opposed GRI in regulatory proceedings. This support was secured by my able successor, Stephen D Ban, who made the accommodations that led to the inclusion of these important constituencies in GRI's governance.

In many respects, the history of GRI parallels that of EPRI. Like A.G.A., the Edison Electric Institute (the electric utility industry's dominant trade association) ran an inadequate cooperative R&D program that had to be severed and administered by competent technical managers in order to gain larger financial support from its voluntary membership. Like GRI, EPRI has had difficulties retaining this support and has had to make repeated adjustments in its policies and governance to prevent defections of existing members and to attract new members. In organizing GRI, I followed the lead of Chauncey Starr, the founding president of EPRI. He established EPRI in Palo Alto, close to Stanford University, for academic support. I located GRI right on the campus of IIT, a major technological university, a location that had the additional advantage of being close to the gas industry's major R&D-performing organization, IGT.

Evolution of the Innovative Gas Research Institute Funding Mechanism and Its Impact on the Gas Research Institute's Program and Governance

In many ways, GRI was a creature of the Federal Power Commission (FPC), which became the Federal Energy Regulatory Commission (FERC) in 1978. Our decision to incorporate GRI followed closely a favorable rulemaking proposed by FPC on June 17, 1976 (which became Order No. 566 on June 3, 1977) that allowed advance approval of R,D&D programs of organizations whose financial support was derived from companies under FPC jurisdiction, under a rather stringent set of guidelines.

First and foremost, the companies to which Order No. 566 was addressed were the interstate gas pipeline companies that delivered about 60% of the gas consumed in the United States, largely to the "city gate" of local distribution companies (LDCs), their major customers. The LDCs were and still are independently regulated by various state commissions, but any component of the price of interstate gas received by the LDCs that is under federal jurisdiction is beyond state control because of the "filed rate doctrine." State regulatory agencies do control entirely all intrastate commerce in natural gas, so the large intrastate pipeline industry and the gas volumes it delivers to LDCs and directly to industrial and power plant customers were and still are beyond the reach of the FPC/FERC. Thus, a critical early decision, made by GRI's interim board under Jack Bowen's leadership, was where we would put the "tollgate" for raising R,D&D funds. As I recall, I favored following the EPRI model and making the LDCs responsible for GRI's support, under the oversight of state regulatory agencies. Wisely, the interim board decided instead to place the tollgate where gas flows in interstate commerce, so the FERC had full jurisdiction.[6] At the time, the 27 interstate pipeline companies that were charter members of GRI were responsible for roughly 11 Tcf per year of gas flow (including both first sales and transportation services for resale), an amount on the order of 90% of FERC-regulated interstate services.

These interstate pipeline companies assumed the responsibility for collecting a uniform surcharge, pre-approved by the FERC, on the gas volumes under FERC jurisdiction. In order to exempt neither the unregulated direct industrial sales by the member interstate pipelines, nor the much larger intrastate sales, the FERC set annual targets for the portion of such sales that had to be included in a total of "funding services." This somewhat overstated total annual gas volume constituted GRI's funding base and was used to compute the surcharge, or so-called funding unit, required to finance GRI's FERC-approved budget. The pre-approved FERC funding unit was originally only 0.12 cents per Mcf. Over time, the funding unit rose gradually to about 1.5 cents per Mcf, supporting ever larger GRI budgets.

This funding mechanism put pressure on GRI and its members to spread the cost of the R,D&D program over the broadest possible customer base, but still eliminated the risk of underrecovery of contributions by the interstate pipeline members on volumes under FERC jurisdiction. Again, the LDC members had no direct responsibility for funding GRI; their recovery of the GRI surcharge on the gas volumes they purchased from pipeline members was protected by regulatory practice, confirmed in judicial proceedings. This certainty of rate recovery is what differentiates GRI's original funding mechanism from EPRI's: a member utility of EPRI (roughly equivalent to a gas LDC) had to recover its contribution to EPRI's R,D&D (as determined by its revenues and power sales) via the rates approved by its state regulatory agency.

