Nuplexes: technology for the 21st century

by Ramtanu Maitra

In the 1960s, Dr. Vikram Sarabhai, then chairman of the Atomic Energy Commission in India and a leading scientist, was concerned about India's small national electrical grid and the money and time that were needed to string the entire nation with transmission lines. His concern was not only the cost and logistical complexities of establishing a national grid, but also the large amount of power loss such long transmissions could be expected to incur. "One has to change one's approach to the problem of establishing electricity-generating stations," Dr. Sarabhai said. "Traditionally, one forecasts the growth of loads and establishes generating capacity to meet the load. Take a different approach," he suggested.

In 1968, Prime Minister Indira Gandhi further defined this "different approach." She said: "The breakthrough which has occurred in the cost of generating electrical power by using nuclear energy on a large scale is reflected in the current forecast that more than 50% of the new generating capacity which will be added in the world during the 1970s will be based on atomic energy. Moreover, large agro-industrial complexes established around low-cost energy centers can permit developing areas to utilize these advantages even though the capacity of the grids is small."

This "different approach" is the concept of the nuplex, the agro-industrial complex established around a nuclear power station, which was originally conceptualized by scientists at the Oak Ridge National Laboratory in the United States at a time when the "Atoms for Peace" program envisioned the large-scale transfer of nuclear technology to developing countries, to help build up their national economies. During Dr. Sarabhai's time, two feasibility studies for agro-industrial complexes for Uttar Pradesh and Saurashtra were carried out.

The idea of the nuplex is to maximize utilization of a large nuclear power station, including both the electricity and heat energy it produces, in conjunction with local raw materials and agricultural and industrial potentials, to create a cultural and economic development center—a new city. During the 1960s, feasibility studies for two such complexes—one in the Kutch of Gujarat and another in western Uttar Pradesh—were carried out by the U.S. Atomic Energy Agency and Oak Ridge National Laboratory. The Kutch site, in an area classified as semi-desert and generally lacking in resources, water, and population, was conceived as an industrial complex, emphasizing industries producing aluminum from the high-grade bauxite that exists in Gujarat, petrochemicals using the natural gas available in Gujarat, and cement plants using gypsum that exists in Kutch and Halar, and the calcium oxide also available in the area.

By contrast, in the nuplex in western Uttar Pradesh, the emphasis is on the agricultural side of the agro-industrial complex. Production of fertilizers and pumping of sub-surface water for irrigation of 3.8 million acres form the basis of the complex, in addition to manufacture of cement and steel. A third nuplex has been suggested (but no feasibility study has been done) for Madhya Pradesh, where rich deposits of bauxite are complemented by deposits of coal in the form of lignites and iron ore. Currently, lack of electrical power prevents the manufacture of aluminum in large quantity. **Table 1** summarizes the economic and social results of power production and application for each of the three proposed nuplex sites.

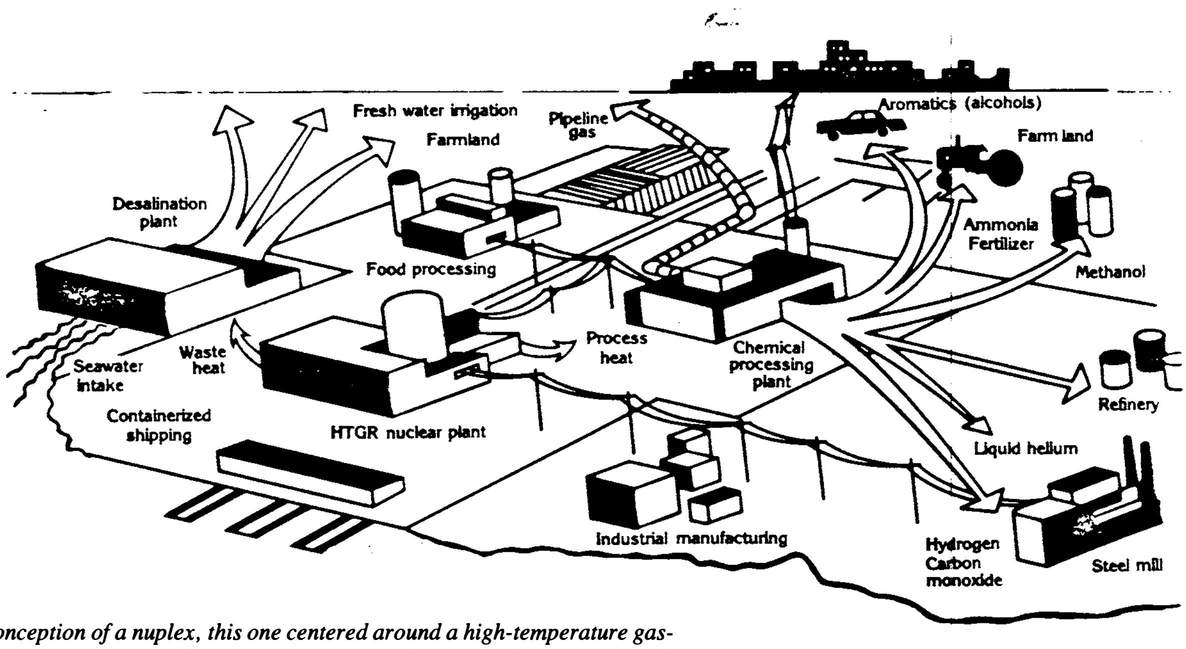
Oak Ridge originates the 'nuplex'

