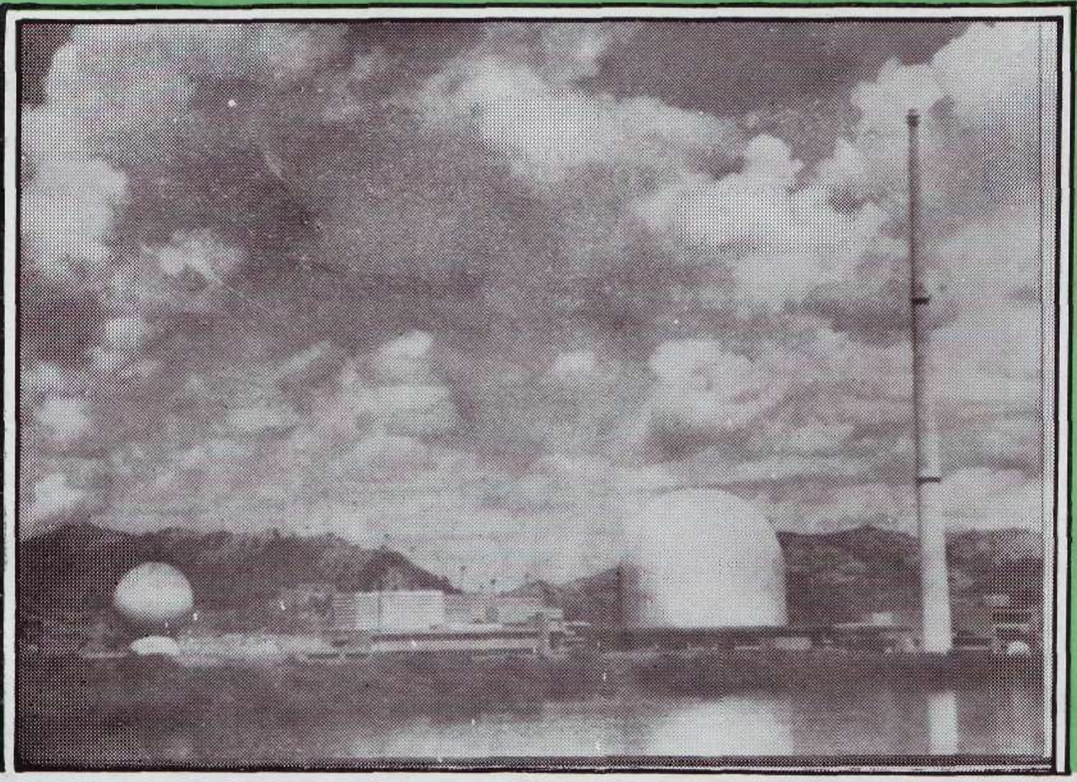
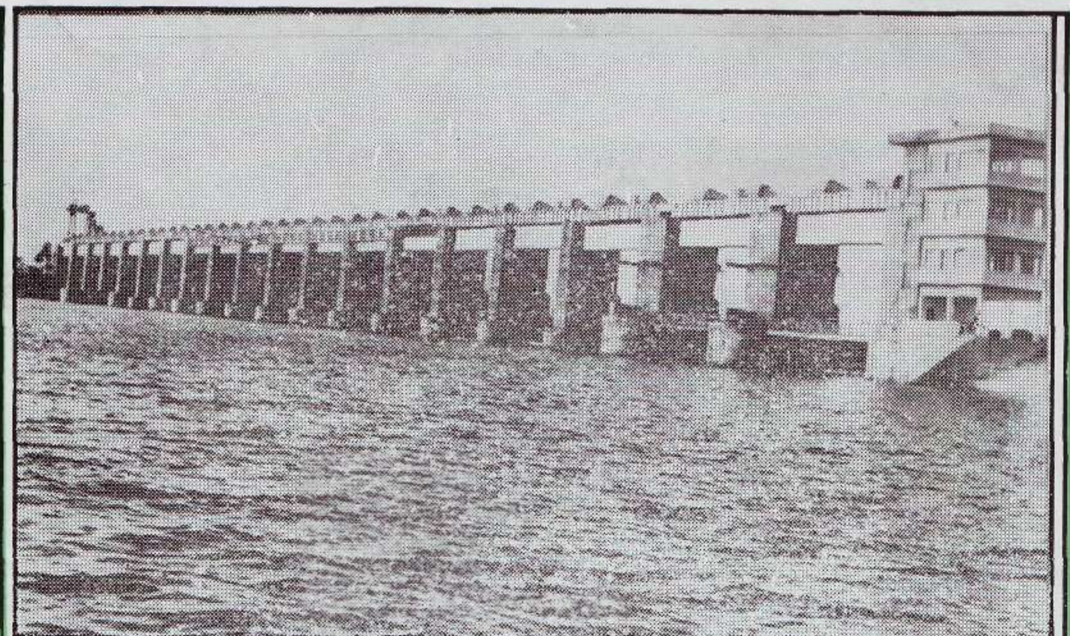
INDIA IN THE YEAR 2020



A 40 Year Programme To Make India An Industrial Giant



INDIA IN THE YEAR 2020

A 40 Year Programme To Make India An Industrial Giant

Published by :

New Wave Society
1001, Rohit House, 3 Tolstoy Marg,
New Delhi-110001.

Printed by :

N. W. S. at New Wave Printing Press,
Sector-7, E-146, NOIDA

Price Rs. 10/-

India in the Year 2020

Foreword to the Second Edition

It has been almost three years since we issued the forty-year perspective programme to make India an industrial giant, *India in the Year 2020*, worked out by the Fusion Energy Foundation and the Executive Intelligence Review magazine of the United States. It is our feeling that developments during the course of the intervening two years underscore the urgency of adopting a long-term development strategy along the lines proposed by this programme.

In the past three years we have found that while some of our economists, planners, scientists and politicians have not agreed with every detail of the programme, they *have* recognised that the approach taken is fundamentally in agreement with that taken by our planners under Jawaharlal Nehru. The most frequent criticism we have received is that the programme is "too ambitious"—a criticism which we would be the last to deny. The best response we have for this criticism is the following quote from a speech Jawaharlal Nehru delivered at the golden jubilee of the Indian Merchants' Chamber in Bombay on 3rd February 1958:

"We are building three major steel plants and doubling a fourth one. So we really have four plants. An eminent German engineer was telling me at Rourkela that he did not know of any country which had the courage to start four plants like these simultaneously. Still we have done that. And when people say, 'You have been over-ambitious in regard to the Second Five Year Plan,' I will reply that we propose to be over-ambitious every time. It is that outlook that we wish to produce in the country, not the outlook of caution and of creeping along slowly. For the stakes are high. We dare not go slow—for we may fail completely by going slow."

It is precisely as a result of that "over-ambitious" approach of the post-Independence period that India has become one of the most advanced of the developing countries, and is rightly looked to for its scientific and and technical capability, its strong industrial base, and its ability to achieve self-sufficiency in food production. India has proven the Malthusian dogmas of the impossibility of progress—ritual justification for keeping the developing sector in a state of brutal backwardness since the heyday of British colonialism—to be pure fraud. But in spite of the strength of our political leadership and the resilience of our economy, India today faces a crossroads.

The world is staring into the abyss of a new general great depression provoked by the enforcement of bankrupt economic and financial policies—including varieties of "free market" and monetarist lunacy—in the advanced sector, principally the United States. The imposition of these economy-wrecking policies on developing sector nations through the medium of the commercial credit markets and the International Monetary Fund-World Bank institutions is posing an increasingly grave threat to developing countries' very survival, much less their efforts to build strong self-reliant and modern economies.

Since at least 1979 the Western powers that be—a grouping of bankers and aristocrats centered around the Euro-American oligarchy and gathered in such institutions as the elite Bank for International Settlements and the monetarist Mont Pelerin Society, and their bought-and-paid-for bureaucrats in governments and policymaking institutions—have been set upon a course to achieve what they have themselves described as the "controlled disintegration" of the world economy. Under the pressure of growing world financial instability, an international program of austerity and "free market" looting of economic and human resources in both the advanced and developing sectors was undertaken on top of the neo-Malthusian "low growth" and "appropriate technologies" campaign of the 1970s. In the United States, Federal Reserve Chairman Paul Volcker announced that American workers' living standards would have to be reduced, and, citing the "controlled disintegration" policy, proceeded to raise US interest rates to their highest level since the Civil War—unleashing a vicious speculative spiral, a US industrial breakdown, and trade collapse throughout the world economy.

Attack on "economic nationalism"

But the special target of this "blueprint for the 1980s," as it was spelled out in a US Council on Foreign Relations multi-volume study under that title, is the "neo-mercantilist," "economic nationalism" of developing sector nations. One after another, these countries have had their sovereignty violated and their economies held to ransom by the IMF-World Bank "conditionalities" policies in circumstances where the rise in oil prices, the fall in prices of raw materials, the spread of usurious interest rates and the collapse of world trade pulled the bottom out from under economic development plans. As their indebtedness has soared, their ability to meet debt payments has crumbled.

Invariably the price for assistance from the international bankers has been the dismantling of national economic sovereignty—state sector industries, public sector planning, foreign exchange and investment controls, and "protection" for domestic industry. Invariably the price for assistance has been the replacement of national plans for high-technology, capital-intensive development of basic industry and agriculture with programmes of budget and credit austerity, zero growth in industry and adoption of low-level "appropriate" technologies, and an "open door" policy for trade and investment. Massive and growing indebtedness is institutionalised at the same time that the wealth-creating economic activity on which not only debt-servicing but the possibility for rising living standards is based, is systematically destroyed.

Instead of the new international eoonomic order based on an expansion of directed credit for industrial development, major international infrastructure projects and a massive expansion of capital-intensive technology transfer to the developing sector, the international bankers and their paid policymakers have only austerity to offer.

This is the gameplan for India, as it is for every developing nation. The bankers and their policymakers in London and New York and Geneva are waiting and watching. Many hope that they have successfully lodged one proverbial foot in the door with the multi-billion dollar IMF loan, and otherwise are relying on their "echoes" within the Indian bureaucracy to build support for the treasonous, economy-wrecking policies from within. Like every developing nation, India has its quota of Mir Jaffars, creatures of the World Bank-IMF school of British political economy and assorted vareties of "free enterprise" monetarists. The case of Brandt Commission leader L. K. Jha, whom no less than former World Bank president Robert McNamara recently identified as "the Paul Volcker of India," is just one case in point.

Whether India's sovereignty is broken depends on the quality of political and economic discussion and decision-making in the nation over the coming months. We are now at the half-way mark of the Sixth Five Year Plan with major goals unmet, and unmeetable on present performance. The Seventh Plan awaits formulation, but in truth it will prove to be a hollow excercise unless the most fundamental and basic problem in the Indian economy is remedied. Stated briefly, that problem is the fact that the most basic requirements for a viable and sovereign national economy—power, water management and transportation—are at this point dangerously inadequate.

This single problem is placing a near-crippling burden on both industry and agriculture, as even a summary review of the past two years' performance clearly shows. It is furthermore this single problem which gives the lie to the recent concern over the rise in the capital-output ratio (COR)—an argument which is being used to organise a new assault on the approach set for India by Nehru's commitment to scientific planning for industrial modernisation based on the most a dvanced science and capital-intensive technologies.

With the failure to invest massively and concentratedly in power and other infrastructure development, properly conceptualised and implemented, is it any wonder that India's capital output ratio is twice as high as that of most developed countries and still rising? Yet we can expect the refrain to get louder, boosted by all the World Bank crowd's echoes: "The more capital we invest, the less output we get...How can we justify continued indulgence in expensive capital-intensive projects?... Perhaps we will have to forget the petro-chemical complexes, aluminium plants, etcetera, and find another way—something more 'appropriate'..."

Contrary to the fraudulent logic of such arguments, it is a vastly stepped up and concentrated investment in basic infrastructure, along the lines we have recommended since 1980, that is required. Without it, the nominal production gains of the past two years will prove worse than illusory. Without it, it matters little whether there is slightly more or less of this or that in the Seventh Five Year Plan. Only thus can production and productivity be increased, and, incidentally, the capital-output ratio be brought down.

Review of the Indian economy

A quick review of the economy over these past two to three years indicates the scope of the problem.

Power

Take the power sector, without a doubt the single most important parameter of an economy's health and growth prospects. In 1980 India's total installed electric power generating capacity was approximately 31,000 megawatts. With a population of 684 million, this is about 45 watts per capita. By comparison, Japan, with less than one-sixth the population, has an installed capacity of 250,000 megawatts, or almost ten times the amount in India—its installed power capacity per capita is therefore almost fifty times greater.

The lack of power in India has created a vicious circle of inefficiencies and bottlenecks throughout the economy, seriously inflating the cost of production overall. For the past two years power availability has fluctuated between 10 and 15 percent short of conservative nominal current requirements. Not only is industry debilitated—routinely forced to shut down for as much as ten hours a day, with the associated loss in productivity and damage to equipment—but the general scarcity of power has poisoned the investment climate generally. Further, India's electrical power transmission line losses continue to be among the highest in the world; the absence of a national grid, and poor quality materials is exacerbated by illegal line-tapping to cause transmission losses to run as high as 26 percent (as in Rajasthan), compared to 10 percent in advanced sector economies.

Presently, out of sheer desperation, a number of licences have been issued to heavy industries to build captive coal-based thermal power plants—a decision of far-reaching consequences. Not only is captive power distinctly cost-ineffective because of its localisation and small capacity size, but it also lengthens the gestation period for building a new plant and adds an enormous overhead cost that is replete with a range of logistical burdens in terms of coal handling that are both local and nationai in scope.

The Sixth Five Year Plan projects an increase of power generating capacity to 50,000 megawatts by 1985. Not only is the projected goal much below even conservatively estimated requirements, but at the rate that new capacity is presently being installed this goal will be impossible to achieve. Against a plan target of 4,000 megawatts per year, during the first two years of the Sixth Plan new capacity added was a mere 1,600 and 1,700 megawatts, respectively.

But even on its own terms, the power programme is incompetent; first, because it treats power capacity as just one more item in the 500-page Plan and is far too conservative to allow for rapid economic growth. Secondly, because it is based almost entirely on hydroelectric and coal-based thermal power stations. Hydroelectric power, aside from being seasonal, is often too far from the consumption centres, and if fully tapped could still only provide some 40,000 megawatts of installed capacity.

The relative inefficiency of coal-based power—inspite of India's large reserves of coal—is severalfold. Where the power station is not located at or near the source of coal, transport is an immediate and serious problem due to the ;ineffective state of the nation's rail system. On the other hand, the super-thermal plants sited at the pit-head that are now planned or under construction run directly into the problem of transmission losses. Even with a major upgrading of the grid, indeed the creation of a national grid which does not presently exist, distances would still be significant enough to cause inevitable inefficiencies. Moreover, the quality of coal in India is characterised by low fuel efficiency, and would therefore, from an energy-efficiency standpoint, be much better used in the form of coal gas as a feedstock for petrochemicals, fertiliser manufacture, or ultimately, for power production via the much more efficient magneto-hydrodynamic (MHD) process.

Although hydel and coal-based power should be tapped to as great an extent as possible, the void in India's power development planning remains its nuclear energy programme. Not only is nuclear-based electricity safe, clean and free of the logistical-transport problems of coal-based power, but India uniquely possesses the full scientific, technical and industrial capability indigenously. Aside from China, India is the only developing nation to possess the complete nuclear fuel cycle. India also has the largest thorium reserves in the world. We cannot afford to equivocate any further on this vital option, so deliberately and emphatically advocated by Jawaharlal Nehru and Homi Bhabha.

