THE MAKING OF AN ENERGY ANALYST: SOME PERSONAL REFLECTIONS

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Running Head: Making of an Energy Analyst

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Introduction (1)

I was born in 1930 in the South Indian city of Bangalore, which was then known as a pensioners' paradise and as a garden city with its greenery and parks. Its climate was salubrious and I never saw a ceiling fan until I was in my teens. I used to walk a couple of miles to school through the center of town, without my parents fearing that I would be run over. Today, Bangalore is the IT capital of India, choked with vehicular traffic and highly polluted. Bangalore always had excellent schools and colleges. I did my schooling in a Jesuit institution, St. Joseph's, with the motto: *Faith and Toil*. There, I was fortunate in having an outstanding and inspiring science teacher, Alec Alvares, who created in me an abiding love of science and the importance of systematic work. The interest in science was strengthened during my late teens by my close friendship with Radhakrishnan and Ramaseshan from the family of Professor Raman, the Nobel Laureate in Physics. I went on to do my B.Sc. (Honors) in Chemistry and M.Sc. in Physical Chemistry in Central College, Bangalore, after which I went to U.K. to do my Ph.D.

Electrochemistry research (1955-1973)

The first 18 years of my research career were devoted to electrochemical topics. The work was carried out at four venues (1) -- the Applied Physical Chemistry Laboratory of the Department of Chemical Engineering, Imperial College of Science and Technology, London, where I did my Ph.D. from 1955 to 1958; the Central Electrochemical Research Institute, Karaikudi, South India, from 1958 to 1961; the John Harrison Laboratory of the University of Pennsylvania, Philadelphia, USA, from 1961 to 1965; and the Department of Inorganic and Physical Chemistry, Indian Institute of Science, Bangalore, India, from 1965 to 1973. A principal focus of my work was the structure and growth of electrodeposits (2) and *in situ* optical techniques for the study of anodic films (3).

The most well known product of my electrochemistry work was the two-volume textbook ***Modern Electrochemistry*** (4) that I co-authored with J.O'M. Bockris. The book was both an agony and an ecstasy. The agony consisted of interminable discussions ending up with marginal changes, the draft after draft, the continuous expansion of content, the weeks stretching into months and the months into years, the constant tension, the massive intrusion into family life, etc. The book dragged on from 1964 till I returned to India in 1966 but it was finally finished only in 1969. The ecstasy consisted of my discovering electrochemistry for myself, being excited about what I learnt and communicating a fresh account of that learning. It was this excitement and freshness that readers found attractive and stimulating. They found it excellent for self-study. For a technical book, it was a best seller and a money-spinner. Above all, it made me well known in the world of electrochemistry.

The Shift from Electrochemistry

After six years in the USA as a Post-doctoral Fellow and Research Supervisor, a number of research contributions and the two-volume textbook, I joined the

Department of Inorganic and Physical Chemistry, Indian Institute of Science in 1965 as an Assistant Professor. It was wonderful returning to my hometown Bangalore.

I began electrochemical research at the Institute with a team of students. Experimental work was hard going. Facilities had to be built up. And funding was scarce. Eventually, most of the students got their Ph.D.s. During this period, ***Modern Electrochemistry*** came out in print. I was made a Professor. I was also elected a Fellow of the Indian Academy of Sciences. The many invitations per year to speak at international conferences were some measure of success. But, my research had no grand theme. Gradually, a conviction grew in me that most of the fundamental discoveries in electrochemistry had already been made, and it had become an applied science. So, I tried to give my research an applied thrust. With an innovative colleague, Sathyanarayana, I took up the indigenous development of batteries without the disadvantage of the short shelf life of the common zinc-manganese dioxide 'dry cells'. We turned to the magnesium-manganese dioxide system with its long shelf life and started getting some success.

1973, however, was a year of personal crisis. Firstly, we came to know that the magnesium-manganese dioxide system that we were developing was being tested in Ladakh bordering Tibet. That information upset me because I realized that our work was part of a defense effort against the Chinese and I felt that the people of India had no quarrel with the people of China. I did not want any part of this type of scientific relevance.

Secondly, it became clear to me that the electrochemists whom I had attracted to the Department of Inorganic and Physical Chemistry would never gel into a cohesive school however outstanding their individual work. I realized that my dream of building a center of excellence in electrochemistry would not be achieved. It was only two decades later that I heard the saying: "One Indian = three westerners; one westerner = three Indians" which implies that, in typical situations, Indians are individually brilliant but hopeless as a team because they do not work together. Not only do they produce no synergism, but the whole may even be less than the sum of the parts.

In this crisis, there occurred a rare event, a single experience that altered my whole pattern of thinking. I heard a lecture on *Poverty in India* by the economist, Professor C.T. Kurien, at the Ecumenical Christian Center, Bangalore, in which he said that poverty had increased with industrialization. This observation shattered my faith in the dictum of India's first Prime Minister, Jawaharlal Nehru: more science and technology $\rightarrow$ more industrialization $\rightarrow$ less poverty.

A period of intense intellectual searching began. It was neither organized nor focused. I was really groping. I took a small step forward when I presented a paper in 1973 entitled *An Asian Science to combat Asian Poverty* (5) at the *One Asia Conference* in Delhi organized by the Press Foundation of Asia. I argued that the industrialization-poverty nexus arises from the capital-intensive labor-saving nature of the pattern of industrialization based on imported Western technology and that an attack on poverty required a different science and technology. My paper attracted favorable attention at the conference from several scholars there including the Swedes, Gunnar and Alva Myrdal.

The real personal "break-through" occurred in 1973 at Bangalore. The Minister for Science and Technology, C. Subramaniam, was organizing conferences of scientists to get reactions to the document of the National Committee on Science and Technology (NCST) entitled *An Approach to the Science and Technology Plan.* My paper to the *One Asia Conference* was brought by Ramaseshan to the attention of the host for the Bangalore Conference, Satish Dhawan, who included me as a discussant of the NCST paper.

In my discussant's paper *Choice of Alternative Technologies* (6), I argued that India was a dual society with "islands of elite affluence amidst vast oceans of poverty of the masses". I went on to say that this poverty was primarily due to inadequate income-generating employment in the rural countryside, and that such employment would not come from capital-intensive industrialization with its low ratio of employment created to capital invested. I criticized Indian science and technology for allying itself with the elitist pattern of industrialization and demanded that it should devote itself to the generation of an alternative pattern of capital-saving labor-intensive technologies of relevance to the rural poor. While the essence of this argument is still valid, I soon realized that one must also consider the down-stream benefits of investment. Thus, capital-intensive chip manufacture can generate considerable down-stream employment in the services sector.

Remembering the hero of Jack London's *The Iron Heel* addressing the capitalists club, I expected to be attacked by the scientists, but to my surprise, my presentation was received with thunderous and prolonged applause. One is fortunate if there are a few such moments of glory in a lifetime. But the applause was not for me; it was primarily because I had echoed concerns shared by a large number of people. There was an interesting episode during the ensuing discussion -- a well-known industrialist criticized me saying "Reddy is asking us to go backwards!" and the Minister, who was chairing the session, jumped up and said: "No! No! He is taking us forward!"

But, what was really gratifying was the large number of faculty from the Institute who came to me after my presentation to express agreement. Even more important, they declared a desire to do something to implement an alternative science and technology.