The rationale behind GRI's funding mechanism was that the surcharge would pass inelastically to the ultimate beneficiary—the gas consumer—and would have no impact on the pipeline or LDC shareholder who, because of rate of return regulation, could not benefit from technologies developed and commercialized by GRI. This mechanism is why GRI from its inception was dedicated to the interests of the ultimate gas ratepayer, whereas EPRI functioned more like a true industrial R&D consortium, primarily responsive to its members rather than to the electric ratepayers. Over time, as the interstate natural gas pipeline industry has gradually been restructured, and as the electric power market has

[6] However, in many other respects, GRI did use EPRI as its model, notably in respect to its advisory body structure.

become more competitive, GRI has become more sensitive to the interests of its members and EPRI has become more consumer oriented.

I retired as GRI's founding president and CEO in 1987. Except for some serious problems in the early years with state regulatory commissions, consumer advocates, and court challenges that went as high as the Supreme Court, my term passed quite smoothly. When I turned GRI over to Steve Ban, who had previously served as executive vice president and chief operating officer, its annual budget had risen to about $175 million, and over $80 million in coordinated funding was provided by government agencies and industry.

The restructuring of the gas industry began on October 9, 1985, with FERC Order No. 436, which created open access to the interstate pipeline system. It ended on November 1, 1993, with the full implementation of FERC Order No. 636, which mandated complete unbundling of the traditional pipeline services—gas sales, storage, and transportation—so that interstate pipelines were no longer the merchants of gas they delivered. Because of the resulting transparency of the cost of each individual service, pipelines began to compete with each other and to discount their FERC-approved rates for firm and interruptible transportation. Competition among gas merchants also depressed wellhead prices. Increased pressures on rates and gas prices led to a reexamination of the premise that the GRI funding unit was passed on fully to the ultimate consumer. Gas producers claimed that they paid for GRI's R&D program through net-back of the funding unit to the wellhead. Interstate pipelines, forced to discount their transportation tariffs to remain competitive, claimed that their shareholders were really the ones who paid for the program. Thus, just at the beginning of Steve Ban's tenure in 1987, he faced the threat of active producer opposition and pipeline member defection.

The evolution of GRI's governance reflected these challenges to its funding and operational principles from its diverse constituencies. Originally, GRI was governed by a 25-member board of directors, 12 elected by the interstate pipeline members and 12 by the investor-owned LDC members. The president of GRI was, ex-officio, the 25th member. Early on, I faced opposition in regulatory proceedings from municipality-owned LDCs. Our solution was to set up a Municipal Gas System Advisory Committee that was given the right to nominate two candidates for the 12 board seats assigned to gas distribution companies. Soon thereafter, regulatory intervention by public-interest and consumer groups led to a further restructuring of the board to provide for two directors-at-large nominated by GRI's Advisory Council to represent these constituencies.

The Advisory Council included in its large roster not only eminent economists, labor leaders, environmentalists, consumer advocates, academics, R&D executives from outside the gas industry, and former regulators, but also five, and later nine, sitting state regulatory commissioners, one of whom served either as chairman or vice-chairman of the Council. The role of the Advisory Council in GRI's governance was further expanded in 1991, when the number of directors-at-large selected from its ranks was expanded from two to three, although at no time could directors be sitting state commissioners. The other major advisory bodies were the Industry Technical Advisory Committee and the Research Coordination Panel, composed, respectively, of R&D and technical experts within and outside of the gas industry.