Furthermore, as Dr. Vikram Sarabhai pointed out in the late 1960s, besides utilising nuclear power plants to supply electricity to industry, the construction of nuclear-centered agro-industrial complexes—"nuplexes"—could provide the key to India's otherwise haphazard urbanisation. Over the years, too few new cities have been built while the old cities suffer from decay and congestion. The problems of Calcutta, and now Bombay, give new urgency to Sarabhai's proposal.

Water management

Water management is the second critical infrastructural consideration, in light of India's abundant, though underutilised water resources and great agricultural potential. Despite the long-standing commitment to irrigation development in India, still 105 million out of 143 million hectares of cropped land depend on rainfall. The plan to bring 2.5 million hectares per year under irrigation for the next twenty years, to reach the estimated full potential of 113 million hectares under irrigation by the year 2000, conservative as it is, is unlikely to be met under the present circumstances in which bottlenecks and inefficiencies add to lack of focus, resulting in delay and diversion of needed investment funds.

The Rajasthan Canal Project is a case in point. Begun in 1958, and scheduled for full completion in 1984, the first phase has yet to be completed. According to announcements in 1982 the first phase will be completed by .985. A large project in scope and effect, in fact the largest of its kind in the world when initiated, the Canal is straight-forward from a technical standpoint and was recognised from the outset to carry a major payoff—its completion would transform a barren desert into a productive agricultural area dotted with economically active population centers. The delays—all related to infrastructural weakness—amount to sabotage of the economy. During 1982, for instance, canal construction was halted for lack of fuel to manufacture the tiles to line the canal. All the while, the cost of the project has predictably escalated and returns on the completed sections are thus far below projection.

Ironically, the fixation on irrigation per se—actually only one aspect of water management proper—has had a deterimental effect. Attention and funding has been focussed on large canals and dams to the exclusion of land preparation and farmer or other user education essential for the water's effective use. As a result, the returns from large irrigation projects are delayed and reduced overall. Meanwhile the broader aspects of water management, including especially flood control, are consistently delayed. Construction of the Tehri Dam, augmentation of the Ganges River's water and construction of the peninsular river system are cases in point. The latter, announced in 1980, is now on a track where it will take almost ten more years before a decision as to whether or not to undertake the project at all, will be considered!

Transportation

The transportation system likewise needs priority attention. The failure here is glaring. Although efforts have been made to develop the vastly more cost-efficient mode of water transport for barge traffic, very little has been accomplished so far. The Narmada River system can enable some barge activity to-occur in the western region, and with the augmentation of the waters of the Ganges River, barge traffic could ply between Calcutta and Allahabad. At present, transport of raw materials and finished goods depends almost entirely on the railroads and fuel-inefficient trucks.

For the past six years, despite a significant increase in output, the goods traffic carried on the nation's railroads has been stagnant at about 210 million tonnes per year. While the rapidly increasing deterioration of tracks is a very serious problem, the shortage of rail wagons is only an apparent problem; for lack of modernisation, and computerisation in particular, the rail tracks are in fact jammed up with unaccounted for and thus underutilised wagons.

To get an idea of how these infrastructural deficiencies and associated lack of competent planning concerning them interact, consider the following: Presently nearly 25 percent of the freight carried by a rail system acknowledged to be in disastrous shape, is coal. Yet the current programme for expanded coal-based thermal power production projects a doubling of the coal transported by rail over the next fifteen years.

The impact of infrastructural weakness and inadequacy on both industry and agriculture is devastating. Although India has achieved large agricultural productivity gains in certain areas—such as Punjab, Haryana and western Uttar Pradesh—which have kept the nation free from famine, the average per hectare yields for the country as a whole still remain much lower than most countries. India's agricultural science and education infrastructure is at a par with most developed nations, but what is lacking is the large-scale input of dense energy. Per hectare fertiliser input in India is about one fourth that in the U.S. and one fifth that of Japan.

In another ten short years, India will require at least ten million tonnes of nitrogenous and three million tonnes of phosphatic fertilisers, according to conservative estimates—almost four times as much as is now being produced. Despite steady progress in development of fertiliser technology, fertiliser production capability has been seriously undermined by power and transportation constraints. With the discovery of natural gas fields off-shore near Gujarat the feedstock is at hand for an expansion of fertiliser production capacity. Intrastructure constraints cannot be allowed to prevent this.

Aluminium and steel

The aluminium industry, which could play a key role in India's economy, has been hurt badly by the power shortage. Despite the fact that India has fully 25 percent of the world's bauxite reserves, present production of aluminum amounts to only two percent of the world total. India's present installed capacity is 350,000 tonnes annually, but power cuts and transportation bottlenecks have held maximum production in any given year to 195,000 tonnes.

India's basic metals industry generally has stagnated under the weight of power and other infrastructural deficiencies. While no new plant has been built since 1964, the nation's major integrated steel plants have had expansion plans approved—but every one of them has already run into major delays. These delays have doubled project costs, and immobilised the invested capital for an extra two to three years.

Infrastructure—key to productivity

One could proceed through every sector of the economy in this fashion to detail the effect of the failure of infrastructure. As was demonstrated in an April 1982 study of the U.S. economy using the LaRouche-Riemann economic analysis—on which these recommendations for India are based—infrastructure investment is the key to productivity. This is a fact which most conventional economic analysis methods cannot possibly recognise or account for. Since infrastructure does not produce output, conventional cost-benefit analysis treats investment in this area as a net expense with little or no return. But while infrastructure does not produce output, *it does increase productivity*, and thus acts to increase the energy throughput, profoundly enhancing the thermodynamic efficiency of the economy as a whole.

Any planning projections which cannot or do not take such basics into account are therefore bound to be misleading and dangerously incompetent.

—Publisher

★

Introduction

The Industrialisation of India, 1980-2020

by Dr. Uwe Parpart

In a speech delivered in the Lok Sabha on May 23, 1956, Prime Minister Jawaharlal Nehru, initiating the debate on India's Second Five Year Plan, spoke on the principles adopted by the Planning Commission in the preparation of its report:

"When we talk of planning we have to think in technological terms, because it is this growth of science and technology that has enabled man to produce wealth which nobody could ever have dreamed of. It is that which has made other countries wealthy and prosperous, and it is only through the growth of this technological process that we shall grow and become a prosperous and wealthy nation; there is no other way... Therefore, if India is to advance, she must advance in science and technology, and India must use the latest techniques, always keeping in view, no doubt, the fact that in doing so, the intervening period, which is inevitable, must not cause unhappiness or misery... But the fact is that our poverty is due to our backwardness in science and technology, and by the measure that we remedy that backwardness, we create not only wealth but also employment."

This report on the future industrial development of India, intially commissioned in July 1979 by U.S. presidential candidate Lyndon H. LaRouche in consultation and after discussion with Indian scientists, engineers and political leaders, was prepared in the spirit that guided Nehru's 1956 remarks, although—as he would be happy to note—its proposed goals and objectives well exceed those he envisaged 25 years ago. The report's principal conclusion is that in the 40-year period between 1980 and 2020, India, while almost doubling the size of its population from 660 million to slightly less than 1.2 billion, is entirely capable of advancing from abject backwardness to the status of a modern industrialised nation with an educated population and an industrial infrastructure comparable to those of the Soviet Union today.

This of course presupposes precisely what Nehru demanded: utilization in the development process of the latest, most advanced production technologies rather than reliance on the World Bank or Club of Rome "appropriate technologies" concept which stresses labor-intensive production methods and technologies appropriate only to the present backwardness of the overwhelming majority of the population. Nor can a gradual, "organic growth" approach to economic development—the type of growth currently advocated by the Club of Rome in contraposition to the allegedly "cancerous" exponential growth experienced by the advanced sector nations during the past century and a half—be expected to alleviate India's misery. Nothing but a sharp, well-defined shock delivered to the entire economy, especially to the dominant but at best marginally productive rural and so-called unorganized sectors, will break the cycle of underdevelopment.

This can be accomplished by marshalling the 10 million most highly skilled of Indian workers joined by India's extraordinary and well-qualified corps of scientists and engineers, exceeded in size only by the Soviet Union and the United States, and set in motion by a necessary initial infusion of imported capital, bringing this concentrated force to bear on two principal objectives:

1. A crash nuclear-based energy development programme to power the industrialization process; by 1990, ten years into the program, more than 50 1000 MWe nuclear power plants should either be operating or in various phases of construction. Simultaneously the first nuclear-centered agro-industrial complexes, so-called nuplexes, will come on line and become the highly productive cores of several major new cities. This will spearhead a rapid urbanisation process which by the turn of the century will have increased the share of the urban population from today's 22 percent to almost one-third. Detailed plans for nuplexes at two separate locations were initially drawn up in the mid-1960s by the Atomic Energy Commission of India and Oak Ridge National Laboratory in the United States.

The extent to which worldwide energy development, industrial development, and standard of living go hand-in-hand is well known, and there should be no illusions about the fate of tens of millions of Indians between now and the year 2000 if the "hard technology" energy program detailed below is not enacted. This fact is well known in India. As the great Indian scientist Homi Jehangir Bhabha remarked in 1955 before the Geneva Conference on the Peaceful Uses of Atomic Energy, "For the full industrialisation of the underdeveloped areas, for the continuation of our civilisation and its further development, atomic energy is not merely an aid; it is an absolute necessity."

2. The second principal target area for Indian economic development is water management—the huge but entirely unavoidable task of harnessing the subcontinent's immense water resources, if the deadly, centuries-old cycle of droughts and flood is to be broken and a modern agricultural industry is to replace one of the world's least productive rural economies. While presently only the Ganges carries sufficient water during the dry season, India's other rivers, if properly dammed up and channeled, could put the whole country under two feet of water year round and in addition, produce at least 40,000 megawatts of hydoelectric power, or four times the present amount.

The irrigation and power reserves stored up in India's river and hydroelectric balance thus are enormous and require a commensurate effort for their development and activation. It is proposed here that a National Water Management System of the kind first put forward by former irrigation minister K.L. Rao, representing an approximate total investment of $180-200 billion dollars over a 30-year period, become the single largest industrial construction project for the subcontinent. This plan, through the required manpower and capital resources mobilisation and its massive impact upon the productivity of agriculture, singularly exhibits those shock properties for the economy mentioned above.

Concomitantly with the high-impact nuclear energy and water development project, an in-depth mass literacy and education policy must be adopted to eradicate illiteracy which still afflicts close to 70 percent of the population. The problem was defined by Jamsetji Tata, the founder of one of India's largest industrial concerns. In 1876, speaking of the preconditions of industrialisation, he listed these priorities: "Knowledge and knowhow. And once again, knowledge, knowhow, and experience. In addition our own iron and steel. Plus our own cheap electricity."

Through the expansion of primary education, the broadening of secondary education to enlarge the base of an already in many areas qualitatively excellent higher education program educating the teachers of the next generation, and the targeted development of adult manpower training programs geared toward specific industrial projects, illiteracy can be substantially eliminated by the turn of the century. At that point, what now appears as India's greatest liability and is defined by the World Bank as the principal barrier to its development, its population, will turn out to be its greatest asset. In 2020, the final years in the projections for this program, the productive industrial (non-agricultural) labor force will reach between 230 million and 240 million—greater than the world's entire manufacturing work force today.

Agricultural labor will decline to around 130 million. But India's agricultural potential is so large, the gap between the present production per hectare and the productivity levels reached in advanced sector countries so wide, that the water and energy inputs provided for by the water and nuclear projects will transform the country into a major exporter of agricultural goods. Here are some of the relevant figures: India now has about 190 million hectares under cultivation which could easily be increased by 20 to 30 percent; but even of the existing cultivated land on average only two-thirds was sown in recent years. Even more telling: U.S. farmers use five times the amount of fertiliser per hectare as their Indian counterparts.

While these figures demonstrate the enormous development potential of Indian agriculture—provided advanced sector levels of energy throughput, representing higher degrees of mechanisation, irrigation, and fertilisation, are realized—these same figures, left unchanged, and juxtaposed to present consumption levels of the population, show an equally enormous potential for ecological catastrophe. Out of 660 million Indians, 360 million, or well over half of the population today receives less than the government-designated daily minimum requirement of 1900 calories, and this minimum is already 500 calories less than that specified by advanced sector countries, for their populations. At least a half-million people die of malnutrition every year bound to decline, and there is no margin between the present standards and sheer disaster on the grand scale." and the mortality rate of children under five years of age has risen from 32.2 percent in 1951 to 36.1 percent in 1976.

These last figures are the most telling, but the trend they indicate can be reversed. The physical parameters generated by the program presented here allow us to chart a navigable course for India which will find the country well on its way toward advanced sector status by the turn of the century.

Politically, and as a matter of historical record, it is not unimportant to point out at this juncture that India today is not so much an underdeveloped country as it is a country that was ruined by centuries of British colonial rule and imposed backwardness. As late as the 17th century, India was a developed country by the standards of that time and throughout its long history had, over several protracted periods, achieved cultural heights and initiated developments exemplary for the rest of the world. "Arabic" numerals should rightfully be called "Indian," advanced techniques of iron and textile production have their origin in India, and, at the time of Emperor Ashoka in the third century B.C., India had the world's most highly developed educational system.

India now must reconnect its destiny to this tradition and in attempting to do so, she will find herself confronted every step of the way by today's disciples of the British East India Company's most evil product, Thomas R. Malthus. An ugly mixture of updated Malthusianism and cultural relativism is presented in the chapter "India and the West" of Arnold Toynbee's *The World and the West*. Explaining that Western culture on the planes of technology and science, language and literature, adminstration and law is "extremely alien" to Indians, he voices hypocritical concern that "the tension in Hindu souls must be extreme, and sooner or later it must find some means of discharging itself." Aside from the social catastrophe implied by such an "emotional discharge," there looms, according to Toynbee, the truly unsolvable problem of overpopulation: "Since progressive improvements in productivity must sooner or later bring in diminishing returns, the standard of this swollen population seems

To the extent that India's present political leadership understands the very palpable threat behind Toynbee's theorising will it be able to recover India's historical greatness following the course outlined two decades ago by Nehru and the scientific elite exemplified and organised by Bhabha.

——

Projections for the Year 2020

Part I

Introduction

A detailed study of the overall development plan was prepared using a computerised economic model, the Riemannian Ecconomic Analysis (REA). This model, in contrast to conventional econometric models, is based on a *fundamental distinction being* drawn between productive components of an economy—those which contribute to further economic reproduction—and nonproductive components—those aspects of consumption which are a net tax on the capabilities of an economy for further growth and development. This distinction is used to construct a dynamic set of equations which describe the interrelations between capital investment, productivity, living standard, and technological development. These four factors are the principal determinants of economic development and form the core of the REA'S quantification of economics.

To study the problems of the industrial development of India using the REA, a data base was prepared which consisted of two "economic states." The first was an estimate of the current potential of the Indian economy as it stands today. Given the stagnation of the Indian economy over the last decade, we chose 1976 as indicative of the highest productivities and capacities of the economy. Secondly, we chose a *final state*, to be achievable in 40 years, corresponding to an economic profile of a large-scale industrial economy with a significant agricultural sector. We approximated this final state for the Indian economy with that of the Soviet Union today. The Soviet economy has a still significant agricultural sector and work-force (of approximately 30%—very nearly what our population projections determined independently for India), but is an economy which is heavily industrialised and urbanised. In overall terms, the transition from the Indian economy today to an economy of the state of development of the Soviet economy (for the population in India in 40 years) requires a sustained growth rate of almost 10% per annum, a 25-fold increase in per capita personal consumption and a vast expansion in capital investment.

The questions which the computer analysis allows us to answer are the following:

(1) Is it possible to start from where the Indian economy is today and reach the hypothetical industrialised state in 40 years? That is, does a "trajectory" exist through the economic phase space defined by the REA which has the Indian economy today as an initial state, and which passes though the state of development of an economy like the Soviet one?