It was then that I made the decision to quit electrochemistry in favor of rural technology. I felt that I had to burn my bridges. Otherwise, if things became difficult in rural technology, as I was sure they would be, I could escape into the cocoon-like expertise that I had built up in electrochemistry. At that time, I could start from "zero" and derive any one of the equations in the two volumes of *Modern Electrochemistry.*

The Formation of ASTRA (1974-75)

A cell for the Application of Science and Technology to Rural Areas was created in the Indian Institute of Science in 1974 to initiate and promote work of rural relevance as a weapon against poverty. It became known by its acronym ASTRA, which means “weapon” in Sanskrit. Quite deliberately, it was designed as a multi-disciplinary effort drawing on the expertise from the various discipline-oriented departments. Major presentations were made to the faculty and students and, at the instance of the Institute

Director, Satish Dhawan, to the Senate Committee on Research and Academic Policy. Those were heady days. The best and the brightest in the Institute worked for ASTRA or supported it. Its open seminars were widely attended. A number of projects were initiated, many in the area of energy. There was camaraderie. ASTRA was an interacting community of scientists and engineers. It had discovered how to build a team out of Indians -- create a shared vision. But, the vision must be grand enough to inspire, and the vision had to be shared.

Unfortunately, the immediate appreciation of ASTRA's work and efforts in many national and international quarters was in sharp contrast to the scorn and disdain of many leaders of the scientific establishment in India. It was all right to make at the NCST meeting -- as one distinguished scientist did -- an insightful and passionate exhortation: "We as scientists are intelligent observers. What we lack is direct exposure. So, all that we need to do is to live for some time in a rural environment and we will be able to identify the problems." But, once ASTRA tried to implement that very suggestion, exhortation became denigration. Was it because ASTRA was rocking the boat of conventional science, setting an uncomfortable example and becoming a threat with its demand for a new orientation to science and technology? Was it because ASTRA was changing the paradigm for scientific work?

The Director of a prestigious scientific institution publicly declared that those who were failures in science took to rural technology. The Editor of a well-known Indian scientific journal said: "What Reddy is doing is not science. I will never publish him in my journal!" It was not easy going. Mentors became tormentors, friends became foes, and colleagues became critics. The intensity of the critique increased as national and international recognition for ASTRA's work grew. The situation was aggravated by the BBC film *West of Bangalore* that publicized ASTRA worldwide. At the national level, I was awarded the Rathindra Puraskar, a prize in memory of Rathindranath, the son of Rabindranath Tagore. After hearing the citation, Prime Minister Indira Gandhi said to me whilst giving the award: "It must have required rare courage!" In contrast, some leftist friends jibed: "This rural technology is a trick of the industrialized countries to keep us in the bullock-cart age! See, the World Bank is supporting it." By the same token, they should have rejected the dams, the power stations, etc., all of which were funded by the World Bank… but they did not.

Those who want to change a paradigm must be prepared for a long and lonely struggle. There was neither a Gandhi nor a Raman to turn to for support. However, there were some steadfast, albeit tacit, supporters among the scientists -- Satish Dhawan was a beacon among them -- and some fellow-scientists like C.V. Seshadri who decided to join the shift to rural problems. Above all, my wife Vimala was "constant as the northern star!" What the ASTRA workers had in abundance was conviction in the path they had chosen and faith that they would succeed. This faith was a crucial source of strength. In the ultimate analysis, faith is what keeps us going when there is no hint that our efforts will succeed and no evidence to justify what we are doing. Fortunately, the villagers in the areas where we worked developed faith in ASTRA.

And ASTRA maintained a publication record. Apart from a stream of concrete and conceptual papers (7, 8), I edited an Indian Academy of Sciences monograph on ***Rural***

Technology (9) that attracted wide attention. It was even suggested that rural technology could become the theme of a separate journal but those struggling to get articles for conventional journals felt that this would undermine their journals.

Appropriate Technology at UNEP (1975-76)

In 1975 I went on sabbatical to the United Nations Environment Programme (UNEP) at Nairobi, Kenya. Before I went there, I was assured that I could make several trips to India to keep in touch with ASTRA. Things did not work out as planned. After landing in Nairobi, I found that the management had changed. I was grounded.

The good news was that UNEP asked me to develop a conceptual framework for environmentally sound and appropriate technologies. It thereby provided me with a tremendous opportunity to think about the inherent characteristics of western technology and about the nature of development.

The first thing I learnt was that development must not be equated with mere economic growth (as measured for instance by GDP). Genuine development is a process of economic growth that is directed towards *equity* -- the satisfaction of basic needs, starting with the needs of the neediest, *empowerment* -- the strengthening of self-reliance and *environmental soundness* -- harmony with the environment. This understanding of development stood me in good stead for almost two and a half decades. However, the recent controversy over the Narmada valley projects has forced me to include in the definition of development an insistence that *the benefits of development projects must start with the people at the project sites and then radiate outwards*. Otherwise, the very people at the epicenter of the projects become the victims of development. Further, with my growing understanding of the importance of women as agents of development, and indeed its main objective, I now insist on *engenderization* as a crucial element of the development process.

I also came to the view that however attractive modern technology may be, there have to be special safeguards against its intrinsically unwelcome tendencies of amplifying inequalities, alienating people from their work and from each other, and degrading the environment. All this went into my UNEP publication ***Technology, Development and the Environment -- a Reappraisal*** (10). This tract was seminal for the evolution of my perspective, but unfortunately it was not disseminated widely.

Rural Energy consumption patterns (1977-81)

I returned from sabbatical in 1976 after resisting the temptations of a UN job. I plunged into ASTRA work. An Extension Center was established at Ungra, a village about 120 km from Bangalore, and we began our studies of the Ungra village ecosystem with Ravindranath as a valuable lieutenant and an excellent team including Somasekhar. The team lived in the Ungra Extension Center. We did what was probably the first detailed empirical study of energy consumption patterns in third world villages (11).

Interestingly, these consumption patterns highlighted the importance of kerosene for lighting in unelectrified homes. It also showed that in order to make this lighting source accessible to the poor, kerosene had to be subsidized. But this subsidy had the associated effect of forcing diesel fuel to be subsidized and tilting the economics of goods transport against railways and in favor of trucks (12). Thus, a key to the country's oil import problem lay in the rural domestic sector -- an interesting example of unforeseen inter-sectoral energy interactions.

Our energy consumption studies owed a great deal to the late J.P. Naik, then Secretary, Indian Council for Social Science Research (ICSSR). During a coffee break at a Delhi meeting, I mentioned to him that we knew far more about how energy is used in London or New York than in villages 10 km away from the Indian Institute of Science. We would like therefore to study the sources and end-uses of energy in Indian villages. He promptly asked me how much money we needed and in a few days we had an ICSSR grant. Such visionary and generous people are rare -- but for them, pioneering and non-conventional work would not take place and mavericks could not survive.

From energy consumption patterns in villages, we went on to deepen our study of village ecosystems (13, 14) and to design (15) and build rural energy centers. The ecosystem work required a great deal of survey work and analysis of data.

At the height of our activity, Vimala and I made weekly visits to the Center lasting a couple of days at a time. We used to live in a 30 square meters house with no furniture, electricity, running water and flush toilets, but those were among the happiest days of our life. It is not irrelevant to mention here the importance of the spouse in unorthodox ventures such as ASTRA – it is difficult to fight a battle in society unless there is unqualified support at home. And Vimala gave me this in abundance!

The discussions were excellent and the learning process was intense. We gained many insights. Copying from the West is the conventional approach in India to academic knowledge but we found that learning from the immediate environment is certainly a more powerful heuristic.

Unfortunately, much of the work (for example on animal energy utilization (16) and the role of women in agriculture) was not published even though it was written up by my colleagues. The blame was entirely mine for this sin of omission of quitting a field/activity before writing up the papers. By taking up a new venture of global energy studies before completing the previous one of publishing our ecosystem studies, I landed in a common situation where the urgent takes precedence over the important.

Biogas-based Rural Energy Centers (1981-83)

One of ASTRA's first outputs was the 1974 paper on *Biogas Plants -- Problems, Prospects and Tasks* (17) published in the premier Indian policy journal, *Economic and Political Weekly*. The paper had some errors, but it said many important things that still remain valid. For instance, it showed that the official biogas program based on family-scale biogas plants would neither make a dent on the energy problem nor spread beyond the rural elite. It revealed the economies of scale associated with community biogas plants. Though it was merely a paper exercise, it immediately attracted international and national attention. On the international front, it was widely cited.