To respond to the claims of producers that they shared the costs of GRI but not its governance, the composition of the board of directors of GRI was changed again in 1988 to give producers equal representation with interstate pipelines and gas distribution companies. Then, in 1993, after years of regulatory and judicial confrontation with the Process Gas Consumers Group, the large gas purchasers it represented were also given board representation. In addition, after staying unchanged for 15 years, GRI's simple volumetric-surcharge funding mechanism was modified to reconcile diverse interests in the drastically changed regulatory environment, most notably to solve the problem faced by the interstate pipeline companies seeking to recover the volumetric surcharge. The current funding mechanism provides for the collection of roughly equal amounts through a reduced surcharge on nondiscounted interstate gas volumes and through a new surcharge on nondiscounted demand/reservation fees for firm pipeline capacity.[7] However, because of widespread discounting in response to competitive pressures, actual GRI revenues have fallen short of FERC-approved budgets. Further changes to reduce the complexity of the funding mechanism and to reduce the uncertainty of GRI program funding and its recovery by GRI members are under consideration. This flexibility continues to be the key element in preserving GRI's funding base and its excellent rapport with the state and federal regulatory community.

Reasons for the Gas Research Institute's Unique Success as a Research and Development Consortium

GRI's measure of success from the outset was the ratio of the present (discounted) value of the quantifiable benefits derived by gas consumers from its R&D program, divided by the present value of contract R&D expenditures and operating costs. By insisting on this measure, GRI was able to reject the "pork barrel" projects that plague the R&D programs of governments and even

[7] As part of FERC-approved interstate gas transportation tariffs, the GRI funding unit has remained beyond the reach of State commissions even after the unbundling of pipeline services, thanks to the filed rate doctrine.

private consortia. GRI's benefit-cost ratios have consistently run in the 4:1 to 8:1 range, far above what is typically achieved in comparable government and industrial R&D programs. These ratios would be even higher if, in calculating the ratepayer benefits, GRI were to include not only the fuel and capital cost savings associated with new products, processes, or techniques over their economic life, but also such benefits as productivity increases, the ability to perform entirely new functions, improvements in environment and safety, and increased economically recoverable domestic gas resources. Benefit-cost ratios would be further increased if they were based only on the R&D expenditures for completed projects, rather than on the present value of all contract R&D expenditures and operating costs.

Numerous studies of the reasons for GRI's success have been conducted on behalf of FERC by the DOE, the General Accounting Office, the National Research Council, and GRI contractors, as well as by independent investigators (24). This success is not only captured by GRI's benefit-cost method of self-assessment, but also by more conventional measures, such as the project success rate, which is 30%, or more than twice the US industry-wide average. Much of the credit for our high project success rate belongs to William M Burnett, now GRI's senior vice president for supply and operations programs, who came to us in 1978 via ERDA and DOE and who became the key architect of our program planning methodology. However, I take pride in having set a course for GRI, with the help of my original associates, that I believe accounts for our superior performance. Among the critical principles of successful R&D consortium management that we established are these five:

1. No in-house R&D capabilities or facilities, to avoid creating a vested interest in pursuing projects with limited potential. All R&D is contracted to competent performers on a competitive basis, except cases in which the need for sole-source solicitation can be fully documented.

2. Minimum in-house staff, restricted to performing essential functions such as planning, contracting, contract management, fund-raising, regulatory and government interface, technical communications, and advisory-body liaison. Total operating expenses for these purposes limited to no more than 20 and, preferably, 15% of total budget.

3. A rigorous project appraisal methodology, capable of rank-ordering a large universe of projects addressing gas supply, transport, storage, and end-use, developed through internal analysis and expert advisory-body inputs, embodying quantified probabilities of technical and commercial success and expected benefits and costs at various funding levels.

4. Annual formulation of an R&D program, constituting whatever mix of projects rank-ordered in conformance with this project appraisal methodology remains above the budget cut-off point. Some judgmental decision-making is allowed for projects whose ranking places them marginally above or below this cut-off point, especially in respect to their relative prospects for commercialization. Judgmental considerations also govern the allocation of a 10–13% set-aside for basic research and the selections from among cross-cutting environment and safety projects.

5. No funding of a project beyond proof-of-concept, unless there is a clear-cut commercialization path, and then usually only if there is direct participation by an industrial partner.