(2) If such development is possible, what rates of capital investment are required? What productivity changes, and what rates of manpower development?

(3) Given political and economic constraints, what is the investment strategy which will minimize the time and investment required to achieve this development?

The REA is uniquely premised on the crucial role that overall transformations of the modes of technology piay in producing sustained economic growth over a long period, as envisioned in the program. The REA encompasses the transition from one mode or "geometry" of relations of productive forces, to a successive, "higher" mode characterised by a much higher efficiency and productivity. No economy could sustain the projected growth rates of this program if confined to a "linear" extrapolation of a fixed economic structure. In the Indian case, the water and agricultural development program, which will turn India into a major agricultural center of the world, and the nuclear energy/nuplex program, together provide the "non-linear" inputs on which the REA India projection is based, and make the indicated growth targets quite feasible. The present and future technologies to be introduced will radically increase the productivity of the work force which is the crucial parameter for sustained growth, to the point where a mere 50% larger productive work force will produce an annual output 50 times the present output, and six times the number of industrial workers will turn out more than 100 times more industrial output than is produced presently.

The details of the investment plan studied are contained in the body of this report, but the conclusions of the computer analysis of this development program are unequivocal—the projected development of India is not only possible, but is achievable within the bounds of quite modest (but sustained) increases in productivity and capital investment. The requirements for external capital, while substantial, are achievable in a rationally organized world credit market, and economically viable given the rapid development of the Indian economy which they make possible.

Part II

Projections of the Riemannian Economic Model for the Indian Economy

The data in the following tables and graphs was generated by computer according to the only econometric model based on the principles of continuous reinvestment of profits in expanded reproduction : the Riemannian Economic Model. The computer run demonstrates that while ambitious the overall development targets of the Indian Development Program presented here are entirely feasible. It also permits analysis of potential bottlenecks, and specifies certain parameters, such as levels of outside capital inflow, that must be met if the targets are to be reached.

For India to reach the level of development and material well-being reached by the industrialized sector at the beginning of the 1970s, India's overall national product must grow approximately 50-fold, which implies an average annual growth rate of 10.4% for the next 40 years. This translates into a 67-fold increase of the industry/transport/communications sector, and a 28-fold increase in the value of agricultural output (11.1% and 8.7% respectively).

How the Model Works

The model for India was constructed by specifying an assumed starting state for the economy based on present performance, and a targetted end state, which was derived in this case, as indicated above, by taking the present Soviet economy and assuming that India reaches approximately the same internal ratios of productive sectors, rates of productivity, and per capita material consumption. The other assumptions were a steady shift in the percentages of total reinvestible surplus (S') out of agriculture into industry and construction (though the absolute value of investment in agriculture continues to rise); a gradual transition between starting and end state productivities; an ongoing increase in investment in constant capital "C" (new plant, equipment, machinery and additional raw materials) relative to variable capital "V" (wage bill); and a declining relative (though at first increasing absolute value) input of capital from outside aid and loans.

What the model does is apply a series of differential equations involving C (Constant capital), V (Variable capital), S (Surplus product) and S' (Absolute surplus) to generate equivalents of each year's successive *reinvestments* in expanded production. S' is defined as the year to year growth of $C+V$. A (i) in the input tables for each sector of the model tells what fraction of total domestically produced S' goes into that sector, while the alpha ratio determines how much of that sector's portion of S' goes into V or into C. The delta ratio, or productivity, tells how much Surplus product is produced per unit of Variable capital in each sector. The delta ratios were determined by interpolating the values required to move from present values to the productivity values of the present Soviet economy. The alpha values were determined as the values needed to end up with the target proportionalities between the different sectors.[1]

The model is unique because it is not a *projection* of trend lines, as is every competing econometric model, but a calculation of actual investment decisions which are the *cause* of growth. The model will tell what the constraints are to achieving certain levels of growth, permitting one to see if a particular goal is realistic. In this case, the model shows that the primary limitation of the program can only be the absence of the political will to implement it.

The actual figures used are those of the Indian economy in 1976, using that year's prices. So all values in all the tables are in 1976 rupees. 1976 was the last year with complete enough data for the model. Given the present economic problems, it is safe to say that on January 1, 1980, there will have been little growth since 1976, and what growth may have taken place will at most shift the model projections 6 months or a year forward, without altering the validity of any of the projections.

Growth Projections

Table I presents the growth of national product 1980-2020. In the model, "Net National Product" as normally defined is broken down into direct wage income of the directly productive portion of the labor force (ie., factory operatives agricultural cultivators, transport workers, but not office personnel even if they work in a factory, service personnel, etc.) or "V" (variable capital); and the remainder of the value added in the production process, or "S" (surplus), which includes the direct wages of the remainder of the population, expenditures for public services (education, health, etc.), such non-productive items as defense spending, all of which constitute the non-productive portion of S ("D"), and the reinvestible portion, or S', which is used to invest in new productive facilities, irrigation works etc., and/or a larger and/or better paid work force, in the following year.

Thus, the growth of S+V gives a measure of the growth of traditionally defined Net National Product (NNP) under the assumptions of the model. As can be seen, NNP grows slightly more than 50 times, at an average rate of 10.4% per annum. This is broken down as an 8.7% annual growth of agriculture, and an 11.6% rate for the remainder of the economy, both attainable targets under the assumptions of the overall program.

The model further breaks the economy down into five sectors: agriculture, construction, steel (as the core of the heavy industry basis of industry), nuclear plant construction (as nuclear energy production is vital to the program) and the remainder of the productive economy, which includes the remainder of manufacturing industries, mining, and transporation/communications (called "residual" in the model). The respective growth rates of these subsectors, besides agriculture, are 11.1% for residual, 14.4% for construction, 13.2% for steel, and 13% for nuclear (measuring from 1990).

The industrial growth rate of around 11% is an ambitious target to keep for 40 years, but the assumptions of the overall program justify this goal. Both the Soviet and Korean economies have maintained this level for extended periods, the Korean achieving well over it for 17 years (and still doing so), and the Soviet achieving well over that rate during the 1930s and again for 15 or more years after World War II. India's own planners in the past have projected this rate or higher, and they were justified in thinking these rates possible.

The only question mark concerns the ability to maintain these rates after the economy has become quite large in magnitude; the dramatic slowing down of the Soviet economy in recent years might suggest that this growth cannot continue. While an extended discussion is not possible in this location, the following should be noted. There is nothing inherent in economic processes which dictates the slowing down of growth rates. In fact, with proper allowance for major and continuing technological breakthroughs, some of which have the effect of increasing the productivity of all other sectors, there is every reason to postulate an increasing rate of growth.

The Soviet case demonstrates the point. The crucial determinant of growth rates is the S' ratio, that is, ratio of S' to the entire economy, and the concomitant absolute growth of S', and the assumption that S' is continually pumped back into the most advanced technologies available.

In the Soviet case, because of exigencies of national defense, something over 10% of total GNP is plowed annually into a largely non-productive military sector. Even at the end of 40 years, India's entire presumed S' comes only to a little over 12% of NNP. Were the Soviet military budget converted into additional S', Soviet S' might easily double or even triple—and Soviet growth rates would rise back to double digits. The potential is there. The Soviet

Table I

Overall and Sectoral National Product (S+V) and Rates of Growth

	%Total	1980	1985	1990	1995	2000	2005	2010	2015	2020	%Total	%Rate/ Growth 1980-2020	Times increase
Total S+V	100%	670.2	1,096.4	1,982.0	3,196.6	5,231.9	8,278.6	13,290.4	21,239.2	34,717.4	100%	10.4%/Yr	51.8-Fold
5-Yr Growth Rates			10.2%	12.5%	10.0%	10.3%	9.6%	9.8%	9.8%	10.2%			
Residual S+V	40.7%	272.8	480.9	919.3	1,536.3	2,583.6	4,164.2	6,792.9	11,001.5	18,229.2	52.5%	11.1%/Yr	66.8-Fold
5 Yr. G.R.			12%	13.8%	10.8%	10.9%	10.0%	10.2%	10.1%	10.6%			
Agriculture S+V	55.4%	371.2	556.6	919.8	1,384.0	2,117.0	3,139.3	4,692.4	6,983.3	10,555.9	30.4%	8.7%/Yr.	28.4-Fold
5-Yr. G.R.			8.4%	10.5%	8.4%	8.9%	8.1%	8.3%	8.2%	8.6%			
Construction S+V	3.2%	21.2	47.6	111.4	215.3	419.0	772.8	1,429.0	2,562.0	4,617.3	13.3%	14.4%/Yr.	217-Fold
5-Yr. G.R.			17.6%	18.5%	14.1%	14.2%	13.0%	13.1%	12.3%	12.5%			
Steel S+V	.7%	4.9	7.8	15.4	27.6	53.0	102.8	201.1	376.8	712.2	2.1%	13.2%/Yr.	142-Fold
5-Yr. G.R.			9.7%	14.5%	12.4%	13.9%	14.2%	14.4%	13.3%	13.6%			
Nuclear S+V	neg.	.1	3	15.7	33.0	59.2	99.7	175.6	315.1	601.7	1.7%	N.A.	
5-Yr. G.R.			97%	39.2%	16.0%	12.4%	10.9%	12.0%	12.4%	13.8%			

Note : All non-percentage numbers are in billions of 1976 rupees. The growth rate indicated beneath each number is the annual rate of growth of that sector in the preceding year.

economy has also been hampered by restrictions on foreign technology, and bureaucratic and planning errors that are assumed to be less operative in the Indian case.

The only other question is whether India can sustain a better than 8% rate of agricultural growth. Such a record has no precedent in history. However, India also has the best agricultural potential of any country in the world, barring none, and is starting from a still abysmally low base (with over 160 million arable hectares, India still produces under 140 million tons of grain in the best years—ie., less than 1 ton/ha.).

Within 40 years, the unprecedented development program envisioned in this plan will have matched the water to the land in such a way that 70% of the land area will be irrigated and capable of producing 2 or more crops per years. With comparable levels of fertilizer, 5 mil. tons/ha. is eminently feasible, raising India's protential grain production well over one billion tons—a ten-fold increase! With quick ripening varieties, other types of crop rotations, and other to-be-developed technologies, even this is far from the limit. India can and will become the bread-basket of the world.

Standard of Living

The model cannot directly yield a value for the wage level of the work force. As explained above, V represents the total wage bill of the productive segment of the labor force. The average per capita wage depends on the number of workers sharing the total V. However, some straightforward assumptions govern estimates for this figure, as presented in Table II. The top part of the table gives population estimates somewhat under Government of India figures, but higher than World Bank estimates, amounting to a total estimated population in 2020 of 1,185 million. To get a labor force estimate, we used a median figure of 45% of the total population based on advanced countries today (India's labor force is presently 41.6% of total population). We took the Soviet percentage of productive to non-productive workers (7 to 3, or 70% of total labor force is productive)—(India today has 87%, reflecting its top-heavy labor force in marginally productive agriculture), to derive productive workers, and we assumed that productive employment has shifted from six to one agricultural to non-agricultural, to one to two agricultural to non-agricultural, a reasonable assumption, also close to recent Soviet figures. The numbers of agricultural and non-agricultural workers for the chosen years are then interpolated, giving a quite adequate estimate for our purposes. Changes in any of the assumptions will of course change the exact numbers slightly.

In the second part of the table, we divide variable capital or wage bill by the number of workers, to get a per worker V, and then further multiply by the labor force/total population ratio to get per capita V. The results, shown, indicate a 26-fold increase in agricultural average wages, and a 10-fold average increase in industrial wages, rising at 5.9% a year. The final level, 14,500 rupees represents an adequate base line of existence as currently defined in the industrially advanced countries.

"Riemannian" Features of the Model

There is a central feature of the transformation of the Indian economy implied in the program that is not directly accessible, but which the model suggests. That is, within 15 to 20 years, the Indian economy will already be so transformed as to be operating under a different set of internal relations—in Riemannian mathematical terminology, it will have a different internal "geometry" As the economy makes such transformations, it can be said to pass through "singularities," that is, transitional states in which part of the economy's functioning is characterized by the new mode of development, part by the old. The graph for S'/(C+V) (Graph 9) suggests such a "singularity." This value falls for the first ten years, gravitates around the low level for the next ten years, and then begins to rise back up again. (S' as a magnitude, of course, is rising continuously.) The initial fall is caused by the necessarily more rapidly rising investment in C and in raising present unacceptably low living standards: C and V rise rapidly, while productivities (which determine S') rise more slowly, especially as the very heavy complement of new industrial workers necessitate a low rate of productivity at first. This ratio also falls because of the heavier impact of outside development capital, which adds to C, but not directly to S', which is defined as domestically produced.

After the initial period, that decline stops, as the economy shifts into a new mode. By the turn of the 21st century, the entire population will be literate and the work force all at least at the level of semi-skilled workers. Per worker output will rise dramatically, and new generations of technologies will simultaneously

Table II

Labour Force Projections and Model-Estimated Advance of Living Standards

	1980	1990	2000	2010	2020	times increase	%rate growth
(1) Population: Est.	660	793	925	1057	1185		
(2) Labour Force: %	41.6%	42%	43%	44%	45%		
(3) Labour Force: No.	275	333	398	465	533		
(4) Productive L.F: %	87%	83%	79%	75%	70%		
(5) Prod. Lab. Force: No.	239	276	314	349	373		
(6) Ag/Non. Ag: %	85%/15%	75%/25%	60%40%	50%/50%	36%/64%		
(7) Ag. L. F: No.	203	210	192	174	137		
(8) Non-Ag. L.F: No.	36	70	128	175	248		
		COMPUTER		RESULTS			
Total V	339.8	876.7	2,111.2	4,968.9	12,043.0		
Ag. V	208.5	435.3	896.2	1,801.9	3,704.2		
Non. Ag. V	131.3	441.4	1,215,0	3,167.0	8,838.8		
Using 7&8 above							
— Ag. V/worker	1,027	2,073	4,668	10,066	27.038	26-Fold	8.5%/yr
— Non Ag V/worker	3,653	6,301	9,492	17,693	35.640	10-Fold	5.9%/yr
— Ag V/cap	427	871	2,007	4,429	12,167		
— Non-Ag V/cap	1,520	2,647	4,082	7,785	16,038		
Overall Average							
V/workers	1,422	3,176	6,724	14,238	32,287	23-Fold	8.1%/yr
V/Cap.	591	1,334	2,891	6,265	14,529		

All aggregate values are in billions of 1976 rupees. All per capita figures are in 1976 rupees.

be introduced. As this new condition consolidates, the S'/C+V ratio begins a steady exponential rise that would shortly surpass the starting value. This rise is what makes possible a possibly even rising rate of growth beyond the period chosen.

Physical Parameters of the Program

The model also permits certain cross-checks on the viability of some of the output targets. For example (see Table III), since industrial growth is projected at 11.1%, electricity can be assumed to need to rise about 12.2% a year (advanced country experience suggests about a 10% higher rate). This can be directly translated into yearly requirements in kilowatt hours (KwH). In 2020, India will need approximately 12 trillion KwH.

As the table indicates, the amount not fulfilled by projected levels of power from coal and hydel will be adequately met by projected yields from the planned nuclear program through 2005, the last year we have projected the nuclear program. (While nuclear appears to fall about 6% short, there are likely to be more than 6% savings from such sources as increased efficiency of transmissions and other benefits of a very dense energy grid.) After 2005, there is no reason nuclear energy cannot keep pace with requirements, especially as fusion power, advanced magnetohydrodynamics (MHD) and other new advanced technologies will be coming onstream.