Unfortunately, the national biogas program felt that we were poaching into its reserves. And so, I discovered an important problem of the sociology of science, perhaps not unique to India -- subjects become territories, and when "outsiders" work on a subject, they are treated as invaders. A good deal of the problem arises from the fact that these "outsiders", with extremely limited manpower, money and resources, but with the dedication, freshness and innocence of newcomers, achieve far more than large establishments set up for the subject. Thereby, they expose the ineffectiveness of Big Science and its bureaucracies; hence, they are a threat. But, their competition is essential for progress, and it can come mainly from universities, which is why these institutions must be nurtured.

The biogas paper also revealed that there were new allies of whom we had been unaware. Professor K.N. Raj, the distinguished Indian economist, called on me at my home to commend the biogas paper and to encourage us to continue work at the technology-economics interface. He went on to invite me to give seminars at the Center for Development Studies, Trivandrum, and join the Governing Body of the Center, an association from which I am just retiring. This inspiration and encouragement from a well-known economist was extremely important for making us feel that what we were doing was important and the way we were doing it was right. The point is that rural technology was forcing us to work in new areas with economics and sociological implications. We went in with great trepidation thinking "Fools rush in where angels fear to tread!" But, many eminent economists were very positive to our writings. I particularly recall the famous Cambridge economist Joan Robinson telling me when I diffidently expressed my ignorance of conventional economics: "Don't worry, you are doing fine!"

I have always been impressed by the saying: *Think globally, act locally*. The challenge of designing and building rural energy centers led ASTRA as early as 1979 to the community biogas plant project at Pura village, 2 km from our Ungra Extension Center. During the first phase of this project, we attempted to provide all the households of the village with piped biogas for cooking. We failed because of an overestimation of cowdung resources and an underestimation of biogas requirements. When I was away on sabbatical at Princeton in 1984, the project came to a standstill. However, on my return, the villagers petitioned me to restart the project with the emphasis on drinking water. This was done with invaluable support from my colleagues Rajabapaiah, Somasekhar and Jayakumar and with funding from the Karnataka State Council for Science and Technology.

The scheme (18) consisted of the villagers supplying cow dung to the biogas plant where it would be anaerobically fermented to yield biogas that would fuel a modified diesel engine that in turn would run a generator. The electricity thus produced would run an electrical submersible pump and lift drinking water for the village, and in addition be supplied to the households to provide electrical illumination. When every household was illuminated with a fluorescent tubelight on Mahatma Gandhi's birthday, October 2, 1989, we felt that we were implementing his vision of the role of science and technology. This modified scheme was successfully operated by the villagers from 1987 up to 1996 and at its best, it demonstrated what we described as "The Blessing of the Commons" (19) in which there is a confluence of private and community interests.

Lessons from Village Work

The attempt at working on rural problems quickly revealed my serious shortcomings. I was born and raised in a city and therefore knew virtually nothing about life in villages. I had received a western type of education and therefore found it difficult to understand traditional attitudes and approaches. I came from the family of a middle-class professional and therefore found it very difficult to see the world through the eyes of the poor. My predicament was captured by a poster in my study, which said: "Just when I thought I knew all of life's answers, they changed all the questions!" All this meant that I had humbly to undergo a great deal of unlearning (in addition to learning) before I could attempt to become a scientist capable of understanding and addressing rural problems. The interaction with the villagers of Pura and the Ungra region has been one of the most precious, enriching and enlightening experiences of my professional life. I learnt many lessons (20), a few of which are briefly described below.

Rural people may be poor and illiterate, but they are not irrational. In fact, the poorer they are, the more their survival depends upon their rationality, i.e., upon a proper evaluation of costs and benefits. And, in their attitude to returns and risks, they invariably take the “worst case scenario” more seriously than the "best case scenario” because the former can lead to total ruin whereas the latter often only means marginal improvement. For example, their choice of traditional seed varieties in preference to high-yielding varieties is often dictated by the fact that the latter can give even lower yields than the former if the inputs are not in the optimum range. Thus, given the options within their range of awareness, *the technological choices of rural people are rational.* For example, the load-bearing capacity of traditional bullock carts is low because the average payload in rural areas is only about 250-300 kg.

It also follows that *scientists must understand rural rationality if they want their technological suggestions/recommendations to be accepted.* For example, if smoke from wood-stoves is essential to control termite attack on the thatched roofs of villager houses, then it is unlikely that smokeless stoves will be accepted unless they are accompanied by a solution to the termite problem, for instance, a termite-proof roof. *Hence, scientists must first be students (learning from the people), if they want to be successful teachers to the people.*

There are several important steps in this two-way information flow between scientists and the people. (a) A scientific understanding of the lives of the people is the crucial starting point. This understanding cannot be acquired through naïve questions to villagers such as "How many kilograms of firewood do you use for cooking?" One may have to actually use a spring balance to weigh head-loads of firewood being carried back from forests by women, and then find out how long they last and how many persons consume the food cooked with this fuel supply. (b) The focus must be on the identification of *felt* needs, rather than *perceived*, needs. For instance, villagers are completely aware of the fact that thatched roofs leak, catch fire, are attacked by termites, harbor insects and rodents, and need constant maintenance. However, if they are asked what roof they want, they express their perceived need for a tiled or reinforced cement concrete roof because those are the only alternatives that they know. But, their felt need is really for an improved roof that does not have the defects of thatched roofs. An understanding of felt needs is essential therefore for working out the design criteria for improved technologies. (c) Before a major effort is launched on the development of new technologies, it is vital that the various technological options are presented to the people and their preferences elicited. (d) If the intention is ultimately to spread the technology and to ensure that it does not remain a museum piece, it is imperative that the final decision on the selection of technology is made by the people and not by the technologists. Scientists must curb their tendency to develop technologies in response to imaginary and imagined needs identified in remote and alien settings. For example, a number of 'modern' designs of bullock-carts were developed in India with the capacity to carry 1,000-2,000 kg of load even though such high loads do not arise frequently in typical rural situations except, for instance, in the 'catchment area' of a sugar factory. (e) The arduous task of R & D has to be taken up at this stage. (f) The next important step consists of testing out the technology in the field and getting the reactions of the potential users. This is democratization of innovation as distinct from mere popularization of science. (g) The feed-back from the field must be used to improve/modify the product/process before the technology is finalized for diffusion. (h) The process of disseminating the technology has to be a multi-institutional effort involving rural users, development agencies, scientists, financial and/or credit institutions, etc.

Women are often the best agents of disseminating technologies for rural development. Unfortunately, even where scientists work with the people, the tendency is to restrict popular involvement to the men. This gender bias is often difficult to avoid because most scientists and engineers are men; their technologies are often male-oriented; there are social taboos in traditional societies discouraging direct interactions with women; rural women do not come forward to articulate their views in the presence of their men, etc. But, with many technologies, once the women are seized with it, the dissemination takes off. Thus, once the women began to have a vested interest through a dung delivery fee in the delivery of dung to the Pura community biogas plant, the operation of dung collection and delivery started running smoothly.

Traditional technologies were optimal solutions for the challenges of the past and therefore they must not be ignored as possible sources of innovation -- they have evolved over centuries through a long process of the natural selection of innovations (21). For example, computer analysis has shown that the geometry of traditional bullock carts represents a optimum solution. Despite this pristine optimality, *almost all of them are sub-optimal and inadequate today* because of changed expectations, resource availability, materials and circumstances. For instance, in the past when India was heavily forested, teakwood may have been an optimum material for constructing the highly stressed wheels of bullock-carts, but today teak has become such a scarce material that it is a costly and therefore sub-optimal solution (22). On the other hand, *the so-called "modern" technologies, which are often just bad "xerox" copies of western technologies, are rarely accessible to the poor.* For example, the poor cannot afford a modern roofing technology such as reinforced cement concrete.