In the mid-'60s, U.S. Oak Ridge National Laboratory in Tennessee conducted extended studies of large seaside and other industrial and agro-industrial complexes integrating a

TABLE 1
How nuplexes would affect production

Commodity	Production	Power capacity consumed
1. Kutch, Gujarat		
Ammonia	3,000 tons per day	100 MWe
Aromatics	13,000 bbl* per day	100 MWe
Methanol	3,000 tons per day	60 MWe
Aluminum	1,500 tons per day	650 MWe
Cement	1,000 tons per day	500 MWe
Grid electricity		500 MWe
Desalination	1,000 mgd**	100 MWe
2. Western Uttar Pradesh		
Ammonia	3,000 tons per day	100 MWe
Chlorine	1,000 tons per day	100 MWe
Liquid H_2	100 tons per day	50 MWe
Finished Steel	3 million tons per year	300 MWe
Phosphate	700 tons per day	150 MWe
Pumping water	1.5 million acre-feet	150 MWe
Cement	1,000 tons per day	500 MWe
Grid electricity		650 MWe
3. Madhya Pradesh		
Aluminum	2,000 tons per day	900 MWe
Finished steel	4 million tons per year	450 MWe
Ammonia	3,000 tons per day	100 MWe
Phosphate	700 tons per day	150 MWe
Grid electricity		400 MWe

* bbl = billion barrels; ** mgd = million gallons per day



An artist's conception of a nuplex, this one centered around a high-temperature gas-cooled reactor (HTGR), with a desalination plant providing water for irrigation and consumption.

variety of energy-consuming processes with low-cost energy centers. It called these energy centers "nuplexes"—the shortened nomenclature for a nuclear-based agro-industrial complex.

One study designed a large industrial complex centered around a 1,000 MWe (3,800 MW thermal) reactor. Such a nuplex, the study showed, could produce about 250 tons a day of elemental phosphorous, chlorine, and caustic soda, and 550 tons a day of oxygen, and still have a surplus of 100 MW of electricity. On the same basis, an agro-industrial complex centered around a 2,000 MWe reactor and a desalination plant with a capacity of 500 million gallons per day (mgd) could produce a variety of crops on about 240,000 acres of surrounding desert, and various industrial products as well.

In the latter half of the 1960s and early '70s, a great deal of enthusiasm existed for building such large nuclear-centered, agro-industrial complexes to speed up economic development. Feasibility studies for large agro-industrial complexes in India, Israel, and Egypt appeared in bulletins of the International Atomic Energy Agency and were under discussion at the highest government levels in many countries.

The nuclear power plants recommended for nuplexes are dual-purpose high-temperature reactors (HTRs). These reactors will produce both high-temperature process heat and also electricity.

One of the major objectives of a nuplex is to utilize the process heat for industrial applications. Process heat can be used in the paper pulp industry and also in the production of metals, chemicals, fertilizers, cement, glass, petroleum, and rubber products. Low-heat process steam (90-120°C), which is available with the present generation of nuclear reactors, has significant use for space heating and in the food-processing industry.

Agriculture is also a potential user of waste heat. Irrigation with heated water can promote winter seed germination and growth, and extend the growing season in cold countries. Hothouses could be used to grow tropical or subtropical crops in more temperate regions of the country. Although warm-water irrigation is a viable alternative, it is neither a year-round nor round-the-clock requirement. However, one promising potential use of condenser discharge water is in aquaculture. Marine and freshwater organisms may be cultured and grown in channels and ponds fed with heated water. For example, it may be possible to grow commercially valuable oysters in areas where they cannot normally reproduce or survive due to low water temperature.

Advantages of nuplexes

The advantages of the nuplex are many. First, most developing nations do not possess an adequate grid system that can distribute electricity reliably and with minimum losses. This poses an immediate and serious obstacle to expanding energy generation and consumption. Besides being highly expensive and time-consuming to install, long transmission lines also cause a great deal of line loss. In the nuplex, the power is consumed locally, thus eliminating the large transmission expense and waste associated with line loss.