In the case of steel, it is possible to calculate the rough value of the steel plants that must be built to create the capacity for about 700 million tons—which would give India the present Soviet per capita consumption of steel—a reasonable assumption given India's construction needs. At the past rate of about 4 billion rupees per one million tons of steel capacity, a cumulative total of 2.8 trillion rupees (constant 1976 rupees) will be needed. The cumulative total of C in the model comes to within 3½% of this total, indicating the appropriateness of the steel target figure.

Finally, the model gives an estimate of foreign net import of capital for development required. This is given by the sum of the A(i) values for each sector. Since A(i) is the percentage of domestic Absolute surplus or S' allocated to each sector, if the total A(i) is greater than 1, the overage must be filled from outside. The model show that only a relatively modest rate of capital import will be required. The first year's 16 billion rupees is not necessarily equivalent to the present foreign aid import. That 16 billion will be strictly capital goods for development, and it assumes the effective channeling of domestic resources into appropriate industrial development projects as well Until 2020, this figures rises in absolute value to over 64 billion rupees per years, but it rises much more slowly than the overall economy, so capital import as a percentage of Net National Product drops from 2.5% to below 1% in 2020 and to only .5% in 2010. In 2030, India can actually be a net exporter of capital.

Footnotes:

(1) For a detailed description of the REA from both a mathematical and economic point of view, see S. Bardwell, U. Parpart, "Economics Becomes a Science: A Riemannian Model of Economic Development." *Fusion* magazine, July, 1979. (Available through Central News Agency; 23/90 Connaught Circus; New Delhi 110001.)

(2) An interesting question raised at this point in our preparation of this development plan for the Indian economy was that of the "existence" of other trajectories for economic survival. A simulation of the World Bank-IMF "trajectory" was prepared which showed several striking aspects of economic development:

If we assume, along with the World Bank that population growth is not halted, and yet there is continued economic stagnation, (also the World Bank's projection), we find that such stagnation could continue for roughly 7-8 years, at which point a rapid and irreversible economic collapse would take place. This catastrophic mega-depression is a singularity in the Riemannian sense of the term and is not a mathematical fiction—the World Bank is correct in their estimate. However the solution they propose is not economic development, but rather decreasing population.

We prepared several simulations to study this alternative, and found that if one is willing to accept a *decline* in population of 30% then a quasi-steady state can be reached in the Indian economy. However, this steady state has the interesting property of being an unstable state—that is, any small perturbation will precipitate a similar catastrophe to that seen in the above example. We found that a decrease in investment of the order of a mere 80 *million* rupees in the economy in this "steady state"—the order of magnitude of loss that a severe

Table III

Selected Physical Parameters Derived from Model

	1980-2020	1980	1985	1990	1995	2000	2005	2010	2015	2020	Times increase	Annual % rate growth
Overall Growth Rate	10.4%											
G.R. : Non-Ag.	11.6%											
G.R. : Residual	11.1%											
ELECTRICITY												
(10% higher G.R.) 12.2% (BKWH)		120	213	380	675	1,202	2,138	3,803	6,765	12,035	100-Fold	12.2%
From Hydro (4,000 hrs)		36	56	96	128	160	160	160	160	160		
From Coal (4,000 hrs)		83	128	156	156	156	156	156	156	156		
Deficit		1	29	128	391	886	1,822	3,487	6,449	11,719		
Proj. from Program (5,000 hrs 95) (6,000 hrs 95-20)		1	40	180	430	906	1,716					
STEEL												
Constant Growth Rate		10	17	29	49	84	142	242	412	700		
Decelerating Rate		12	24	44	78	125	200	300	460	700		11.2%
CEMENT		22	33	50	76	115	174	263	397	600		
NET FOREIGN CAPITAL IMPORT												
A (i)*		1.2275	1.2300	1.1865	1.1425	1.1095	1.0890	1.0550	1.0270	.996		
S' Billion Rupees		72.1	112.9	156.9	272.0	435.0	734.0	1,259.4	2,202.4	4,331.8		
Required Import of Productive Capital (Rs.)		16.4	26.0	29.3	38.76	47.6	65.3	69.3	59	—17		
Natl. Income		670	1,096.4	1,982.0	3,196.6	5,231.9	8,278.6	13,290.4	21,239.2	34,717.4		
As % Natl. Income		2.45%	2.37%	1.48%	1.21%	.91%	.79%	.52%	.28%	-049%		

*Ratio of Surplus Reinvested (S') to S' domestically produced.

storm would cause—would result in the descent of the economy into the above described singularity.

The fact is that the much-touted steady state of the World Bank does not exist: an economy either grows and progresses or it collapses—there is no steady state possible.

Explanation of the Graphs

The first two graphs show the growth in absolute terms of three of the key sectors: steel and cement (Graph 1), and electricity (Graph 2).

Graphs 3 to 9 were drawn from the values generated by the computer model for C, S, V and (for totals only) for S', and plotted on a non-logarithmic scale. Each graph has a different scale in the vertical dimension, so that curves may not be directly compared from graph to graph. All figures are in 1976 rupees.

What the graphs show is the different relative behaviours of the three variables in the five selected sectors. For example, in agriculture, Graph 3, where productivities, are lower than in modern industries (and will remain relatively lower throughout the period under examination), and where capital improvements are crucial but where labor will still be abundant after 40 years, S rises something more than twice as fast as V and about the same as C.

By contrast, the most capital-intensive industry studied, the nuclear industry (Graph 4), ends up with a very large S compared to V, and an even more enormous C, representing the extreme sophistication of the capital investment required in the industry.

Steel (Graph 5) also capital intensive but somewhat less so, has a high rate of S to V (meaning a high productivity) but C is in line with S.

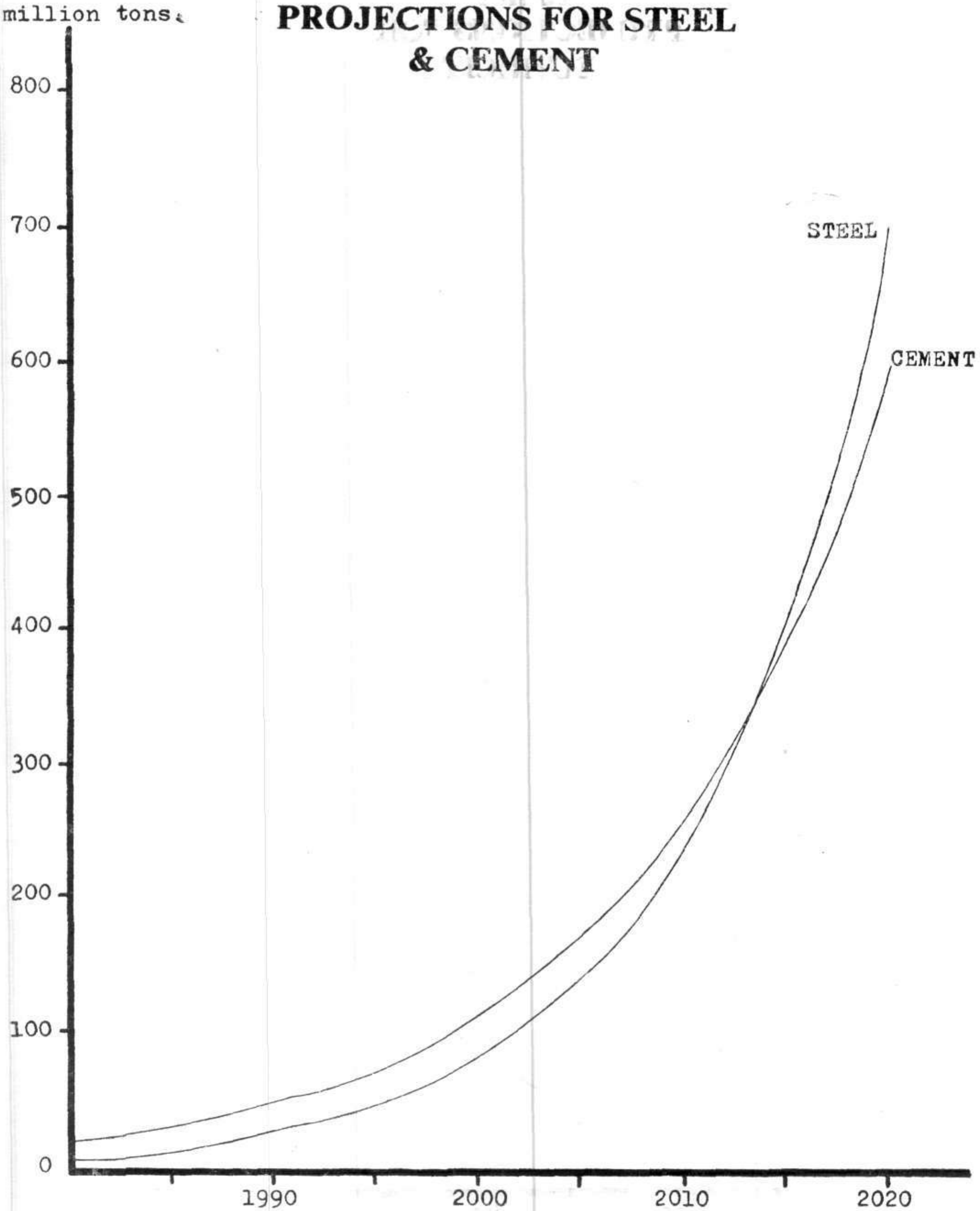
In the construction industry (Graph 6), C is relatively small because the capital investment in the construction industry per se is not great.

The residual category (Graph 7), all remaining productive sectors, is closest to the agricultural curve because it includes not only the large scale industry, but all industries including those that, even in 2020, will be highly labor-intensive, and small scale industry, etc. It also includes transporation, whose productivity is derived from actual industry.

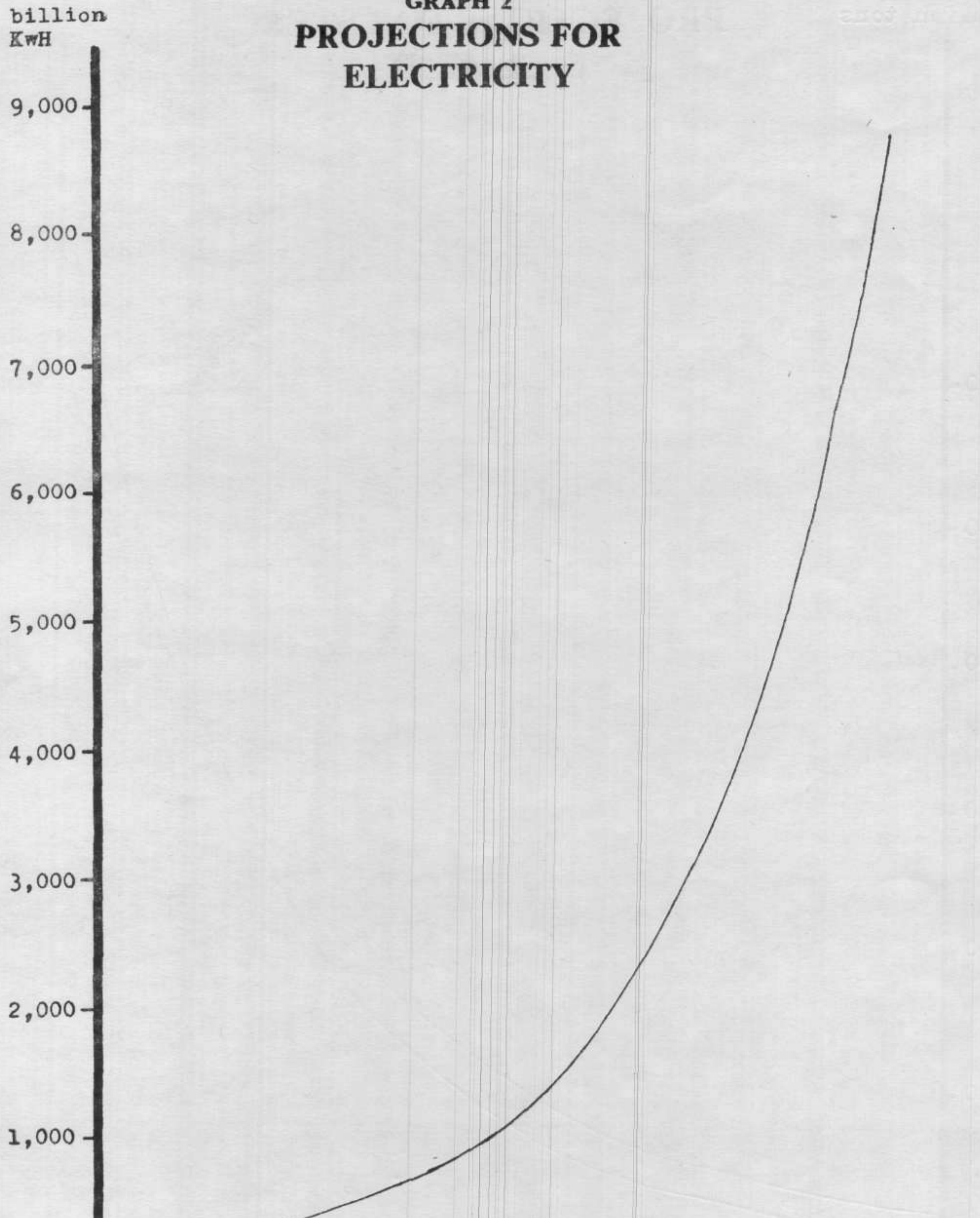
Graph 8 shows the totals of these categories for all sectors. Graph 9, which plots the ratio S'/C+V for the whole economy, was discussed earlier in this section.