The application of these principles led to numerous early successes in the end-use area, where R&D investments in cost-effective efficiency improvements to counteract rapidly rising gas prices received the highest rankings. As a result of breakthroughs such as the commercialization of the 96% efficient pulse-combustion furnace, the rapid decline of gas market share in heating of new homes was reversed from a low of less than 40% in the late 1970s to nearly 70% today.

But the biggest success of GRI and its rigorous project selection process resulted from the identification of so-called unconventional gas sources as a promising target in the early 1980s. Although this approach conflicted with the prevailing consensus, we decided to aim much of GRI's gas supply R&D toward the huge amounts of gas locked in low-permeability formations and unmineable coal seams. At the time, these sources of gas supply were not even identified as separate categories of the recoverable US resource base in assessments by the US Geological Service and by the independent group of industry, government, and academic experts of the Potential Gas Committee. More than 400 Tcf of technically recoverable natural gas has since been added to the domestic resource base, in good part because of GRI-sponsored R&D and in-house analyses that generated confidence among producers and policymakers that these large domestic hydrocarbon resources had economic potential. The availability of this gas has extended resource life at current rates of consumption by 20 years and considerably reduced expectations for escalation of annual average wellhead prices above their recent upper bound of about $2.00 per Mcf. If this additional 400 Tcf of potential supply proves to be worth only 10 cents per Mcf to gas ratepayers, the resulting $40 billion benefit would more than pay for GRI's program over its entire likely existence.

Moving from Contract Research & Development Management to Academia

Through my outside board service, I had been thoroughly indoctrinated with modern principles of corporate governance, which require chief executive officers to retire no later than at age 65 and to get out of the way of their successor. For this reason, I retired promptly upon reaching this age in 1987. To prove that there is life after a long career as a not-for-profit research institute manager, I became involved in the affairs of IIT, on whose faculty I had held various nontenured positions since 1954. This arrangement gave me the freedom to pursue my rather heretical views on the benefits of the electrification of energy supply and end-use and on the likely positive impact of carbon dioxide (CO_2) emissions from fossil fuel use on the global ecosystem. I also developed the energy-environment-economy paradigm as the logical successor to the least-cost energy service strategy, helped incorporate it as an interdisciplinary specialization in the undergraduate and graduate engineering curricula, and talked and wrote extensively on this subject (20, 23, 25).

In spite of my new-found affinity for electricity, my colleagues and friends in the gas industry, who had so loyally supported me during my 40 years with IGT and GRI, did not shun me. I still serve GRI as Executive Advisor and, following a six-year stint as a member of the Advisory Council of EPRI, now also serve as a member of GRI's Advisory Council. IIT offered me a chair, first as Frank W Gunsaulus Distinguished Professor of Chemical Engineering and then, when I was able to obtain an endowment from the McGraw Foundation, as Max McGraw Professor of Energy and Power Engineering and Management and as Director of IIT's Energy + Power Center. I made full use of academic freedom in publishing a series of papers highly critical of past and current US energy policy and, beginning in 1990, attacking what I consider to be hysteria about global warming (26–29).

From the self-interested point of view of the gas industry, attacking the hypothesis of global warming is not only contrarian but also heretical: The gas industry likes to claim, among the benefits of gas relative to coal and oil, that producing energy from gas involves the lowest value of CO_2 emissions per unit of energy. Gas-fired combined-cycle turbine power generation emits as much as 50% less CO_2 than conventional coal technologies for the same electricity output, a fact with considerable political value and, potentially, monetary value if carbon taxes are ever imposed and methane emissions traceable to natural gas production, transport, and end-use are as minimal as currently indicated. (Methane is also a greenhouse gas, and it has 20 times the potency of CO_2.) Although this line of argument is correct, many other claims about the environmental benefits of natural gas are, in my view, much more credible.