It is therefore a Hobson’s choice for the poor -- *on the one hand, traditional technologies are inadequate, and on the other hand, modern technologies are inaccessible.* To enable the poor to escape from this dilemma, scientists and technologists must generate new options, each more effective than the traditional and more accessible than the modern. Ideally, the options should constitute a hierarchy of technologies with upward compatibility. Then, with rising incomes, the poor can climb from a cheaper less effective option to a costlier more effective option. Only in such situation will the people have genuine choices. Thus, *the role of scientists working on rural problems is to be option-generators and choice-wideners.* For example, in the matter of cooking fuels and stoves, rural technologists can widen the options of villagers so that they can also choose improved (smokeless) stoves and more efficient fuels.

There are three approaches in generating technological options: (a) cheapen western technology, (b) develop *ab initio* an alternative technology and (c) transform traditional technology. For example, in the case of low-cost building technologies, the approach of cheapening western technologies may consist of developing fibre-reinforced materials, that of *ab initio* alternative technologies, geodesic domes, and that of transforming traditional technologies, compacted unfired mud blocks. Even though it is a hitherto untapped source, *the transformation of traditional technologies is a rich source of, and promising route for, technologies appropriate for rural development.* The transformation of traditional technologies involves an understanding of the scientific basis of traditional technologies, followed by qualitative changes achieved through marginal improvements.

Appropriate technologies are very likely to be region-specific, location-specific and culture-specific. And, the local culture may have many surprises. This is probably why Mahatma Gandhi is reported to have advised Laurie Baker, an Englishman who has devoted his life to creative low-cost architecture in India: "When you design for the poor, restrict yourself to materials that are available within a radius of 10 miles!"

An important lesson is that *any fool can make a thing complicated, it takes a genius to make it simple.* The end-product may have to be, or may turn out to be, simple, but the thinking that goes (or went) into its development can be quite sophisticated. In fact, there is a desperate need for wise ideas and ingenious solutions. Rural technologies are therefore neither trivial nor second-class because they invariably pose the extremely tough challenge of having to be virtually "zero-cost".

Of various technologies contending for dissemination, those technologies succeed in spreading (i.e., penetrating the “market") that simultaneously solve several problems. Charles Berg who enunciated this “theorem” illustrated it by pointing out that energy-efficiency improvements were introduced into the US steel industry during a period of declining energy prices because those improvements were accompanied by other useful characteristics. The Berg "theorem" is very relevant to rural technologies too. Thus, of the various designs for woodstoves those that simultaneously eliminated smoke, cut down cooking time and reduced fuel consumption have been successful. .

At the risk of appearing sentimental, I would like to stress that *scientists must approach rural work with empathy and affection for the people.* Otherwise, they tend to be afraid of the people and hide behind the walls of their rural centers. Then, the poor tend to conclude that their poverty is being used as a resource for professional gain. Even if the people do not get something back in return from the interaction, the feelings with which scientists make efforts are extremely important in the eyes of the people. Given the right attitude on the part of scientists, the rural poor are far more understanding of the fact that technical failures are the usual precursors of success and technological progress occurs via mistakes. In fact, the understanding of the villagers of Pura was far superior to that of my highly educated colleagues in the Institute who cheer when the satellite goes up and jeer when it crashes into the sea. In response to my public admission at a village meeting that we had failed to deliver sufficient biogas cooking fuel through the biogas project, the villagers highlighted the sincerity of our attempts and insisted that we should change our objectives and focus on pumping drinking water. Eventually, this is what we did.

Energy for a Sustainable World (1978-88)

1978 was an important year in my professional life. I met Theodore (Ted) Taylor at an Indian National Science Academy meeting at Delhi and was greatly impressed by the fact that he was a nuclear physicist who after designing a whole generation of atomic bombs at Los Alamos gave it all up to lead a crusade against nuclear weapons and for solar energy. That major changes could occur in professional lives intrigued and impressed me. We became good friends and from him I learnt the importance of what he called in any context: "thinking it through". Implementation can fail for many reasons but often it is because the implementers have not "thought it through".

In 1978, I also met Jose Goldemberg at a meeting organized by him in Sao Paulo where I presented the results of ASTRA's field study of rural energy consumption patterns. We discovered an identity of outlook and affinity of views. Thus began a lasting friendship that resulted in an important on-going collaboration.

On my way back to India, I visited the Center for Energy and Environmental Studies at Princeton University. I established instant rapport with a number of well-known scientists -- Rob Socolow, Robert Williams, Frank von Hippel, Hal Feiveson, Gautam Dutt and others -- all of who had turned their backs on conventional physics for studies on energy and the environment. I found them to be like-minded souls with deep social concerns and a determination to pursue science with a humane touch. I also came across unexpected reactions -- for instance, a leading physicist from the Institute of Advanced Study saying to me after my rural energy seminar: "I envy you!"

Jose Goldemberg, Thomas Johansson, Robert Williams and I (popularly referred to as the "Gang of Four") began a collaboration that was to play a major role in my subsequent professional life. What initiated and sustained this perhaps unique and now famous collaboration is of some importance.

Each of us started his career as a physical scientist and turned eventually to energy research. Also, we lived and worked in different countries -- Brazil, Sweden, India and the United States. And, our cultural backgrounds and experiences were very diverse. Though we were four individuals from four continents, our meetings at various international meetings and visits to Princeton revealed a remarkable measure of shared values and concerns about the interaction of technology and society. They also showed an identity of outlook, a great deal of like-mindedness and a similarity of approach on matters concerning energy in society.

These interactions showed that the four of us could work together with mutual respect and equality. Above all, we could avoid the hierarchical modes of functioning that nearly always vitiate international, particularly North-South, collaborations. We also had humility in the sense that each one of us knew that we did not know it all and that, in order to develop greater understanding, we had to listen to the others and learn from what we had heard. Our chemistry worked. We have sustained our interaction for over 20 years. Even without an institutional umbrella, we created a “virtual institution” long before modern communication technology with email, fax, etc.

At that time, energy thinking was dominated by growth-oriented supply-sided consumption-directed considerations. Deeply troubled by the environmental, security and equity implications of that paradigm, we wanted to evolve a different perspective. To us, the human dimensions of energy were as important as the technological. We were acutely sensitive to the environmental impacts of energy production and use. We were deeply concerned about equity between industrialized and developing countries and within developing countries with their small islands of glaring affluence amidst their vast oceans of abject poverty. Above all, we shared a vision of energy as an instrument of development, and of technology as a crucial mechanism for energy to play this role. This unity of perspective and values was enriched by the diversity arising from the differences in our backgrounds, culture, experience and expertise. We forged bonds and functioned as a well-knit team. As a result, we produced together what none of us could have produced alone -- the whole was greater than the sum of the parts.

As we combined our efforts, we were led from a critique of conventional wisdom on energy to a new approach. When significant progress had been made, we felt that we should expound and elaborate the new approach -- and that is how our book ***Energy for a Sustainable World*** (23) came to be written.

The book, which was published in 1988, emphasized that energy is not the only major global problem. So, the solution to the energy problem must contribute to, and be consistent with, the solutions of the other major problems such as poverty, population growth, under-nutrition, ill-health, environmental degradation, etc. Energy must be an instrument for advancing economically viable, need-oriented, self-reliant and environmentally sound development -- what is now referred to as sustainable development.