GRAPH 1

PROJECTIONS FOR STEEL & CEMENT

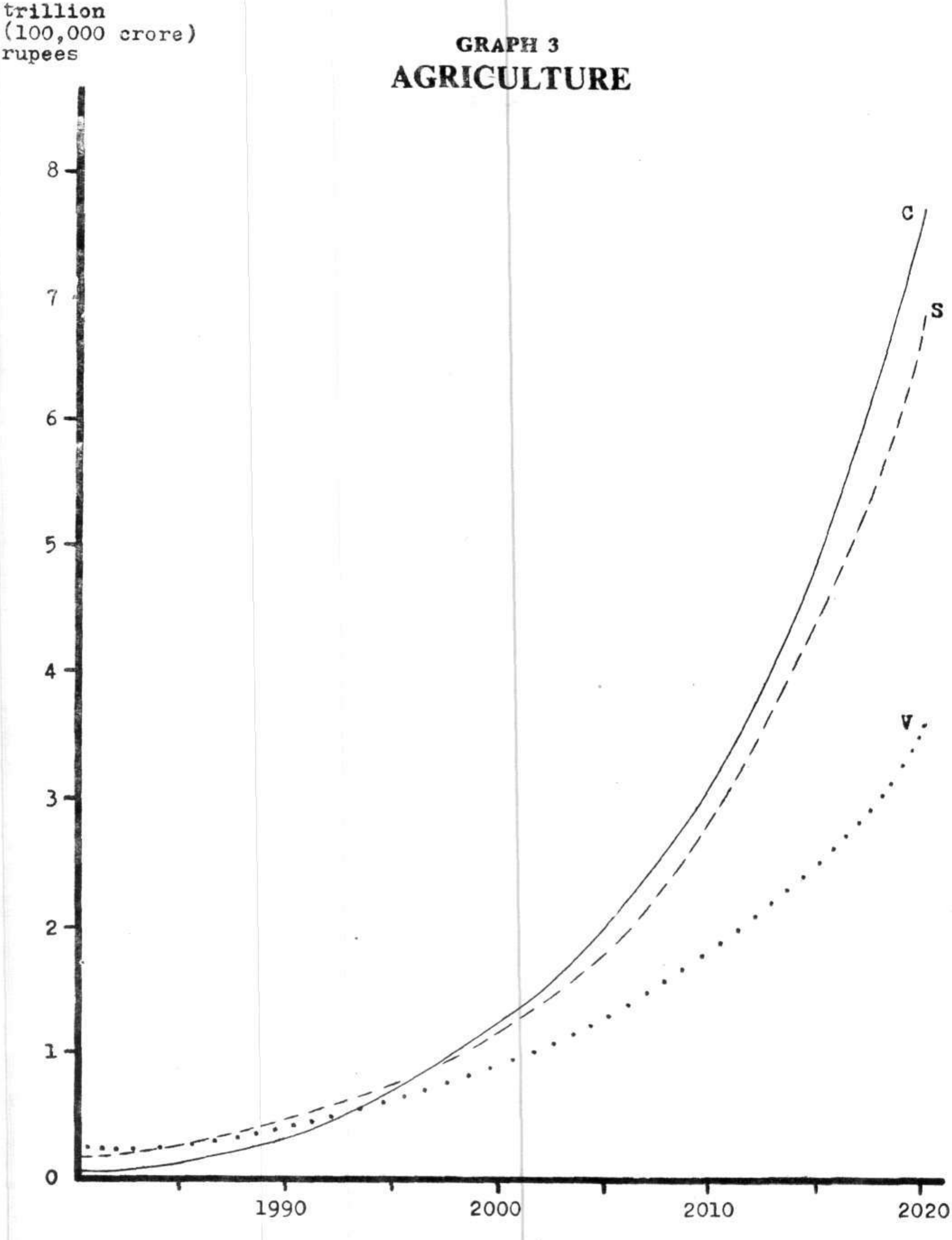


GRAPH 2
PROJECTIONS FOR ELECTRICITY



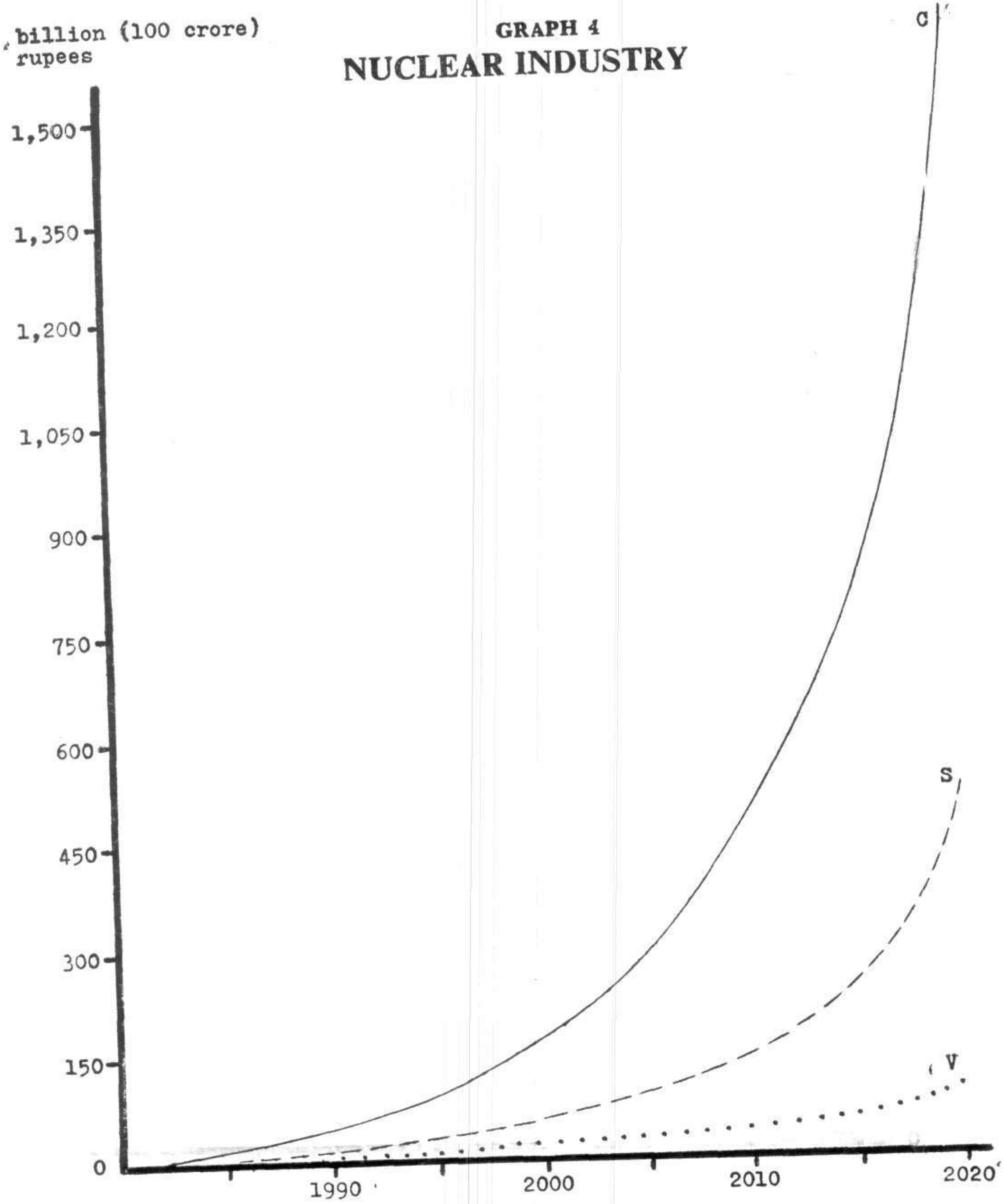
GRAPH 3

AGRICULTURE

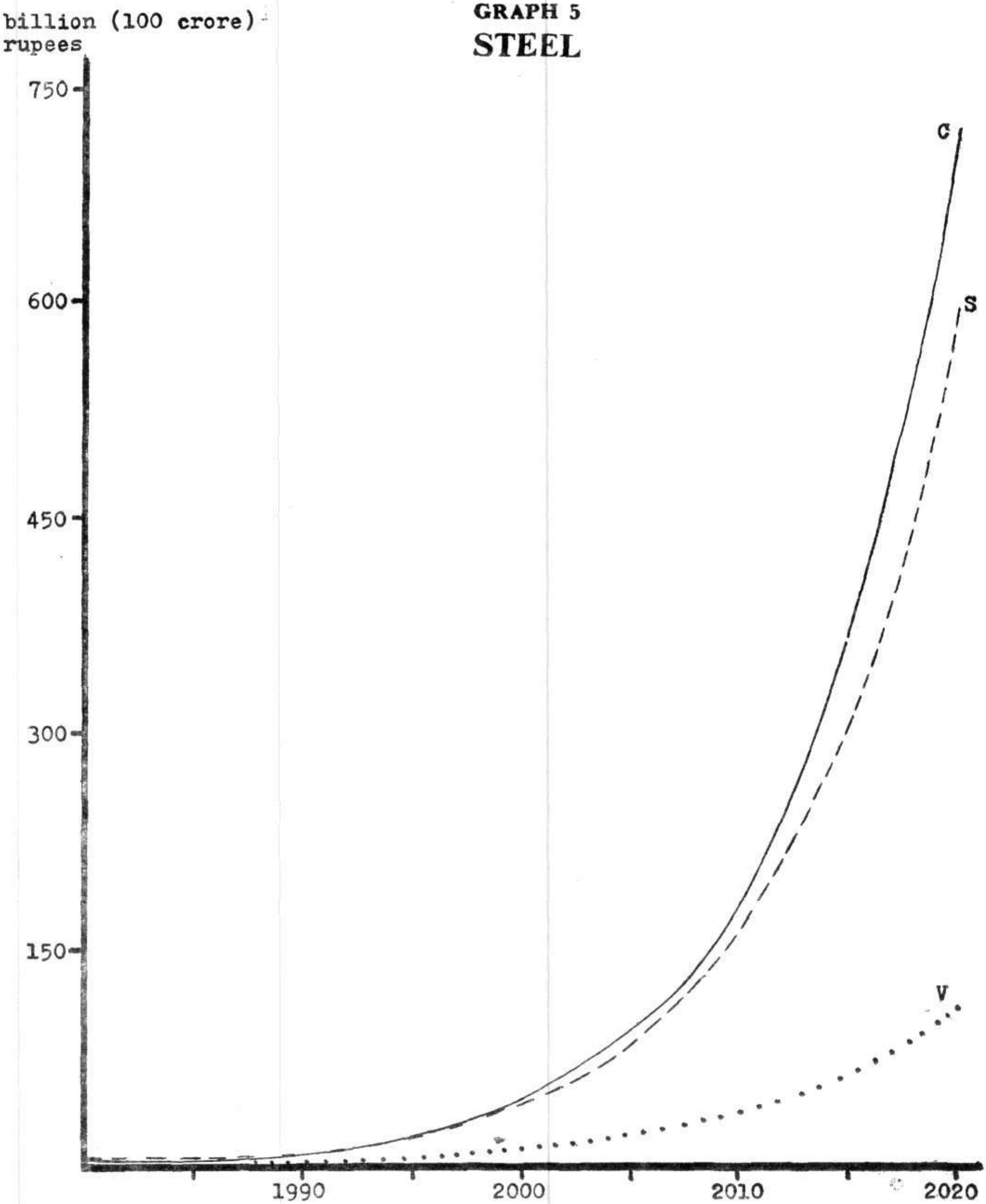


GRAPH 4

NUCLEAR INDUSTRY

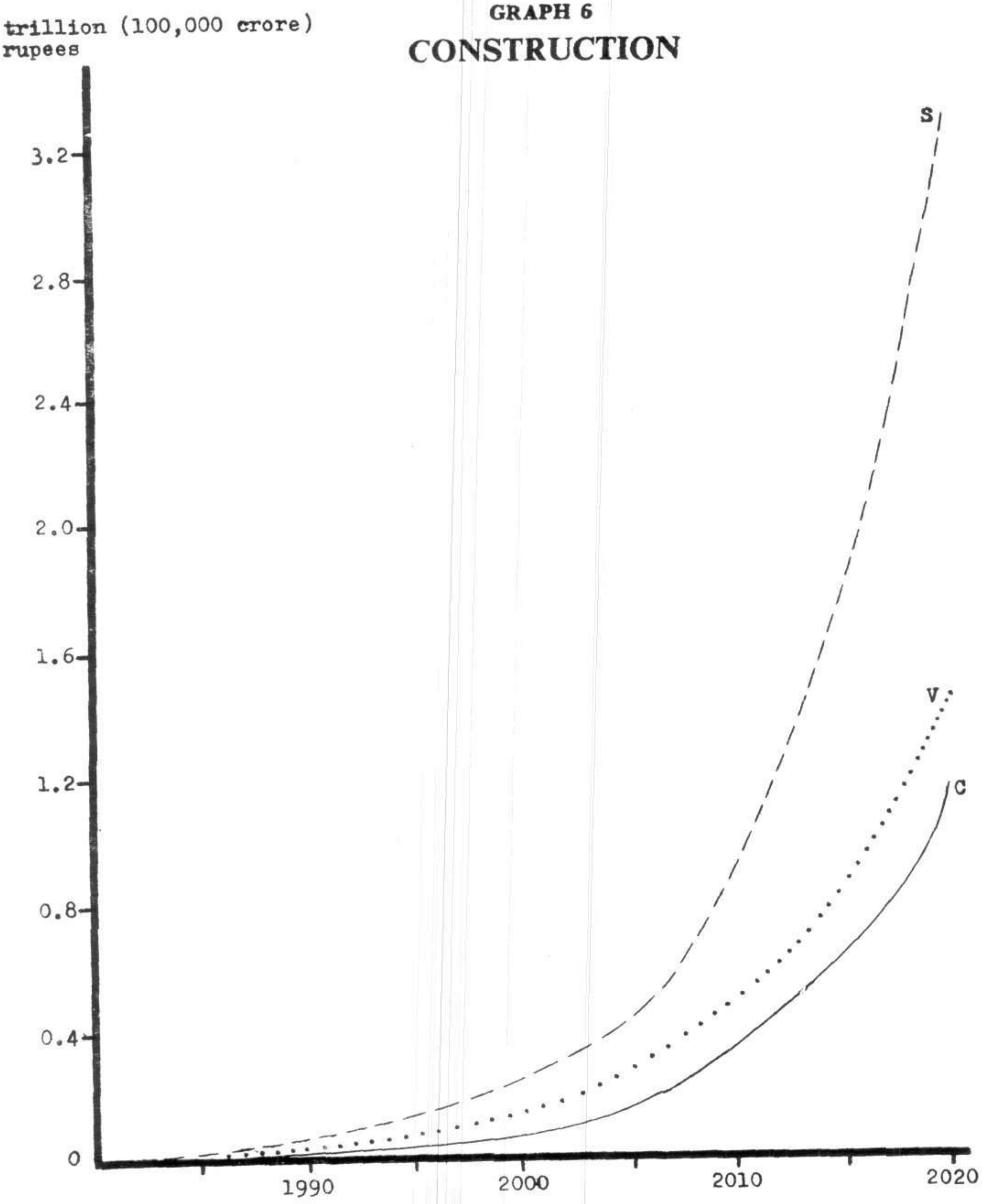


GRAPH 5
STEEL



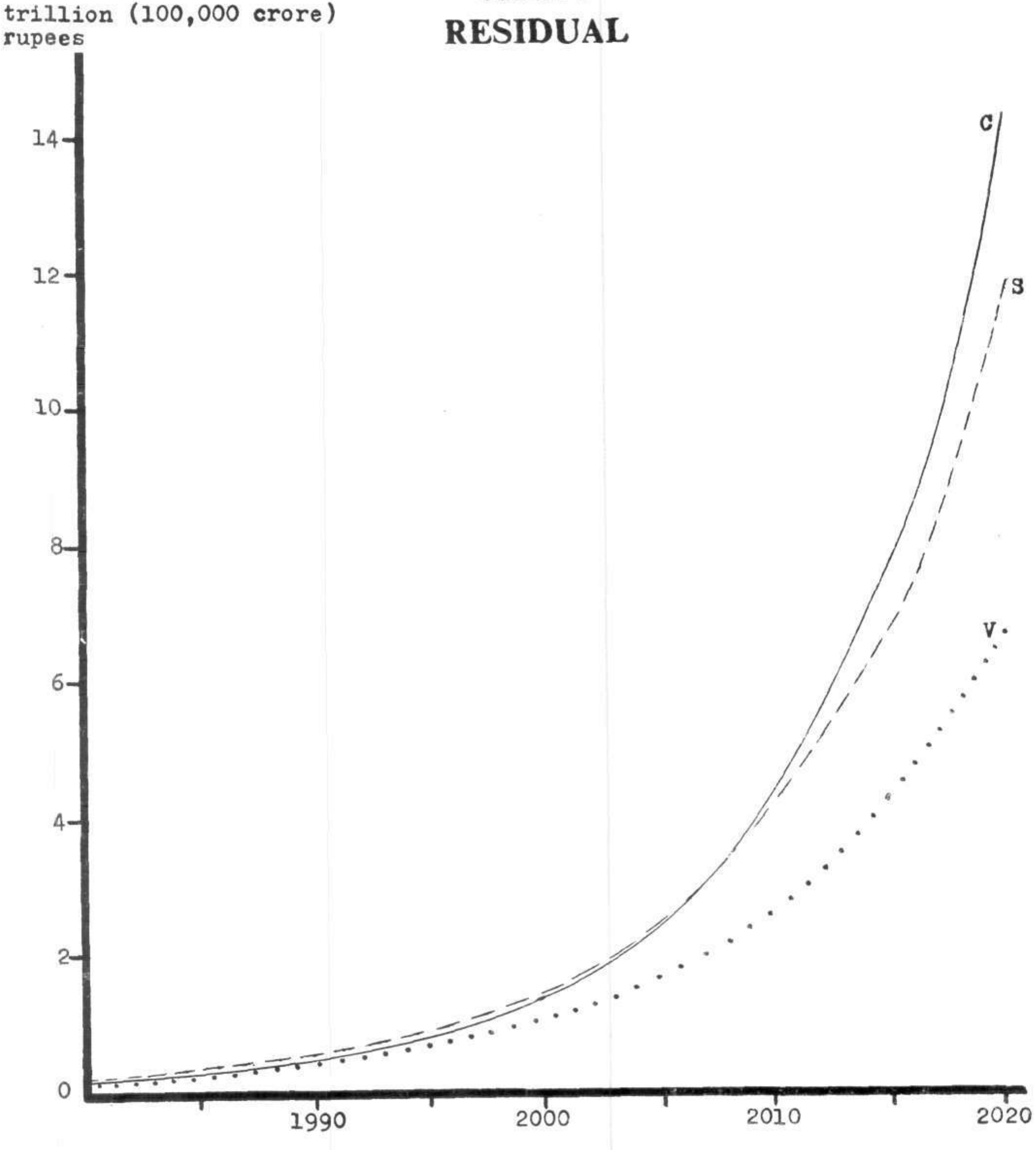
GRAPH 6

CONSTRUCTION



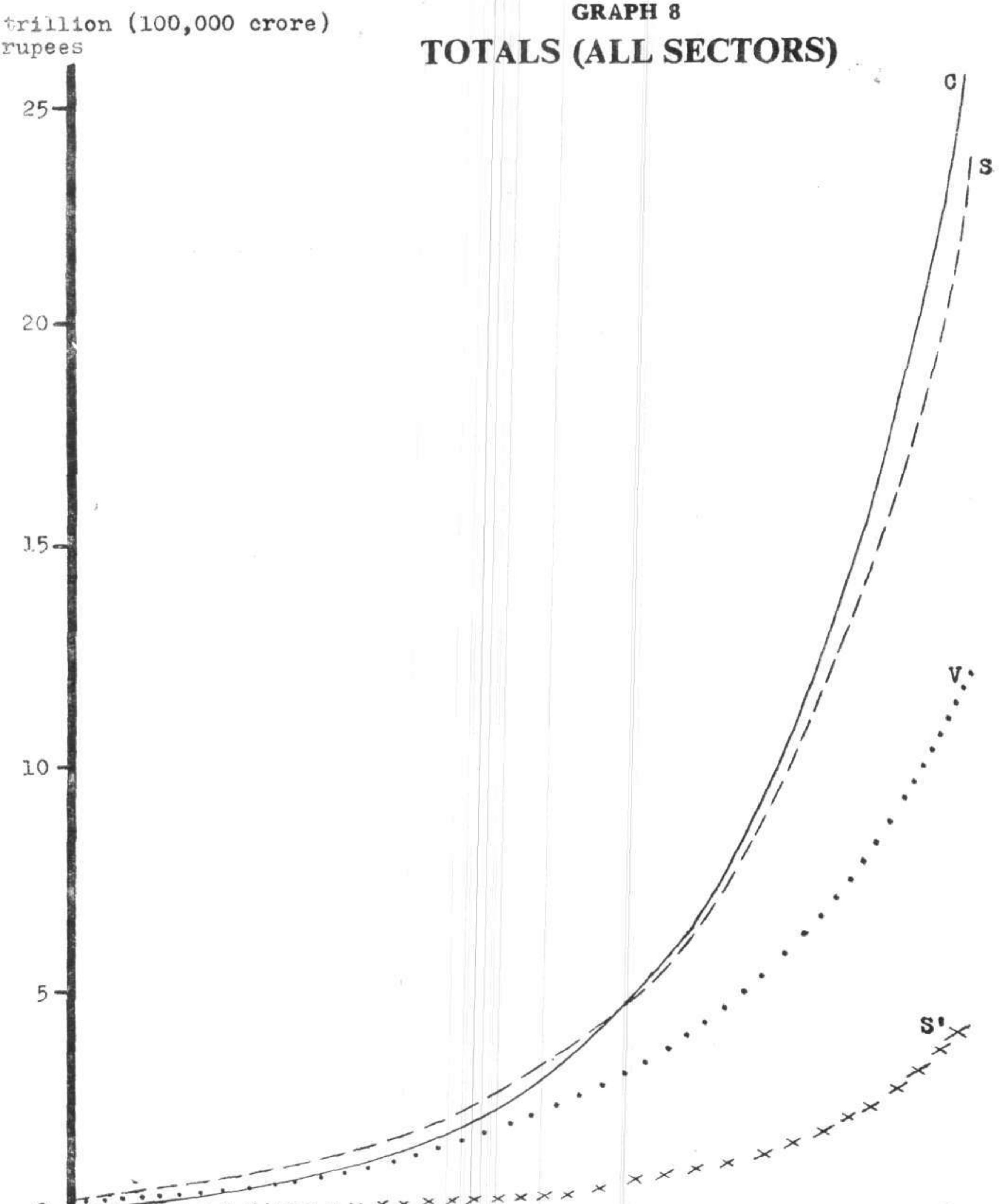
GRAPH 7

RESIDUAL



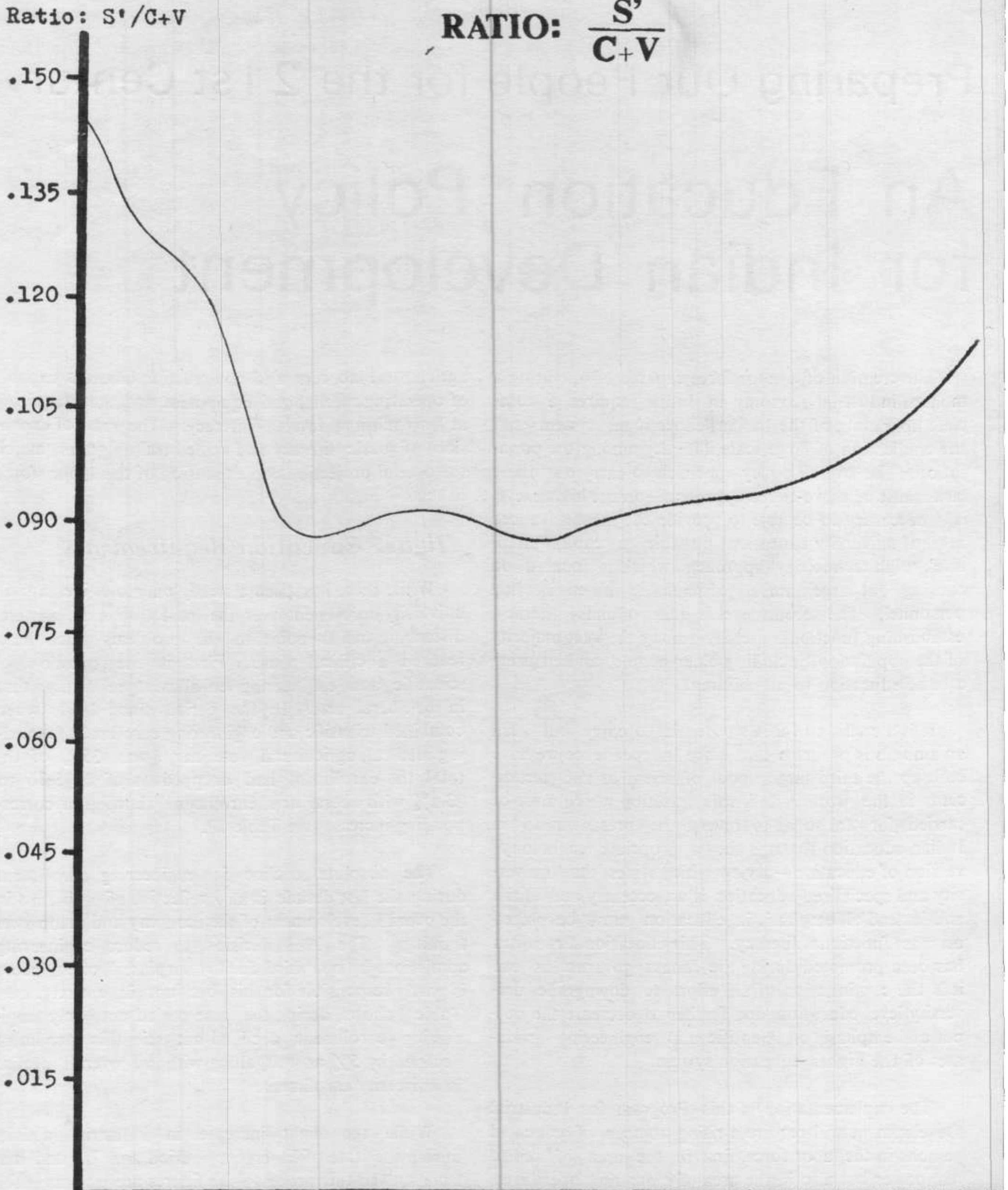
GRAPH 8

TOTALS (ALL SECTORS)



GRAPH 9

RATIO: $\frac{S'}{C+V}$



Preparing Our People for the 21st Century

An Education Policy for Indian Development

The creation of a labor force capable of operating a modern industrial economy in India requires a complete upgrading of the Indian educational system and the eradication of large scale illiteracy among the population. The overall policy approach to carry out these tasks must be a two-tiered approach—on the higher level it is neccesary to be able to provide the most advanced level of university education possible, a 'capital-intensive', 'high technology' approach which is focused on turning out large numbers of scientific and engineering personnel. The second level is that of mass literacy, establishing functional literacy among the vast majority of the population, including older people, and ensuring a basic education to all children.

It is a credit to India's potential to carry out such an ambitious program that since Independence we have built up the third largest pool of scientists and technicians in the world. It is this tradition which must be carried forward so as to reverse the present trend in Indian education towards the "appropriate technology" version of education—a view which states that university and specialised education is unneccesary and elitist and instead all emphasis in education must be placed on mass functional literacy. This educational ruralism has been promoted during the Janata government but it is the continuation of an effort to downgrade university level education, and further to decrease the output and emphasis on scientific and engineering graduates of the higher education system.

The implementation of this Program for Industrial Development will require a rising number of educated persons in the labor force, first in the area of skilled manpower but also in the area of industrial operatives, agricultural laborers, and construction laborers capable of operating mechanized equipment and thus requiring at least minimal levels of literacy. The rate of expansion of basic literacy and skilled training must match the overall projections on expansion of the labor force in toto.

Higher Education Requirements

While there has been a steady but slow increase in university enrollment over the past 30 years, several disturbing trends point to the problems which have reached a critical phase. First is the question of scientific and engineering enrollment relative to that in the liberal arts. In the period since 1950, when combined scientific and engineering enrollment (excluding medical, agricultural, veterinary) was 35% of the total, the enrollment had dropped as of 1975-76 to 23.1% with liberal arts enrollment showing a corresponding increase (see Table I.).

The absolute decline in engineering enrollment during the last decade is also reflective of problems in the overall development of the economy and manpower training. The 1968 decision to reduce engineering admissions by one/third due to "surpluses" of engineers is partly responsible for this but not in entirety. As Table I shows, during the same period not only engineering enrollment declined but scientific enrollment declined by 5% as well, along with an overall decline in university enrollment.

While the slight increase in industrial activity during the state of Emergency period and beyond may have slowed this process—the figures are not available

Table I
Enrolment in the Science and Engineering Courses

	Years							
	1950-51		1960-61		1969-70		1975-76	
	Enrolment (000)	% of total	Enrolment (000)	% of total	Enrolment (000)	% of total	Enrolment (000)	% of total
1. Science	127	32.0	303	28.9	915	32.8	464	19.1
2. Engineering/Technology	12	3.0	45	4.3	98	3.5	96	4.0
3. Medicine	15	3.8	35	3.3	95	3.4	105	4.3
4. Agriculture	5	1.2	28	2.7	43	1.5	30	1.2
5. Vet. Sc.	1	0.3	5	0.5	6	0.2	6	0.3
6. Arts, Commerce Law, Education etc.	237	59.7	634	60.3	1635	58.6	1724	71.1
Total	397	100.0	1050	100.0	2792	100.0	2425	100.0