In my new academic career, I was often diverted from my primary interest in energy and environmental policy by administrative duties: first as acting chairman of the Chemical Engineering Department, then, from 1989 to 1990, as Interim President and CEO of IIT, as Interim Chairman and CEO of IIT Research Institute (IIT's contract R&D subsidiary), and more recently as a fund raiser and developer of new educational and research programs. I also served on six corporate boards until I reached the applicable compulsory retirement age. I am now down to only two. Being a member of the board of directors of some major US corporations (Sonat Inc., Reynolds Metals Co., UGI Corp., and The AES Corp.) has been as important and formative a part of my career as being involved in energy technology and policy. For an executive of a not-for-profit organization like myself, corporate board service offers badly needed psychic support and financial rewards.

Taking On the Global Warming Alarmists

I close this autobiographical essay with a discussion of my two latest forays into areas of science and technology far afield from chemical engineering but intimately related to energy and environmental policy. The first concerns deleterious anthropogenic global climate change, an issue near and dear to the anti-energy, anti-growth elites and their allies in the population control movement. Their scenarios of rising temperatures, droughts, melting polar ice caps, flooding of coastal areas, and other natural disasters, each avoidable only if the use of fossil fuels is sharply curtailed, are reminiscent of the Club of Rome problematique. The potential impact of their proposed solutions on human well-being is equally frightening. Simply put, even the nominal agenda of merely rolling back global greenhouse gas emissions to 1990 levels and holding them there would be an unmitigated social and economic disaster for the developing world (30). The actual agenda of stabilizing atmospheric greenhouse gas concentrations would require a cutback in emissions on the order of 60%. Such a cutback would essentially destroy the entire global economy, especially if revival of the nuclear option—taboo among those advocating this course—is ruled out.

I believe the case against embarking on such a destructive course in the absence of definitive evidence of anthropogenic global climate change per se, or of its potential detrimental effects were it to materialize in accordance with the latest, less threatening scenarios, has been adequately made in the literature. Nevertheless, the more alarmist interpretations of this threat by the IPCC continue to be widely accepted by the scientific community, the media, and most national governments. IPCC, jointly established by the United Nations Environment Programme and the World Meteorological Organization in 1988, has produced two key studies: the 1990 Scientific Assessment (31) and the 1992

Supplementary Report (32). These studies projected a 1.5°–4.5°C increase in global mean temperature with doubling of the CO_2-equivalent concentration of greenhouse gases in the atmosphere at a rate of 0.2°–0.5°C per decade, and at a most likely rate of 0.3°C per decade. However, in the latest IPCC reassessment—the 1995 IPCC Synthesis Report—the projected temperature rise has been lowered to 0.8°–3.5°C by 2100, with a corresponding lowering of the rate of warming, primarily due to the moderating effects of aerosols (33). This projection seems to further reduce the urgency for stringent CO_2 emission control measures, especially if, as claimed in the Synthesis Report, temperatures would still increase by 0.5°–2.0°C even if atmospheric concentrations of greenhouse gases were immediately stabilized.

The rationalization of the 0.3°–0.6°C temperature increase over the past century in the 1995 Synthesis Report is also more tentative: The increase is characterized as "unlikely to be entirely due to natural causes." Furthermore, the Report avoids overly alarmist statements about weather extremes caused by human activities on a global scale ("little evidence of sustained trends in variability or extremes of weather events such as hurricanes and floods"), but it does contain a rather puzzling assertion that on a regional scale there is "clear evidence of changes in them." Regional changes should translate into cumulative global changes. Finally, the lower bound of the newly projected increase in sea level rise of 0.1 to 0.8 m by 2100 is substantially less than what would occur if the 3–10 cm per decade projection of the 1990 Assessment were to materialize. The new upper bound of 0.8 m still lacks credibility because of published studies that sea levels may actually fall because of arctic ice mass increases (34). Whether atmospheric CO_2 concentrations will increase to the stabilization levels projected by IPCC on the basis of projected cumulative carbon emissions of 770 to 2190 Gtons between 1990 and 2100 is unclear. Evidence is growing of a much greater than anticipated capacity of the terrestrial biomass to sequester anthropogenic carbon emissions, perhaps as much as half of the current annual quantity (35). The capability of the oceans to sequester CO_2 is also far from settled, keeping the issue of the growing "missing sink" for anthropogenic carbon emissions a subject of lively scientific debate.