The emphasis on basic needs meant that the focus must be on the end-uses of energy and the services that energy provides human beings. Technological opportunities abound for enhancing energy services. Developing countries can therefore leapfrog technologically, avoiding a repetition of the mistakes of the industrialized countries. These countries can become exciting theatres of technological innovation. Implementation of the new energy paradigm in industrialized countries leads to the possibility of lowered energy intensities and convergence between the energy consumption of industrialized and developing countries. Above all, the goal-oriented, strategy-based policy-driven approach to energy implies -- contrary to widely held beliefs -- that the future for energy is much more a matter of choice than of destiny. Energy futures compatible with the achievement of a sustainable world are within the grasp of humankind. The joy in our endeavor came from the feeling of being harbingers of hope rather than prophets of doom.

Energy for a Sustainable World attracted international attention. It contributed significantly to the new paradigm for energy. It was referred to in the "Brundtland Report" (24). It led to an invitation from *Scientific American* to write an article (25) on our approach.

Energy Management (1985-91)

Before going on sabbatical to Princeton in 1983 fall, I relinquished the convenership of ASTRA to a younger colleague. When I returned in 1985, I was persuaded by the new Director of the Institute to take up the chairmanship of what was to become the Department of Management Studies.

There I continued my study of energy consumption patterns but now focused (in collaboration with a highly committed and indefatigable student, Sudhakara Reddy) on Bangalore metropolis as an ecosystem. Two important papers on firewood and charcoal supply and consumption in Bangalore (26, 27) had an influence on the establishment of tree belts around the city. I also turned my research attention to the dissemination of technologies. This work led to the view that technology shifts (for example from firewood to kerosene cooking fuel) are analogous to predator-prey relationships where the predator is the displacing technology and the prey is the technology that is getting displaced. Even the equations describing the technology shifts we found to be of the same form as the equations for the time-variation of predator-prey populations (28).

My work led me to understand the importance of *innovation*, which is the process of converting an idea into a product in the economy. *Innovation* obviously is much more than *invention* where the process ends with a working device. But if a device works, that does not mean that it will be produced, distributed and accepted by end-users. It is amusing therefore that technology generators consider themselves a breed superior to the technology disseminators. Perhaps, as a result, there are important actors largely missing in the innovation chain in India -- those who productionize and develop the method of making thousand-off or million-off as distinct from making the one-off prototype. I had a fruitful and enjoyable collaboration with Professor K.N. Krishnaswamy to produce a model backed by several case studies on the factors governing the success and failure of rural technologies (29). This led to two co-edited books ***The Technological Transformation of Rural India*** (30) and ***Rural Energy Planning*** (31). I also tried to understand the barriers to the spread of energy efficiency improvements by listing the barriers presented by various actors, what caused these barriers and suggesting how to overcome them. A paper on *Barriers to improvements in energy efficiency* in *Energy Policy* (32) contributed to an area of interest that came to be called barrier analysis.

However, the most productive part of my stay in the Department of Management Studies was the energy scenario work. During the 1980s, energy had become an increasing concern of mine. I built up a small team for energy analysis. Starting in 1986, Gladys Sumithra, P Balachandra and Antonette D'Sa and I constructed a detailed development-focused, end-use-oriented and service-directed (DEFENDUS) electricity demand scenario for the South Indian state of Karnataka (33,34). We then did a detailed comparative costing (on the same terms) of fifteen technologies of electricity saving, decentralized generation and conventional centralized generation of electricity (35). We used the results to construct a least-cost mix to meet the requirements arising from a demand scenario. It turned out that the least-cost mix consisted of end-use efficiency improvements and electricity substitution measures, decentralized generation and centralized technologies (hydroelectricity, natural-gas-based and coal-based thermal power, and nuclear power).

The detailed scenarios attracted international attention. There was even national recognition when I was given the Om Prakash Bhasin Award for Energy in 1988. But many large national energy institutions were upset with us for stealing the limelight. What they did not realize is that our team at the Institute had put in about three years of sweat to do the end-use analysis for Karnataka, the comparative costing and the scenario construction. During this time, these institutions strove for influence in Delhi, the national capital, and their leaders scrambled to be in the corridors of power. There were lessons here. One can strive for political clout via analytical excellence, but not for the former in lieu of the latter, for however seductive it might be, political influence is ephemeral. In contrast, new ideas and sound analysis have a long-term sustainability.

Our in-depth analysis of the economics of nuclear power (36) was invaluable when a debate on the Kaiga nuclear power plant was organized by the Department of Science and Technology, Government of Karnataka. It showed that, in the Karnataka context, nuclear power is neither necessary nor economical -- in fact, it is the most expensive technology of electricity generation. Its proponents claim that it is safe, cheap, appropriate and modern; but the popular meaning of the resulting acronym SCAM is a better description.

Up till that debate, I had been silent on nuclear power, much to the disappointment of many anti-nuclear activists. But, my silence arose from an unpleasant experience that I had several years earlier. I had always been in favor of a scientific outlook or what is called in Indian discussions, a “scientific temper”. What little disdain I had for the faith and beliefs of rural folk disappeared after I became involved with ASTRA. There I learnt that ordinary people are not at all ordinary if one considers how they cope with the world despite their economic and social handicaps. Despite this, when a leading scientist said to me: "I say, that guy is pestering us, so please sign his Scientific Temper declaration", I signed the declaration in the same way that we often buy charity-show tickets to get rid of the ticket-seller. In doing this, I was certainly irresponsible on a major issue. Then, articles started appearing in the newspapers attacking the declaration and its signatories. To my surprise, I found myself agreeing with some -- but not all -- of the points made by the critics particularly those pertaining to the arrogance of modern science and the disrespect for traditional knowledge. In fact, I had written a paper in which I argued that these technologies deserve respect and study -- as the scientific-temper critics were now saying.

After the Scientific Temper episode, I vowed that "I will go into Advocacy and Action only on issues where I have done Analysis myself!" This vow has often been a handicap but it has increased my effectiveness. I determined to follow the sequence: Analysis $\rightarrow$ Advocacy $\rightarrow$ Action. At the analysis stage, it was crucial to isolate oneself, the subjective analyst, from the object of analysis and also to remove emotions from the analysis. But, once the objective dispassionate analysis is over, it is vital to reconnect with the object and bring in values into the advocacy and action based on analysis.

International Energy Initiative

I retired from the Indian Institute of Science in 1991 in accordance with its mandatory rule for retirement after the age of 60 years. But my interest in the field of energy did not end. After ***Energy for a Sustainable World*** was published, there were frequent questions from supporters and sponsors on the lines of "Now, where is the church?" Meaning, what is being done to implement the ideas? So, the International Energy Initiative (IEI) was set up in 1991 with the generous financial and moral support of the Rockefeller Foundation and other US foundations, and European bilateral donors such as the Dutch, Swedes and the Norwegians. Jose Goldemberg was to have been its President but after he became a Minister in the Brazilian government, I was persuaded to assume this office with Jose Goldemberg as the Chairman.

IEI's mission (37) was to promote the efficient production and use of energy for sustainable development, particularly in the developing countries. IEI was established as a Southern-conceived, Southern-led, Southern-located South-North partnership -- a small, independent non-governmental public-purpose international organization.

The Presidentship of IEI involved a completely new set of activities quite different from those that were the preoccupation of my previous academic life. I now had to address the challenges of raising funds, formulating work plans for regional energy initiatives (REIs) in collaboration with the regional staff, initiating new REIs, designing institutional arrangements for decentralized operation, monitoring activities and expenditures to advance IEI's objectives, promoting public relations and writing reports to donors.

But apart from all this nitty-gritty stuff, the real challenge lay in addressing the energy paradigms or mind-sets of decision-makers in developing countries -- scrutinizing their patterns of thinking and trying to change them if they were obsolete or inappropriate. Once decision-makers adopt paradigms that advance sustainable development, then a favorable environment for projects is very likely to follow. On the other hand, appropriate projects can flourish even amidst obsolete and anti-development paradigms at the national level. Thus, there can be windmills, solar water heaters, etc., under a government that believes in the old paradigm that the magnitude of energy consumption is the index of development. Unfortunately it is not easy to formulate in project format the activity of changing the paradigm for energy thinking. This means that paradigm-shifting activities require core rather than project funds and raising funds for this purpose is a very much more difficult task.