to verify this—the fact remains that even the minimal level of higher educational training, with emphasis on scientific areas, has collapsed. It is also worth noting that the growth of educational institutions, particularly universities and high level technical institutes (like the Indian Institutes of Technology) has slowed dramatically in the past 5 years. While the number of universities increased by 16 from 86 in 1972 to 102 in 1975, from 1975 to 1977 they increased by only 3 to 105.

The reversal of this situation is a major priority of our program. The combined requirements of this program alone—leaving aside the requirements that will result from the input requirements in steel, cement and other heavy industries—define the task of higher education manpower development. The skilled worker requirements also define the need for higher education manpower as trainers and supervisors for the construction projects involved—that is, engineering graduates of a diploma level of training. The engineering requirements are at least at the present degree level, and require in addition an upgrading of existing training. For example this is needed in the area of nuclear plant construction, a training which is relatively recent in Indian institutions.

The combined engineering and skilled worker requirements based on our projections for the nuclear and water development aspect of this program are as follows:—

Table II

Year	*Skilled Workers* (*man years*)	*Engineers*
1980	68,000	22,000
1985	136,700	34,200
1990	171,800	42,900
1995	217,600	54,400
2000	309,500	62,400

As of 1977-78 the estimated number of engineering degree holders in India was 251,860 and diploma holders, 346,730 with a certain percentage (2.4 for degree, 10.4 for diploma) unemployed. It is clear therefore that an increase in yearly output of engineers is required together with an immediate program of increase in the number and quality of existing institutions and their training programs. Certain skill upgrading can take place on the job site itself, as in the case of the Bhakra-Nangal project which provided training for some 2,000 engineers during the lifetime of the project. The upgrading on the nuclear engineering side itself will present the greatest problem to be solved.

One of the tragedies of Indian development over the past decades is that our rate of development has not been fast enough to absorb the excellent scientists and technicians our educational system has turned out. As a result, tens—if not hundreds—of thousands of these young scientists, engineers, doctors and technicians have had to find work abroad.

However, with the ambitious program for industrial development presented here, not only can this process be reversed but in the immediate period ahead we will face a severe shortage of scientists, engineers and technicians which can only be relieved by encouraging those who have already gone abroad to return to India. These skilled scientists and engineers will also bring with them many skills and training which may not be presently available in India. The Government of India has not been able to compile reliable estimates of the numbers of such persons presently living abroad; the available figures record only those who have voluntarily put themselves on the register, a number obviously having little relation to the actual figures. However a program of financial and employment inducement should be drafted to encourage their return to India, with special emphasis on the availability of work which matches their skill levels. This program should follow in the tradition of the patriotic appeal made to Indians living abroad after Independence was won.

The Government should immediately carry out a comprehensive survey, through Indian missions abroad, to draw up a reliable list of such persons, their skills and training, in preparation for such a recruitment program. Not only scientists and engineers but skilled persons in other areas, like medicine, agronomy, and industrial techniques and management, should be encouraged to return to India. Other manpower gaps in highly skilled areas should be filled in the short term with foreign assistance, combined with initiation of training programs to produce such skills within the Indian educational system.

Mass Literacy Program

The upgrading of higher education is the prerequisite for the creation of mass literacy and expansion of secondary education. While literacy rates have steadily risen since independence, the rate is still much too slow. (See Table III for literacy rates by age group). The present predominant view of the illiteracy problem is that higher education is a tradeoff *against* mass literacy, and certain "models" like that of the Cuban educational systems are mis-cited as support for this idea.