In spite of the widespread support of IPCC's positions, as expressed in its "Policymakers Summaries," regarding the magnitude and seriousness of the consequences of anthropogenic climate change, they have not gone unchallenged (36–41). I found *The Greenhouse Debate Continues: An Analysis and Critique of the IPCC Climate Assessment*, edited by S Fred Singer (36), especially convincing. More recently, the George C Marshall Institute published another well-documented rebuttal of the IPCC orthodoxy (37). Prestigious science journals have also criticized IPCC's tendency to digress from the substance of the scientific findings of its working groups in its press releases and "Policymakers Summaries" (38–40). The latest such incident occured in the wake of the mid-Spetember 1994 meeting of IPCC's Working Group I in Maastricht, The Netherlands. I am pleased to have participated in an initiative that succeeded in raising questions about the overly alarmist interpretations of the findings of Working Group I. The other, more prominent contrarians involved in this initiative were Frederick Seitz, president emeritus of Rockefeller University and former president of the National Academy of Sciences; William A Nierenberg, director emeritus of the Scripps Institute of Oceanography; S Fred Singer, professor emeritus of environmental sciences, University of Virginia; and Chauncey Starr.

Another vocal dissenter from the orthodoxy on global climate change is Patrick J Michaels, former chief editor of the quarterly *World Climate Review* and now chief editor of its successor, the *World Climate Report*, both published by the Department of Environmental Sciences of the University of Virginia. These publications have provided invaluable data and analyses supporting the contrarian cause. Probably the most prestigious contrarian who has helped me to understand the complex scientific issues is Richard S Lindzen, Sloan Professor of Meteorology at MIT (41).

Based on these inputs and my reading of the relevant literature, I have made my own rather inexpert contributions to this critical debate (22, 42, 43). First, I do not find the evidence convincing that the global temperature variations of the recent past are traceable to human activities, rather than being random variations typical of those experienced during the current (Holocene) interglacial period. After all, most of the increase in mean global surface temperature since the Industrial Revolution occurred prior to 1940, when anthropogenic CO_2 emissions and atmospheric accumulations were still very small. There is also evidence that the temperature increase has taken the form of an environmentally benign rise in minimum and nighttime temperatures. Second, I interpret the analyses of paleoclimatic data in the literature cited in my articles above (22, 42, 43) as suggesting that past variations of atmospheric CO_2 concentrations have had negligible impact on global temperature changes; rather, these variations were apparently a consequence, not a cause, of the many large and often very rapid temperature fluctuations during the past 250,000 years. Third, I challenge the consensus prediction that a doubling of the CO_2-equivalent concentrations of greenhouse gases in the atmosphere would cause a $1.5°–4.5°C$ increase in global average surface temperature without correction of the effects of aerosols created by human activities, or even that rising greenhouse gas concentrations would cause an increase of $0.8°–3.5°C$ by 2100 including these effects. These predictions depend on assuming particular positive feedback effects due to the water content of the atmosphere in various forms: water vapor and clouds are responsible for 97% of the greenhouse effect. Inadequate weight is given to negative feedback effects. Without any assumed feedbacks, radiative forcing caused by doubling of CO_2-equivalent concentrations of greenhouse gases would cause only a 1.2°C temperature increase.

Fourth, contrary to model predictions, the arctic ice mass has been growing and arctic temperatures have been decreasing for the past 40 years. Therefore, I doubt the orthodox, catastrophic sea level rise scenarios. Climatologists and oceanographers point out that sea levels will fall to the extent that snowfall on the ice in the Arctic and Antarctic increases and accumulates. Fifth, the emissions required for atmospheric CO_2-doubling may be substantially greater than the orthodox assumptions because of the capability of the terrestrial biomass, and perhaps the oceans, to sequester larger than anticipated amounts of anthropogenic carbon emissions. Sixth, NASA satellite observations since 1979 have shown no increase (and, in fact, a small decrease) in the mean temperature of the lower troposphere from the surface up to 15,000 ft, throwing considerable doubt on the accuracy of ground-level measurements, as well as of model projections which exceed both. Finally, how can we know how to intervene in the global energy system today, when by 2100 it will differ from today's as much as today's differs from that in the late 1800s?