Another challenge is to cope with a changing funding environment in which the development assistance pie is shrinking while there are new claimants to the pie. Even the UN is facing a funding crisis. And in the sustainable energy field, UN organizations are going to the same funding sources that international NGOs like IEI are approaching. Hence, there are signs of a growing competition between UN organizations and NGOs. In the process, NGOs are getting pushed out because their objectives look the same (e.g., sustainable energy). Unfortunately, because they work through governments (that are the custodians and defenders of conventional paradigms), UN organizations are very weak in changing paradigms however strong they may be in promoting projects.

Fortunately, competition between UN organizations and NGOs is quite unnecessary. A strong synergism is possible by exploiting their complementarity. UN organizations can exert the top-down pressure on governments to implement programs and projects, and NGOs can generate, maintain and strengthen via civil society the bottom-up pressure for paradigm shifts. If the NGOs are southern-based, then they can achieve their objectives at a fraction of the cost that UN organizations would have to bear. Unfortunately, IEI did not succeed in persuading the relevant UN organizations (with identical perspectives on sustainable energy) to submit joint proposals for sustainable energy to appropriate donors.

Ideas on sustainable energy are necessary, but not sufficient -- one needs to get them into the minds of decision-makers. So, in addition to analysis, there has to be information exchange, training, advocacy and action. Thus, IEI's mission was planned to span information exchange, training, analysis, advocacy and action (INTAAACT).

The main information activity of IEI was envisaged to be its journal *Energy for Sustainable Development.* The case for an IEI Journal is that there is no international journal either with the efficient production and use of energy as its exclusive focus or directed towards energy actors concerned with energy in developing countries. Neither is there a journal devoted to exchanging developing-country experiences in the field of energy. Above all, there is no international journal focusing on strengthening the capability of energy actors in developing countries to choose, plan, establish, manage, operate and efficiently use energy systems. An essential part of this task of strengthening capability is the use of a journal to forge an interacting community of energy actors concerned with the energy systems of developing countries. IEI thus sees the journal as contributing to the process of building indigenous expertise in developing countries on all aspects connected with the generation and use of energy technologies necessary for sustainable development.

IEI’s journal ***Energy for Sustainable Development*** has been published since May 1994. By producing and printing the journal in a developing country like India, the costs have been kept extremely low. On a print order of 1,000 copies per issue, the total costs in the year 2000 were about $3.16 per copy of which the fixed costs were $0.79 and the variable costs, $2.37 per copy.

IEI has also supported a Fellowships Program that helps advance IEI's objectives in several ways. This program builds capacity in the form of energy analysts from developing countries trained in the "new" approach to energy planning; strengthens the training capability of the host institutions through the development of curricula, course materials, laboratories and resource persons; contributes to institution-building through the organization and management of the training programs; utilizes the human resource potential of career professionals and graduate students for carrying out research on important energy issues in developing countries at relatively low costs; and creates agents of change who will go into, or back to, energy institutions and influence them to adopt sustainable development approaches to energy. IEI located suitable institutions in Brazil, China and India, each having qualified faculty who are willing and able to use the fellowships program to help advance IEI's objectives at $5,000 to $10,000 per fellow per year.

Since a small international organization with low secretariat costs can only function in a decentralized manner, regional energy initiatives (REIs) were set up in Brazil and India. Each of these had a director and small office with a separate budget implementing a work plan and reporting monthly on work and expenditures. A successful program of fellowships and integrated resource planning was also organized in China based on the Energy Group at the Tsinghua University but this petered out after the unfortunate demise of Professor Qiu Da Xiong in a tragic road accident.

An effort was made to implement an African Energy Initiative (AfEI) but this ended in failure for reasons that are interesting for the future of energy analysis in developing countries. At the initiation meeting at Harare in April 1994, key African energy analysts were unanimous in ascribing the weakness of African energy analysis to the dominant role of donors. These stated that these donors carved up the continent into regions of influence with donor-driven programs for each region. Recognizing that a common failing of policy formulations is that they proceed without a prior clarification of goals (objectives to be achieved) and strategies (broad plans to reach the goals), the analysts agreed on clear goals (see Box) and argued for an energy strategy derived from the needs of the continent. It was envisaged that a Pan-African theme-based network to overcome the donor-driven balkanization of the continent would implement the strategy.

The bad news is that the AfEI petered out after about a year. In hindsight, it appears that interest in joining the AfEI network was largely based on the expectation IEI would support the core costs of their organizations/institutions. Unfortunately, not being a donor agency, IEI could only support incremental costs. When it became clear that funding was not available for core costs (salaries, equipment, buildings), many of the participants lost interest in AfEI. This was understandable because in Africa core costs have to be provided by project sponsors, in contrast to China and India (for example) where university faculty have adequate salaries and therefore only incremental costs are sufficient.

The situation was aggravated by the fact that there were activities such as the Inter-Governmental Panel on Climate Change (IPCC) and the Global Environmental Facility (GEF) that funded international meetings, consultancies and projects related to mitigation of global warming and greenhouse gas measurement studies. African energy analysts were attracted away into these more lucrative donor-driven programs even though they were emphatically rejected at Harare as priority subjects for Africa. Hence, these international collaborative programs undermined the building of indigenous African energy analysis capacity and the strengthening of African self-reliance.

ENERGY FOR DEVELOPMENT IN AFRICA

GOALS

To give energy a human face
in all regions of Africa
by raising dramatically the level of energy services
accessible to, and enjoyed by, all sections of the population,
particularly women
and the rural and urban poor;

to go beyond energy
and make it a powerful instrument of development
through its linkage with all sectors of the economy
-- industry, agriculture, transport, etc.;

to meet the energy needs of human beings and the economy
with rationally determined mixes
of centralized and decentralized energy sources
and of energy saving measures
(which are equivalent to a supply option)

to use indigenous renewable energy sources
particularly hydroelectric, biomass and solar energy
ensuring that local, regional and global environmental degradation
is minimized, if not avoided,
without sacrificing sustainable development objectives

and simultaneously to strengthen indigenous capacity
and build local, regional and continental institutions
so that African energy problems
are as far as possible diagnosed by Africans and solved by them.

My own energy analysis work in IEI was part of the INTAAACT work of the REI at Bangalore. To promote the efficient production and use of energy for sustainable development, it is essential that the mind-set of energy decision-makers be changed away from a growth-oriented supply-sided consumption-directed approach to a development-focused end-use-oriented service-directed approach (DEFENDUS). This paradigm shifting involves research and analysis as well as advocacy. Following initial detailed studies on the demand and supply scenarios for the electricity sector of

Karnataka, workshops have been conducted to disseminate the approach and the results to relevant policy- and decision-makers and to NGOs.

These workshops necessitated the preparation of analytical training materials for integrated electricity planning using the DEFENDUS approach. The course materials were designed for hands-on computer-based spreadsheet exercises in the construction of demand scenarios and least-cost supply mixes (based on comparative costing). Even if the resistance to least-cost electricity planning is overcome, paradigms shifted and sustainable energy strategies evolved, the next step is energy planning in which demand and supply scenarios are constructed. It is necessary to have an approach that is particularly suited for beginners. In this context, IEI's DEFENDUS spreadsheets seem to offer clear-cut advantages (38) -- they are simple and completely transparent, their parameters are completely under the control of the planners, and they offer a default case that makes it unnecessary to build a model from zero. Apart from the training conducted for several states in India (Workshops in West Bengal, Andhra Pradesh and Karnataka), Latin America, and South Asia, IEI has repeated these and related activities for other South Asian countries, China and Latin America and for the UNDP in New York.