The conception of mass literacy involved in this approach is totally wrong. A populist version of mass literacy is the accompaniment to a World Bank ruralism which foresees a stagnant rate of industrialization of the economy. In reality the creation of literacy can only occur on a rapid basis in the circumstances of large scale development, including large construction projects which can be tied to literacy programs among adults. The role of upgrading higher education is necessary not only for such development but also for creating educational cadre out of university and secondary students who can be mobilized to provide teachers for primary schools. The aim of our system must be to provide an overall feeder of youth into higher and higher levels of skill development. A minimal skill, that is, a functional literacy approach, produces no real surplus in terms of labor power development available for an expanding economy.

The proper approach to mass literacy is the creation of a universal service corp, student brigades of secondary and university level students who on the basis of universal conscription will be deployed throughout the country for mass literacy campaigns. Such brigades can be combined with the development programs outlined here, including deployment of student engineers on actual project sites (as is done on some scale now).

The content of mass literacy cannot stop at functional reading skills but, as Nehru once outlined, must be aimed at the dissemination of basic scientific ideas, mastery of basic technology, among the population. Full scale development needs projected for the 1990s and beyond will require that children, especially in rural areas be taken entirely out of the labor force as rapidly as possible and placed in primary educational institutions. Construction of primary schools will be required to meet this aim.

The program outlined here provides the basis for creating the scientific geniuses that will prepare India to fully enter the next century. An educational policy whose premise is the creation of geniuses requires mass literacy—and the priority must be formulated on that basis.

Table III

	1951				1971			
Age	Number of literates	% age	No. of illiterates	%age	Number of literates	%age	Number of illiterates	%age
10-14	9.72	23	32.62	77	33.64	50	33.98	50
15-24	14.37	24	46.28	76	43.01	48	47.59	52
25-34	11.05	20	43.40	80	26.00	34	50.61	66
35	16.03	16	83.96	84	36.62	24	112.67	76
Age not stated	0.02	9	0.21	91	0.14	14	0.83	86

(figures in millions)

Indian Nuclear Development Program

An Energy Program to Revolutionise the Economy

The indispensable ingredient for an ambitious Indian industrialization program is to concurrently create a rapidly growing energy production sector. Contrary to the propaganda emanating from the International Monetary Fund-World Bank and from related institutions, so-called "appropriate" technologies or "soft" paths cannot meet India's legitimate requirements. These can only be met by a full scale commitment to implement the most advanced available energy production technologies—currently available fission reactors, as well as more advanced designs expected in the near future, and ultimately controlled thermonuclear fusion and magnetohydrodynamics.

The energy development program outlined below is based on goals that seem, from the perspective of the late 1970s, strenuous, but attainable. The achievement of success at intermediate stages in the program will demand periodic reassessment and upgrading of the overall program.

Although according to the projections embodied in this report, Indian per capita installed energy production capacity will still be low compared to European, let alone North American, standards at the turn of the century, the basis will have been laid for a tremendous take-off of the entire Indian economy.

1. Meeting the Energy Requirements

The overall energy growth requirements for India through the remainder of the century were determined by consideration of targets and goals set for expanding industrial and agricultural production capacities and outputs. The basis for those estimates are given in another section of this Indian Development plan. These goals for electrical energy production are shown in Figure I and Table 1, along with a breakdown of the energy sources.

The projected energy production goals established for India over the next two decades will be met initially by a mix of coal, hydro and nuclear power based electrical generating stations, while later, in the second decade, they will be met almost entirely by nuclear power based generation. Most of the coal and hydro power capacity will be manufactured and installed internally by Indian-based companies, while much of the nuclear capacity during the first decade will be imported. However, during this time period, India's current capability of designing, manufacturing and constructing Indian versions of the CANDU reactor power plants will be greatly expanded so that during the next decade and beyond, we can produce an ever rising, percentage of our own nuclear power generation requirements.

In fact, during this second decade, India will also become an exporter of nuclear power plants in order to help other less-developed developing nations to to build up their energy production capacities. The export of nuclear technology will become a major source of income generation for India during the late 1990s and beyond the turn of the century.

The emphasis on the development of nuclear energy as the source of the bulk of the electrical generation capacity beyond the 1990-1995 period is straightforward. India has the largest reserves of thorium, a potential nuclear reactor fuel, in the entire world—over 500,000 tons presently known and no doubt much more yet to be discovered. If this resource can be efficiently tapped, it will quickly become the cheapest way by far for India to produce electicity. Thorium will also become a fuel resource for future export in much the same way that Canada and other countries have exported uranium, thus creating another major income generator for India.

Although hydroelectricity is cheaper than nuclear, its future capacity in India is relatively limited and it is usually located far from the areas which need it. At any rate, when fully developed it can only be expanded to a total of about 40 GWe, thus providing only a small percentage of future power needs. On the other hand, India has large deposits of coal in certain areas of the country, and although it is of the low-grade variety (high sulphur content lignite, etc.), it can be burned in fossil fuel based power plants. However, coal is also located far from where it is needed and therefore transportation costs are very high. Relative to nuclear-produced electricity, coal based electricity is considerably more costly primarily because of the fuel costs—a conclusion that has been proven in the United States, Europe, the USSR and other developed countries.

Table I

Total Power Generating Capacity
(GWe)

Year	Nuclear	Hydroelectric*	Coal and Oil Based
1980	1.0	9.0	23.0
1985	8.0	14.0	32.0
1990	36.0	24.0	39.0
1995	86.0	32.0	39.0
2000	151.0	40.0	39.0
2005	286.0	40.0	39.0

* 60% of peak power

Although according to this program the number of coal-based power plants will be increased over the next ten-year period—requiring at least a doubling of India's current coal production capability—it is clearly not the solution to India's long-term energy requirements. As in most other countries, nuclear energy is the most economical way to produce electricity, while coal and other fossil fuel resources are diverted to more productive and efficient and therefore more valuable uses in the petro-chemical, steel, and fertilizer industries.

The above conclusions were also reached by the founder of India's nuclear program, Homi Bhabha, and were the basis for the ambitious nuclear policy mapped out in the early years of the Atomic Energy Commission. Although that program has significantly fallen behind schedule, it is thanks to Bhabha's foresight that India today has available to it the technical and scientific cadre necessary to carry out the even more ambitous nuclear program that is proposed here.

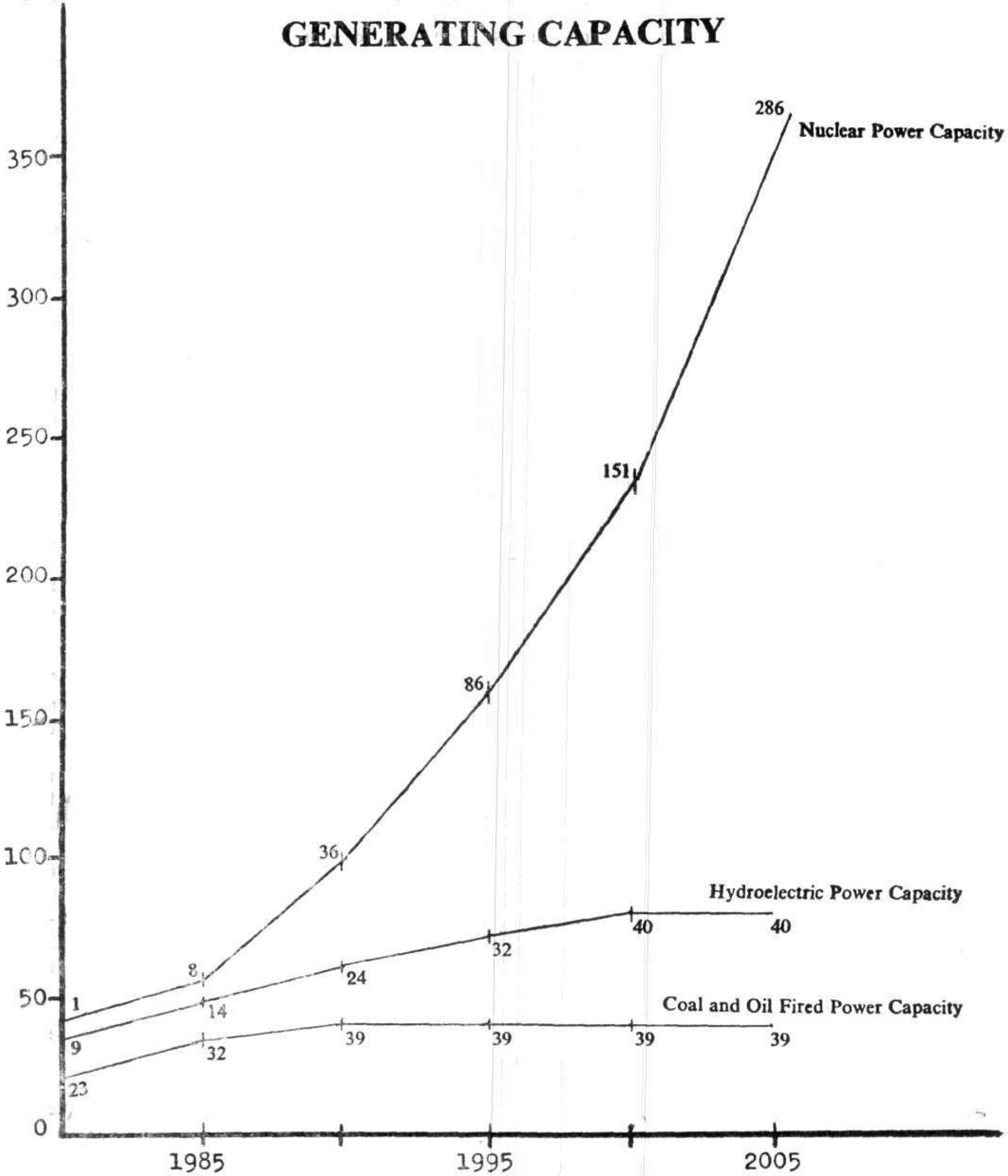
Since India is also in the initial phases of its agricultural and industrialization development programs, we can right from the start make use of the most advanced and productive concepts in these areas that are currently available. Specifically, this program calls for India to incorporate into its construction plans, starting immediately in 1980, the designing and building of "nuplexes", also called agro-industrial complexes. Nuplexes are nuclear power-centered systems that most productively, efficiently and economically produce industrial and agricultural products. This concept is not a new one to Indian scientists and engineers. The concept of the nuplexes was first envisioned by Bhabha, and under Vikram Sarabhai's Chairmanship the Atomic Energy Commission conducted feasibility studies for the construction of two agro-industrial complexes more than ten years ago. These two designs, located at their original sites—Gujarat and Western Uttar Pradesh—can be immediately upgraded to make use of the more efficient reactor for this use, the High Temperature Gas-Cooled Reactor (HTGR), and can be doubled in size, while a third site is added—all three to be completed before 1990, thus making India the first nation in the world to have an operating nuplex.

2. The Basis for India's Nuclear Program

There is only one naturally fissionable nuclear reactor fuel still existing in the earth's crust at

Figure 1

TOTAL POWER GENERATING CAPACITY



this point in our planet's history. This is the isotope of uranium ordinarily referred to as U-235 (atomic weight of 235 grams), which is only a small portion, or about 0.7%, of any uranium dug out of the ground. Most of this naturally occurring uranium, or 99.3% of it, consists of the isotope U-238. This isotope of uranium cannot be used as nuclear fuel in that form. However, it can be converted to fuel if it is irradiated by neutrons in a nuclear reactor.

Therefore, all the naturally unusable uranium, U-238, can be turned into usable reactor fuel if it is placed in an operating nuclear reactor for a few years. Such a convertible material is said to be a "fertile" material since it can be changed to usable "fissile" fuel. The other fertile material that is present in the earth's crust is thorium, which is made up entirely of a single isotope called Th-232. Thorium, therefore, has no naturally occurring fissile isotopes which are usable as a reactor fuel, but, all the Th-232 can be changed into a usable fuel if irradiated in a nuclear reactor.

India has only small amounts of uranium available within its boundaries. Current estimates of U-235 reserves within India are enough to fuel only about 10 nuclear reactor power plants of a 1000 Megawatt (MWe) size. However, the current estimates of 500,000 tons of thorium within India make it the largest single potential supplier of that valuable resource in the world. When converted to usable fuel, this reserve of thorium could provide India's growing energy needs for many decades to come, as well as provide a very profitable product for export.

This fact has long been recognized by scientists, engineers and political leaders in India and has been and still is the basis of India's current nuclear program. That is, the nuclear reactor development program must be designed to employ reactors that most efficiently convert this thorium into usable fuel over the shortest period of time. This means getting India's reactor systems into the "Thorium Fuel Cycle" rather than the more common "Uranium Fuel Cycle" as quickly as possible.

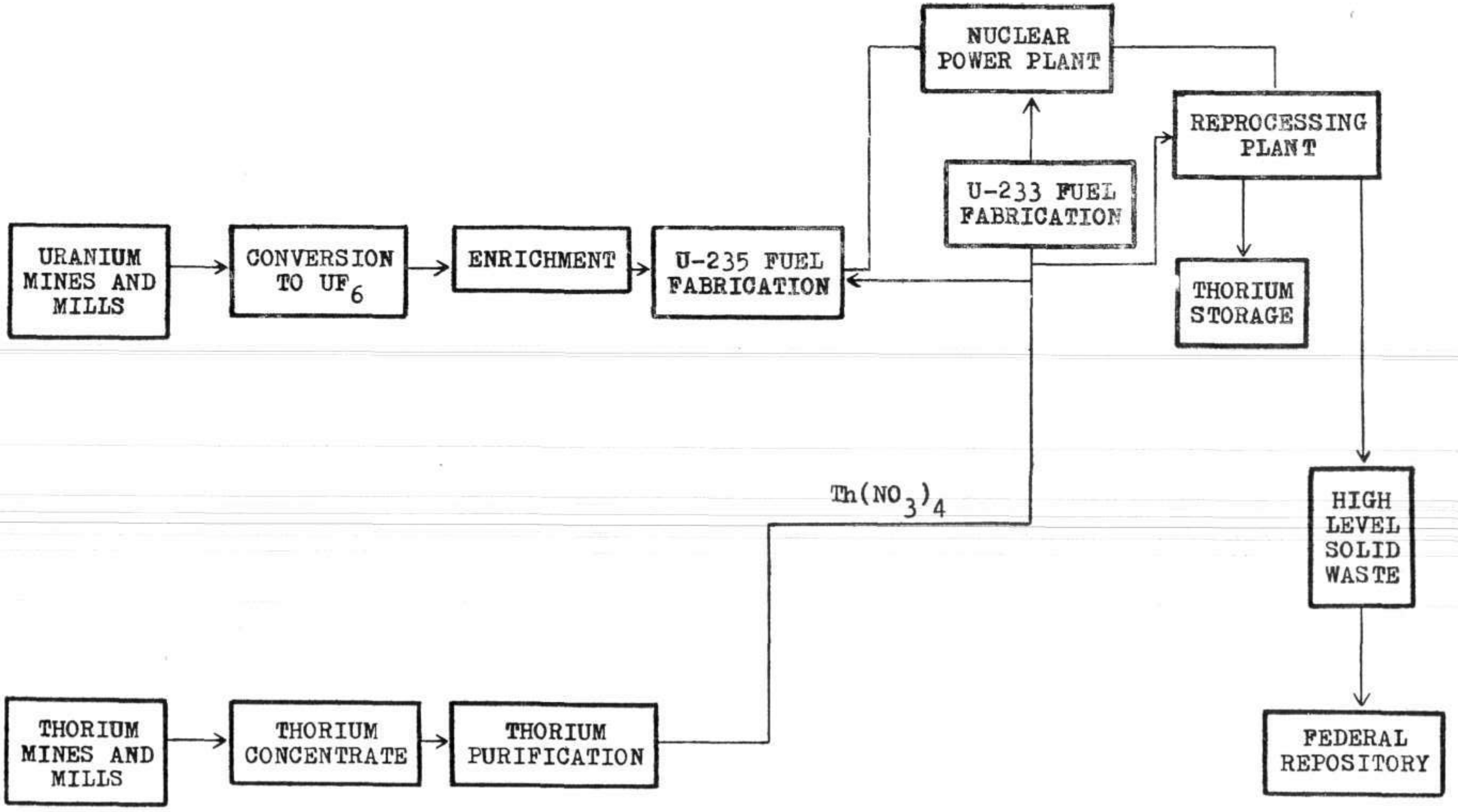
Almost from the beginning of India's nuclear program, the decision was made to go with the CANDU type reactor as its initial, state-of-the-art reactor power plant system. This was to be followed by the development and introduction of the Liquid Metal Fast Breeder Reactor (LMFBR) as soon as the technology became commercially feasible. The current plan is to build up an inventory of plutonium, a reactor fuel produced by converting U-238 in the CANDU reactor, and use it to fuel the LMFBRs. The LMFBRs, which produce or breed more fuel than they burn are then to be used as more efficient power producers, while at the same time converting thorium into U-233 fuel which can be used effectively in any reactor, thus starting the thorium fuel cycle. (see Figure 2)

This plan is still a good one, and the correct one for India. However, in order to even begin to meet India's energy growth requirements it must be quickly accelerated and expanded. India must immediately launch its own CANDU design and construction program for plants of the 1000 Megawatt size, as opposed to the smaller versions it is currently building. Reliance on Canadian CANDU technology and engineering can be phased out as India's capabilities expand. Uranium fuel for these reactors will come in small part from India's tiny uranium ore supply, however the bulk of it must be imported until after the breeder reactors come on line. This ore could come from several locations, most likely Australia, Canada or the Soviet Union.