My Embrace of Industrial Ecology as a Rational Environmental Ethic

My commitment to the principles of industrial ecology and its companion concept—design for environment—stems from a July 1992 workshop held at the National Academy retreat in Woods Hole, Massachusetts. The workshop was under the auspices of the Technology and Environment Program of the National Academy of Engineering (NAE), in which I had been involved for some time. The individuals primarily responsible for organizing this workshop and its follow-up were Brad Allenby, now research vice president, technology and environment, of AT&T; Robert A Frosch, then still vice president in charge of General Motors Research Laboratories and now a senior research fellow at the Harvard JFK School of Government and a senior fellow of NAE; and Deanna Richards, senior program officer of NAE. The workshop led to *The Greening of Industrial Ecosystems* (44), for which I wrote a chapter called "Energy and Industrial Ecology," one of my best and most balanced pieces on the impact of the global energy system on the natural and human environment (16). I owe my participation in this workshop and many other opportunities to learn about industrial ecology to Robert M White, at that time president of NAE, who treated with unusual forbearance my contrarian and often somewhat extreme positions on issues that he and the National Academies have approached with much greater caution and scholarship; most notably, global climate change.

Industrial ecology and design for environment are twin concepts for bringing industrial development, economic growth, and the associated consumption of air, water, land, and mineral resources into harmony with the natural environment. The objective is to minimize those dissipative material flows into the biosphere that originate from human activities, in a technically, economically, and behaviorally feasible manner. Sustainable development is a more concise way to express this goal. Eventually, zero net flow might be achievable, mimicking the natural ecosystem.

Sustainable development recognizes that human well-being has been and will continue to be improved through scientific and technological advances that are often highly energy intensive. In earlier days, introduction of new technologies often increased the emission of pollutants and the generation of wastes, although the benefits nearly always exceeded the social costs by a wide margin. However, in the industrialized West and most of the Pacific Rim, technological development is no longer accompanied by increased environmental impact. In fact, the opposite is generally true, because the basic paradigms of industrial ecology have already gained wide acceptance. Even in developing countries such as China and India, industrialization has proved to be environmentally beneficial, because coal and other polluting fuels used in primitive domestic, commercial, and industrial applications are being gradually displaced by modern end-use technologies powered with oil, gas, and electricity. Moreover, because poverty is truly the most pernicious environmental and social pollutant, industrialization also brings environmental benefits to these countries by leading to greater, more equitably distributed wealth. Nevertheless, the associated, more intensive use of natural resources raises concerns for the long-term impacts on the global ecology. Excessive destabilization of the ecosystem could have adverse impacts on human well-being so severe that they might eventually outweigh the benefits of economic and social progress that are taking the form of greater affluence, consumption, and physical mobility.

Industrial ecology and design for environment address this inherent conflict between growing population and consumption and the stability of the global ecosystem by a set of innovative approaches intended to lead to sustainable development. These approaches embody a faith in technological progress—a faith fully justified by the environmental achievements of the United States, the industrialized countries of Western Europe, and the Pacific Rim over the past two decades. The key element is cost-effective minimization of the flow of waste materials—gaseous, liquid, and solid—into the natural environment: in other words, a commitment to pollution prevention rather than cleanup;

substitution of economically recyclable raw materials, such as aluminum, for materials whose cost of recycling exceeds their value; and design of products to make them inherently recyclable or environmentally benign. In the energy sector, which is responsible for so much of the use of nonrenewable resources and for the generation of atmospheric pollutants, the solutions have already become apparent. They are:

1. Continue the dramatic efficiency improvements that are driven largely by market forces and technology advances.

2. Follow the US lead in aggressively deploying control technologies that sharply reduce or eliminate fossil fuel emissions of sulfur and nitrogen oxides, reactive volatile organic compounds, and toxic heavy metals from stationary and mobile sources.