A case study was carried out of the power sector of the South Indian state of Karnataka (39). It showed that, contrary to conventional wisdom, the financial ills of the utility were not because of the heavily subsidized electricity given to irrigation pump sets (IPS) of farmers. In 1996, this subsidy was shown by IEI to be compensated by cross-subsidy primarily from industrial and commercial consumers. Because the meters on IPS had been removed in 1981, the consumption by IPS and the transmission and distribution (T & D) losses had to be guessed or fabricated every year. If the upper limit of technical T & D losses is taken to be about 20%, then the balance (up to about 10% of Karnataka's electricity) is in fact commercial loss (the utility's euphemism for theft). IEI concluded that commercial T&D losses were the fundamental reason for the utility being in the red. If these losses had been minimized, if not eliminated, and the resulting revenue brought into the utility's coffers, it would have had a revenue surplus that could be used as an internal source of funds for improvement of the system and expansion of capacity. Karnataka's power sector used the fabricated IPS consumption to hide many of its technical and commercial shortcomings, in particular its commercial T & D losses. Many of these observations from IEI's analysis were strongly resisted when they were published, but they have now become conventional wisdom repeated by the authorities in the power sector. IEI's intervention in Karnataka's Power Sector as a case study of Analysis leading to Advocacy and Action suggests that it is possible to outline a tentative model for such interventions (40).

Energy after Rio and World Energy Assessment

In 1996, an invitation was received from the Energy and Atmosphere Programme of the UNDP to co-author a book elaborating the crucial links between energy and poverty, development, environment, and the economy, followed by a statement of the technological opportunities on the demand- and supply-sides of energy systems, and finally a discussion of how to make it happen. The publication was for presentation to the June 1997 special session of the UN General Assembly to review and appraise the progress of Agenda 21.

While writing has always been for me a pleasurable creative activity, it is inconvenient, if not unpleasant, to get one's writings approved by a committee appointed on "political" and/or geographical considerations. Of course, for a large number of actors and stakeholders to acquire ownership of a document, this approval is essential. The only way in which this dilemma can be resolved is for the writer to have an abundant reservoir of "oriental" patience and detachment, which fortunately I was able to muster. The final product of these efforts was an attractive and lucid document ***Energy After Rio: Prospects and Challenges*** (41). It was intended to ensure that energy did not disappear from the agenda of important international forums. Hopefully, it succeeded in this objective.

Hardly had ***Energy After Rio: Prospects and Challenges*** been produced when yet another exercise was initiated by UNDP and UNDESA in collaboration with the World Energy Council (representing private industry) to produce a ***World Energy Assessment*** (42). Under the Chairmanship of Professor Goldemberg, a team of 10 Convening Lead Authors was asked to assemble groups of Lead Authors and produce the chapters of the document. I was the Convening Lead Author of the chapter 2 on *Energy and Social Issues* with inputs from 8 Lead Authors.

During this time, my long-standing interest in rural energy led me in 1999 to write a paper on *Goals, Strategies and Policies for Rural Energy* as part of my analysis work for IEI (43). On the strength of this paper, I was also invited to serve as a Lead Author for Chapter 10 of the WEA on *Rural Energy in Developing Countries.*

India's Nuclear Tests and Auschwitz

The September 1999 Editorial Committee meeting of the World Energy Assessment was held in Cracow, Poland. There I had an experience, which if I was religious, I would describe as a religious experience, a mental turning point after which things will never be the same. The visit to Cracow enabled me to visit the infamous Nazi concentration camps of Auschwitz and Birkenau that are now preserved as museums. There, I came into direct contact with the horrors of the Holocaust.

The tour of the camps left me with a completely unexpected feeling. The scale of human extermination was so enormous that I had to remind myself, particularly because the camps have been unpopulated since 1944, that there used to be human beings there. The powerful impression that persisted was of detailed engineering resulting in "the immense technological complex created ... for the purpose of killing human beings." The meticulous organization and rigorous management were characteristic of mega-industries, "gigantic and horrific factories of death". The main gate of Auschwitz displayed the inscription "Arbeit macht frei" ("Work brings freedom"). Perhaps a more apt announcement would have been "Technology completely decoupled from values". In Auschwitz, it is obvious that nothing happened spontaneously. Everything was designed and planned.

Walking through Auschwitz, I began to wonder how the development of the atomic bombs at Los Alamos, the test at Alamogordo and the bombing of Hiroshima and Nagasaki differed from the Nazi concentration camps. Of course the Allies in World War II were not driven by the racism of the Nazis, and they were not pursuing a final solution of extermination of any particular religious group. But with regard to the scale of killing, the recruitment of capable minds, the harnessing of science and technology (some perhaps hoping that the weapons would never be used and others even opposing the use of the weapons after they were developed), the extent of organization, the resort to effective management, and the choice of targets to maximize annihilation of Japanese civilians, the Manhattan project and its follow-on was like the concentration camps, in fact, even more horrendous in its impact.

I started agonizing over what all this meant for India. Since May 1998, the country has witnessed the scientist-politician nexus underlying the nuclear tests at Pokhran, the use of national security arguments to advance political party agendas and the self-serving jingoism of the scientists. Of even greater importance has been the silence of its journals with a few notable exceptions, the obfuscation of ugly reality and the virtual absence of intellectual dissent.

For several decades, I had been worried about the conventional view that science is amoral and neutral. Scientists can escape responsibility for the horrors that have sprung, or can spring from, science by the clever excuse of the amorality of science. But, like the youth of the 1960s, I rejected that sophistry. I was disturbed that values, feelings and emotions were considered unmentionable in scientific discussions. Since ASTRA, however, I did not hesitate to refer to them in my seminars, even in western centers of excellence. The "scientific temper" debate in India raised my level of understanding of the very fundamental issues involved. India's nuclear tests thrust the whole issue of science and morals into the foreground of my consciousness. After Pokhran II, there was a distressingly and disappointingly small minority of Indian scientists who spoke up against the nuclear tests. Though I was one of them (44), my attitude intensified after my Auschwitz experience (45).

I became convinced that nuclear weapons are not just another class of weapons in the long history of development of weapons. Nuclear weapons are unique – their impacts are primarily on innocent civilian non-combatants, particularly women and children; their radiation effects persist for generations after their detonation; they are intrinsically indiscriminate; they are largely uncontrollable; and above all, they are instruments of mass murder on a scale unparalleled in human history. This uniqueness of nuclear weapons, many aspects of which are common to chemical and biological weapons, has been clearly affirmed in an Advisory Opinion of the International Court of Justice rendered in the month of July 1996.

Nuclear weapons have security, political and economic implications. In the ultimate analysis, however, the issue of nuclear weapons is a moral question. It is a question of right and wrong and of good and evil. It is this ethical aspect of nuclear weapons, especially as it applies to the designing and manufacture of nuclear weapons, which became the focus of my presentations (46). I was therefore forced to think about the claim of the amorality of science.

This amorality emerges from two conventional prescriptions for the relationship between the scientist (the subject) and the object of scientific study. Firstly, the scientist as subject is urged to separate and distance himself/herself from the object of study even when the object is living. Secondly, it is recommended that the study must be devoid of feelings and values, i.e., it must separate emotion (the non-cognitive self) from analysis (the cognitive self). It must be a cerebral objective activity devoid of feelings. The amorality of science stems from these two dichotomies -- the isolation of the subject from the object and the removal or absence of emotions and feelings. And when the object of the study includes human beings, then people are perceived as "things". The first dichotomy leads inevitably to degradation of the objects of study (even humans) into things, and the second, to the removal of feelings for objects. Thus, science is claimed to be objective and amoral.