Second, the process steam or "waste steam" produced by the plant is used directly, "on the spot" so to speak, in many essential industrial processes. This is a further, vital aspect of the optimum utilization of power plant output that defines the nuplex.

Where power economy is concerned, good sense thus requires that the attempt be made to exploit existing oil fields more intensively. The oil industry is developing methods for tapping the oil deposits in oil sands, and also the remnants of oil in already-exploited deposits. Steam, which is blown in under pressure and can be supplied by fossil-fired plants or by nuclear reactors, lowers the viscosity of these oil reserves and increases the pressure in the deposit. In this way, it is possible to extract even the heaviest oils from oil sands, or remove much more oil from existing sources than has been done hitherto. The most economically viable and ecologically compatible method of steam generation would be to employ nuclear power plants. In addition, this would contribute to saving the valuble fossil fuels for other purposes. This is why the German firm KWU is working on the design, for this special purpose, of nuclear power plants with light-water reactors. Oil shale deposits, which can contain up to 33% organic substances, can in the future probably also be better exploited with the aid of process steam than, for example, conventional retorting processes.

The nuclear power plant situated beside the oil field can thus fulfill three functions simultaneously: the generation of process steam for improving the exploitation of oil deposits, supplying process steam for oil-processing plants and refineries, and producing electric power.

Third, the idea of building nuplexes is not simply to develop agricultural and industrial belts, but to build cities. Besides power, water, transportation, and communications, the basic infrastructure for a city includes primary and higher educational facilities, vocational training centers and engineering institutions, research centers, cultural centers such as halls, theaters, and auditoriums, as well as sports facilities, trade and commerce centers, and so forth.

Here the nuplex offers further efficiencies. For example, process steam or heated water from the nuclear plant serving the new city might be used for space heating or cooling, or for water renovation, in addition to industrial applications. Similarly, we are finding increasing usage for radioisotopes in various aspects of our everyday life. It is expected that the demand will increase, and yet more and better uses for radioisotopes will be found. Provisions for obtaining a copious supply of radioisotopes can be built into the nuplex.

The importance of desalination

Nuplexes are also crucial for large-scale desalination, the manufacture of freshwater by removal of salt from sea water. This technology is especially important for the Middle East, where provision of adequate freshwater is essential for resolving the Israeli-Palestinian conflict.

Many different types of distillation processes have been proposed and explored to determine which is the most effective. Desalting of water by distillation is both an energy-intensive and a capital-intensive process, and it is essential to minimize the cost of energy required and the capital investment overall. In a typical case, where a desalination plant of 1 billion gallons per day capacity is integrated with a 2,000 MW power plant, sufficient water would be available to irrigate 300,000 or more acres under intensive agriculture. Chemicals produced in the process would be ample to provide fertilizer at optimum conditions to this newly cultivated area, as well as for an additional 1-2 million acres. The total food production of such an agro-industrial complex, not including t at obtained through the use of fertilizers outside the newly cultivated area, is enough to feed a population of 4 million people with a daily intake of 2,500 calories. These parameters are indicative of the enormous potentials in this area.

One such project was given serious consideration for construction in the United States: the Bolsa Island Project, a dual-purpose nuclear station in southern California, would have eventually generated 1,800 MW of electricity and distilled 150 mgd of freshwater for irrigation or other uses. But, as was the fate of many large infrastructure projects in recent decades, this project fell through due to lack of will and determination. However, a limited version of the nuplex appeared in the state of Michigan. There, the Midland Nuclear Cogeneration Plant of Consumers Power is in the process of setting up two 2,452 MW thermal light-water reactors (LWRs), which will supply 4 million pounds per hour of steam to Dow Chemical Co.'s Midland complex.

Most of the Asian countries involved in the development of nuclear power for commercial use have high annual rainfall. Countries located east of 70° longitude experience a great deal of rain, and this is why these are the major paddy-growing countries in the world. These countries have lagged behind in water management. When attended to using full measures, the utilization of rainfall in these countries makes them the cornucopia of the future. Nonetheless, northern China, a good part of Pakistan, and even western India have low rainfall. Of these, western India is coastal and can be effectively developed using desalination.

In addition, one must take into consideration the local benefit that desalination can bring. Countries like India, China, and Pakistan, in particular, and a galaxy of small islands in the Philippines and Indonesian archipelagos, could easily be made habitable and highly productive with the introduction of nuclear power-based desalination processes. The entire approach should be in line with the nuclear-based industrial complex, where desalination of seawater will be the key to economic success. As the pressure for building new cities is increasing by the day—as one Indian economist said recently, to make a real dent on Indian poverty, India requires "hundreds of Bangalores" (a booming high-technology-oriented city in southern India)—desalination is destined to play a crucial role in the coming years, breaking out, finally, from the straitjacket put on it by petty accountants masquerading as economists, planners, and policymakers in Asia.