3. Accelerate the ongoing trend of decarbonization and electrification of the global energy system.

Today's surface transport technologies play a unique role in enhancing the quality of human life, but making them compatible with sustainable development may prove difficult. I have become an advocate of aggressive R,D&D to achieve commercialization, within the next 50 years, of technologies that triple the current levels of efficiency while achieving zero emissions, typified by hybrid fuel-cell/battery systems using synthetic methanol or hydrogen as the energy source. I am not motivated by concern over the inadequacy of petroleum-based fuel supplies over this period, nor by a lack of enthusiasm for reformulated gasoline as a sensible interim solution to reducing automotive emissions in urban areas. Rather, I am troubled that we are still using 100-year-old technology for automotive transport, a rather puzzling situation when compared to the revolution in air transport technologies over a much shorter time frame. The development of electrochemical transportation technologies has, therefore, become a major part of my activities at IIT.

Concluding Comments

At this late stage in my long journey through the energy world, I have learned to cope with the dilemma of self-interest by simply declaring any biases and potential conflicts up front. Of course, this does not pose much of a problem for an academician funded primarily by unrestricted grants and an endowed chair. As a confirmed neo-Ricardian, I have also become quite comfortable with the notion that a primary focus on improving the human environment through science and technology will also preserve the critical functions of the natural ecosystem. After all, Western Europe is essentially a theme park—a very livable theme park—where the only natural environment left after millennia of intensive human habitation is at the highest elevations of the Alps, Pyrenees, and other mountainous regions. Preoccupation with the preservation of wilderness areas and biodiversity, without consideration of the impact on human well-being, is a luxury only American elites can enjoy. The obvious sustainability of the largely man-made environment of Western Europe, where biodiversity is found primarily in zoos, demonstrates how irrelevant these American preoccupations are to most measures of quality of human life. The dismal conditions of human existence in the developing world make these American elitist priorities not only irrelevant but immoral. The environmental havoc caused by the Marxist dictatorships in their extremely energy-inefficient approach to industrial development does not invalidate these positions, but merely confirms the fatal flaws of command-and-control policies.

To treat humans simply as another species, undeserving of their ability to exert dominance over nature, yet responsible for stopping the evolutionary process, runs counter to well-established philosophical and religious precepts. This position also ignores the fact that most species that have inhabited the earth have become extinct owing to perfectly natural causes. I believe that humans are, indeed, the "crown of creation," destined to control their environment in ways that allow them to be fruitful and multiply. To quote Thomas Palmer, a well-known naturalist: "If biodiversity is regarded as the chief measure of a landscape's richness, then the American continents reached their peak of splendor on the day after the first Siberian spearman arrived, and have been deteriorating ever since" (45).

Unfortunately, Club-of-Rome-type, Malthusian thinking still shapes the liberal energy and environmental policy agenda. Such thinking fails to acknowledge the powerful roles that science, technology, and free markets play in rendering global disaster scenarios invalid or irrelevant. Just as human ingenuity disproved Pastor Thomas Malthus' 1798 thesis that the "power of population" greatly exceeds the "power of the earth to produce subsistence" and must lead to a "giant, inevitable famine," today's confident predictions of inevitable exhaustion of physical and ecological resources and an ever-widening gap between the rich and the poor due to unconstrained population growth and consumption will be invalidated by science and technology. As George Gilder has stated so aptly: "capitalist growth is based on environmentally benign replacement of matter and energy with knowledge and ingenuity." Thus, the claims that China, India, and the rest of the developing world can attain a Western standard of living only at the cost of ecological ruin, and that only redistributive socialism, taxation, regulation, and more bureaucracy can save the planet, are simply not true.

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