I began to feel that there is a way out of this moral crisis. The relationship between the scientist (the subject) and the object of scientific study must be dialectical so that initial separation (and distance) ends in subsequent unification (and embrace). The suppression of emotion during analysis must give way to emotion after analysis. The functioning of scientists as individuals, groups and institutions must be constrained and limited by moral strictures and taboos. Otherwise, the synergism between the isolation of the subject from the object and the removal or absence of emotions and feelings leads inevitably to science becoming the instrument of violence, oppression and evil. Science, therefore, must not be neutral. It must be encoded with life affirming values. The link between science and morality must be re-established. The Gandhi talisman is relevant: "Recall the face of the poorest and most helpless person ... and ask yourself if the step you contemplate is going to be of any use to him. Will he be able to gain anything from it? Will it restore to him control over his life and destiny?"

The Volvo Environment Prize 2000

The link between science and morality highlights the importance of the energy-equity nexus that has been a recurrent theme of my energy work for two and a half decades (and of the work of the Gang of Four and IEI). A great opportunity to emphasize the human dimensions of energy arose through the award of the Volvo Environment Prize 2000 to Goldemberg, Johansson, Williams and myself for "outstanding collaborative achievement since the early 1980s for working out a new policy-driven approach to the technical analysis of world energy needs and how they could be provided for in the early decades of this century."

When I delivered the acceptance speech at Göteborg on behalf of my collaborators and myself on October 17, 2000, I insisted that energy acquire a human face and contribute to "wiping every tear from every face". Among the other visions for energy in the new millennium are the following: drastically reducing, if not eliminating, the coupling between energy consumption on the one hand and economic growth (GDP), materials use and emissions on the other; re-examining the assumption that energy problems can be solved without changes in life-styles in the industrialized countries -- Gandhi said: "The world has enough for everyone's need, but not for every man's greed!" --; providing universal access to affordable modern energy services, particularly in developing countries and especially for the poor and for women; harnessing the immense possibilities of information technology; increasing the scope for people's participation with decentralized energy systems; modernizing rural energy systems leading to a dramatic improvement of the quality of life.

The bad news is that radical ideas do not become new orthodoxy overnight; they require continuous struggle and persistent effort. The old growth-oriented supply-sided consumption-directed paradigm still dominates the thinking of decision-makers, particularly in the developing countries.

These challenges have been addressed by the Gang of Four with a flurry of additional efforts at analysis, advocacy and action. Mention should be made of the books: ***Electricity: Efficient end-use and new generation*** (47), ***Renewable Energy: Sources for Fuels and Electricity*** (48), ***Energy after Rio: Prospects and Challenges*** (41), ***Energy as an Instrument of Socio-economic Development*** (49) and most recently the ***World Energy Assessment*** (42).

I concluded the Volvo Prize acceptance speech thus: "The future is difficult, but the present is unsustainable. Fortunately, ideas are powerful and when they become visionary messages capturing the hearts and minds of the people, mighty empires crumble and powerful structures collapse."

Concerns regarding energy

It has been a rare privilege and a good fortune that I have been able to work on energy problems at the village, city (Bangalore), state (Karnataka), national (India) and global levels. Nevertheless, I am left with two major concerns regarding the future of energy analysis.

Firstly, energy analysis in both industrialized and developing countries is dominated by men. But, the management of energy particularly in the rural areas of developing countries is done primarily by women. In addition, experience is mounting that the decisions of women (for example, in micro-lending programs such as the Grameen Bank in Bangladesh) take into account the long-term and the next generation, a natural consequence of their linkage with children. It is precisely such a view that leads to sustainability. Hence, women are naturally endowed to be better custodians and implementers of sustainable development (50). That being the case, the gender disparity in energy analysis is serious. It must be remedied.

Secondly, energy analysis is still dominated by analysts from the industrialized countries. A head count on any recent edited book will show that the Southern contribution from developing countries is negligible. Obviously, capacity building in developing countries is given low priority even by organizations that are supposed to be committed to this challenge. Capacity building is a slower time-consuming process and program executives in a hurry do not emphasize the task. One must also note the negative and counter-productive role played by the major diversion of extremely scarce Southern energy analysis talent into greenhouse gas mitigation analysis for developing countries even though the global warming problem has arisen primarily from Northern energy consumption patterns.

Our book ***Energy for a Sustainable World*** was particularly sensitive to the importance of building indigenous capacity and strengthening self-reliance in energy analysis. The Gang of Four also organized workshops in Princeton (1980), Sao Paulo (1984) and Princeton (1998) hoping to stimulate new South-South and South-North collaborations. An outcome of the 1984 Sao Paulo workshop was a *Declaration on Self-Reliance in Energy Analysis* (51).

But, on the one hand, alongside the token mentioning of capacity building, the strengthening of self-reliance is not being ensured in most energy programs and activities. One even wonders whether it is on the agenda of those organizing these programs and activities. On the other hand, there is a proliferation of Northern-located energy analysts (often expatriates from developing countries) to intercept the donor funding for energy analysis pertaining to developing countries. In addition to their proximity to Norhern donors, their advantage is their nexus with developing country elites. They soon develop a vested interest in competing with and undermining indigenous capacity.

Thus, there are two major challenges: (a) *engendering* energy analysis, planning and implementation and (b) *indigenizing* energy analysis capacity.

Retirement

A daughter of mine once said to me *a propos* my health: "Dad, after 100,000 miles, parts start failing!" and at the age of 65, one of the parts of my body gave me problems -- I experienced a pain in my chest when I was on my morning walk. I went through the familiar sequence – electrocardiogram, treadmill test, angiogram and a bypass operation. Though I was out of the hospital in ten days, I was quite depressed for about a month or so until I started working with a laptop and writing a paper.

Modern anesthetics and painkillers are so powerful and effective that I have few memories of pain except in the faces of the loved ones who were at my bedside. Nevertheless, a major operation stimulates philosophical thoughts on several issues -- the finiteness of life, my mortality, how medicine has made it possible for me to live longer than my maternal ancestors many of whom did not live into their fifties let alone the biblical three score and ten, how to make the new lease on life meaningful, and so on. I began to seriously review my future particularly when a family member asked me provocatively: "Have you ever heard of any man on his death-bed wishing that he had spent more time at the office?"

It became clear to me that I had to start the process of retirement. It was not easy because of worries concerning the future of the organization I would be retiring from. I have had two different types of experiences. The first is with long-standing institutions (or units of institutions) that I entered without a radically different paradigm. Such units, for example the Department of Inorganic and Physical Chemistry, have continued after my departure with virtually no change. Then, there are organizations like ASTRA that I have designed and built on the basis of a new paradigm. Unless such organizations are left in the hands of successors who are as committed to the new paradigm, it is inevitable that major distortions in their functioning will take place.

In September 2000, I retired from the Presidentship of IEI. To make this retirement meaningful, several lifestyle changes have become necessary. In particular, there should be no acceptance of new administrative responsibilities and a tapering off of old ones, no writing assignments associated with deadlines, no membership of committees/boards/ governing bodies and gradual resignation from current memberships except in special cases, no commitments with routine obligations like regular office hours, etc. Unfulfilled interests of yore (such as book-binding) have to become new hobbies. Hopefully, retirement should not mean cessation of soul-satisfying work, which in my case means study, analysis and writing.

The first test case of post-retirement life was my study of the California energy crisis at the end of 2000 and the beginning of 2001. I was thrilled to discover the power and possibilities of the Internet. Sitting at my home computer in Bangalore, India, (but it could have been any telephone-connected village), I was able to read every day's *New York Times* and *Los Angeles Times* for information and analysis on the power situation in California. Thanks to the quality of their reporting on the topic, I gradually acquired an understanding of the crisis that was hardly inferior to that of privileged analysts in the US, as judged by the reactions to my draft paper. I could also draw the lessons of the California energy crisis for the power sector reform process that was taking place in India and publish a detailed paper on the subject (52). Alongside, my interest in power sector reform issues continued (53).

The whole exercise has intensified my optimism regarding the quality of the rest of my life. The big question mark is that I continue to enjoy adequate health and/or that the body parts that fail can be fixed. That is only partly in my hands.

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