Since CANDUs are designed to be very efficient neutron producers through the use of heavy water, D_2O, as a moderator, they do not require enriched uranium in their fuel. That is, the natural percentage of U-235, i.e., 0.7%, in uranium is sufficient to sustain a fission reaction in a CANDU. A Light Water Reactor (LWR), on the other hand, requires a higher percentage of U-235, or fuel that is "enriched" to 3 to 5% of this isotope. The manufacture of enriched fuel requires very expensive and energy-intensive enrichment plants, facilities that India will not need given the choice of CANDU type reactors. However, India will have to build heavy water production plants instead—a technology, however, that is already well established in India.

Importing Advanced Reactors and Technology

India cannot possibly meet its entire near-term energy requirements through its own internal industrial production capabilities, and therefore a significant portion of the power plants particularly over the next two to three decades will have to be imported. These imports will be mostly nuclear power plants that will supplement those India will itself build over this time period. Initially these imports will consist primarily



Th-U Fuel Cycle with U–233 Recycle

Figure 2

of Light Water Reactors (LWRs), mostly of the floating nuclear plant (FNP) variety, which will come from the United States, Soviet Union and Europe. During the second decade these imports will change to a mix of Liquid Metal Fast Breeder Reactors (LMFBRs), High Temperature Gas-Cooled Reactors (HTGRs) and LWRs, with the balance shifting to the first two types by the turn of the century. An overview of India's proposed nuclear development program is shown in Figure 3.

The country most advanced in the development of the LMFBR is France, which already has a 1200 MWe Superphenix power plant under construction and scheduled for completion in 1983. Furthermore, India is already working jointly with France in this area in constructing a 15 MW experimental LMFBR at Kalpakkam, Tamil Nadu slated for operation in the early 1980s. This effort should be expanded and advanced so that India will have several commercial size LMFBRs coming on line by 1990. France or the Soviet Union can provide these reactors to India.

These fast breeder reactors will have two important goals. The first is to provide India with increased power for its electrical grid—this more efficiently than water-cooled reactors because of the higher operating temperatures allowed. Second, and even more important, is to start producing significant amounts of U-233 out of thorium. This will begin India's conversion to the "thorium fuel cycle". Plutonium generated in India's CANDU reactors as well as its imported LWRs will be extracted and used to provide the initial loadings of fuel for the LMFBRs. The LMFBRs will in turn breed U-233 in their thorium blankets, and plutonium (Pu-239) in their fuel regions—both fuels being used to fuel more LMFBRs, LWRs, CANDUs, or HTGRs, or a combination of all of these. At this point, and beyond, India's thorium becomes a valuable nuclear fuel for use internally or for export.

During these next two decades, India must also greatly expand its nuclear fuel reprocessing plant capability. In order to separate and extract the usable Pu-239 or U-233 from the fuel or blanket elements of the CANDUs, LWRs, HTGRS, or LMFBRs, the uranium or thorium material must go through a system of reprocessing. Not only does this separate out the good re-usable fuel which is about 96% by volume of the material, but it also isolates the 3 to 4% by volume of the material that is called fission product waste. This waste material can then easily be concentrated and safely disposed of in deep underground depositories by processes similar to those already in operation in France, and planned for many other countries. The re-usable fuel is, of course, refabricated into fuel elements and placed back into the appropriate reactor. It is planned that by the early 1990s, India will have the capability to fabricate the fuel loadings for all of its nuclear reactors, including those that have been imported. Indian capability for fabricating CANDU fuel exists now, and will be expanded to meet India's expected production of CANDUs.

Finally, the fourth reactor type to be introduced into India over the next decade, the High Temperature Gas-Cooled Reactor (HTGR), is required because of its superiortity over other types when used in nuplexes, otherwise called agro-industrial processing complexes. This reactor is already a developed system in both the United States and West Germany, and therefore could be ordered almost immediately from those sources. The specifics of its use in such nuplexes is described in the next section of this document. However, a number of additional advantages provided by the HTGR should be pointed out here. First of all, it is the best converter reactor (i.e., producer of Pu-239 or U-233) of the thermal neutron type reactor systems. It uses its neutrons almost as efficiently as the CANDU. Second, it also has been promoted as one of the best systems in combination with fast breeder reactors to initiate and then operate on the thorium fuel cycle. Therefore, this reactor will integrate extremely well with India's planned thorium cycle and should quickly become self-sustaining based on India's thorium reserves.

Obviously, with its current and potential industrial capabilities and skilled work force, India will want to be a producer of both of these advanced reactor types. Therefore, by the middle to the end of the second decade India will be initiating the construction of its own version of the LMFBR and HTGR. These designs will of course be based on the experience gained from those imported plants. Early in the next century then, India will be in a position to export these reactor types in addition to its CANDUs, which will already have been exported for more than a decade or so. Since the CANDU is considered the current state-of-the-art competitor of the LWR, there is no need for India to develop the capability for producing LWRs. We will simply import as many LWRs as needed over the next few decades and then phase them out with more advanced reactor systems such as the LMFBR

Figure 3

NUCLEAR DEVELOPMENT PROGRAM MILESTONES

1980	1985	1990	1995	2000	2005	2010
	First nuplex comes on line 1988	Delivery of first floating nuclear plant (LWRs)	India completes construction of first "CANDUS" for export to developing nations.	India produces first floating "CANDU"		India completes construction of first LMFBRs for export to developing nations (2008).
Begin accelerated expansion of Indian "CANDU" construction program.	Construction of Indian "CANDUs" and import of LWRs, HTGRs and LMFBRs begin on large scale.	Operation of world's first nuplexes begin. Starting of India's first LMFBR initiates Indias's transition into the "Thorium Fuel Cycle."	India begins fuel reprocessing and fuel fabrication on large scale.	Construction of Indian designed and built LMFBRs and HTGRs begins on a large scale. Use of converted "Thorium-to-U233" fuel begins in significant quantity.	Imports of LWRs peak out and begin to decline as the construction of Indian "CANDUs" and advanced reactors (i.e., LMFBRs and HTGRs) rapidly expands.	Fusion fission hybrid reactor "fuel factories" begin coming on line to greatly accelerate India's conversion of thorium to uranium fuel.

and HTGR. India, however, will get into the floating nuclear plant business and should be producing floating CANDUs for both export and internal use by the end of this century.

The role of the Fusion-Fission hybrid reactor

Although developed only conceptually at this time, a final nuclear energy system to be briefly mentioned here is thermonuclear fusion—cited by Bhabha as the "energy source of the future" as far back as 1953. The production of energy by fusion is still in the experimental stage at this time, however rapid progress has recently been made in this area in both the Soviet Union and the United States. These countries now project commercial fusion power to begin coming on line in some form by the late 1990s. These first fusion reactor systems are likely to be what are called Fusion-Fission Hybrid Reactors (FFHR), or better described as "fuel factories" for fission reactor fuel. These reactors can loosely be compared to a fast breeder reactor in principle, exeept they produce fission fuel at much greater rates than the breeders. In fact, one FFHR can produce enough Pu-239 from uranium or U-233 from thorium to fuel ten to twelve fission reactors, whereas an LMFBR fuels only two to four fission reactors.

The FFHR will therefore be the "fuel factory" of the future for India and will convert thorium to useful fuel at far greater rates than the breeders. If these hybrids are introduced in the U.S. and U.S.S.R. by the turn of the century, it seems reasonable to expect that India would have them about a decade later, or about 2010. Therefore, India's energy growth program for the early part of the next century should assume such systems will be available to provide the vast quantities of fission fuel needed then, both internally and for export.

Pure fusion reactor systems will be coming on line commercially early during the next century in the U.S., U.S.S.R., Europe and Japan and can be expected to be available to India at that time as well. It is necessary for India to be involved in fusion research now and over the next two decades so that it is amply prepared to make the necessary transition to a future fusion based economy. A more fully defined fusion development program for India can be put together at a later time.

3. Meeting India's Nuclear Program Goals

The goal of the nuclear energy program outlined here is to install about 150 nuclear reactors, averaging 1,000 megawatt capacity each, in India by the year 2000. During the same time period, India will develop the capacity to have exported about 20 such reactors, produced by Indian skilled labor in Indian-owned and operated production facilities. Due to the present state of the nuclear energy production industry, India will be initially dependent on import of reactors. However, the program envisions the beginning of domestic production of CANDU reactors in 1980.

As a result of this program, India's electrical generation capacity by the year 2000 will be in the range of 220 to 230 gigawatts up from the present figure of 26 to 28 GW. Of this total capacity 65% will be nuclear, as only a small additional amount of coal-fired capacity is envisioned, while due to special topological conditions in India, no additional hydroelectrical capacity is planned beyond 40 GW.

How will the program goals be met ?

Figures 4 and 5 illustrate how the construction of Indian nuclear power plants will proceed. Table II gives a more detailed breakdown of the types and numbers of reactors constructed and whether they are imported, built by India, or exported by India. As shown, the first decade will involve an influx of imported LWRs and a few LMFBRs and HTGRs, along with the construction by India of ten CANDUs. In addition to the ten CANDU reactors by 1990 it will be necessary to have installed imported capacity of 16 LWRs, five of which will be of the floating type; six HTGRs, and three fast breeder reactors, country of origin yet to be determined pending near-term commercial demonstration of these reactor types.

In order to meet domestic reactor production goals, 45 CANDUs, seven HTGRs, and five fast breeder reactors by 2000, India will build four reactor production facilities in the late 1980s and the early 1990s. Two of these will be dedicated for CANDU production, with one each for the other two reactor types. Of the 45 CANDUs produced, 20 will be for the export market to other developing countries.

During the 1990s, India will continue to import reactors other than CANDUs totaling 29 floating

Figure 4

NUMBER OF REACTORS IMPORTED, BUILT and EXPORTED

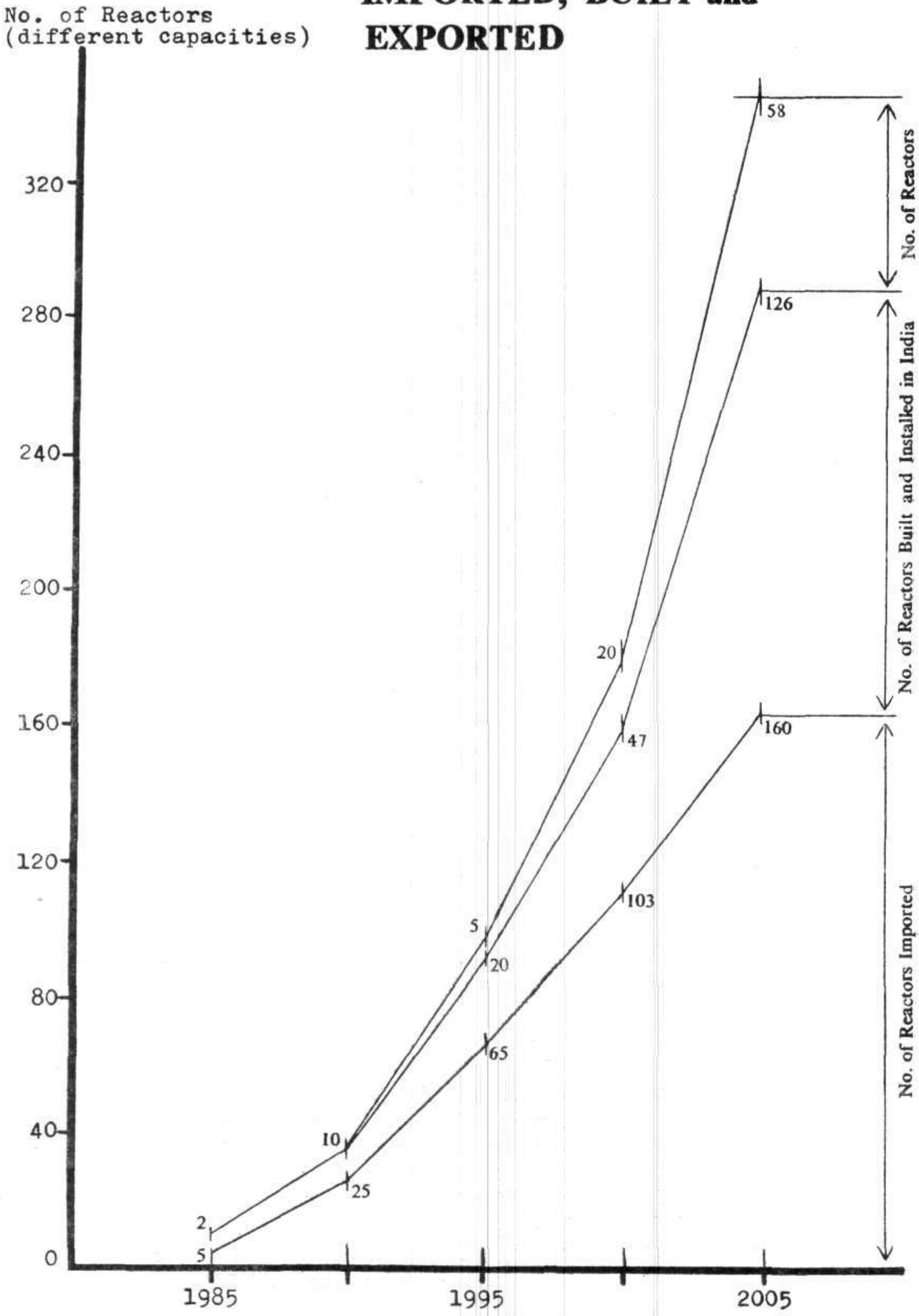


Figure 5

NUCLEAR POWER GENERATING CAPACITY

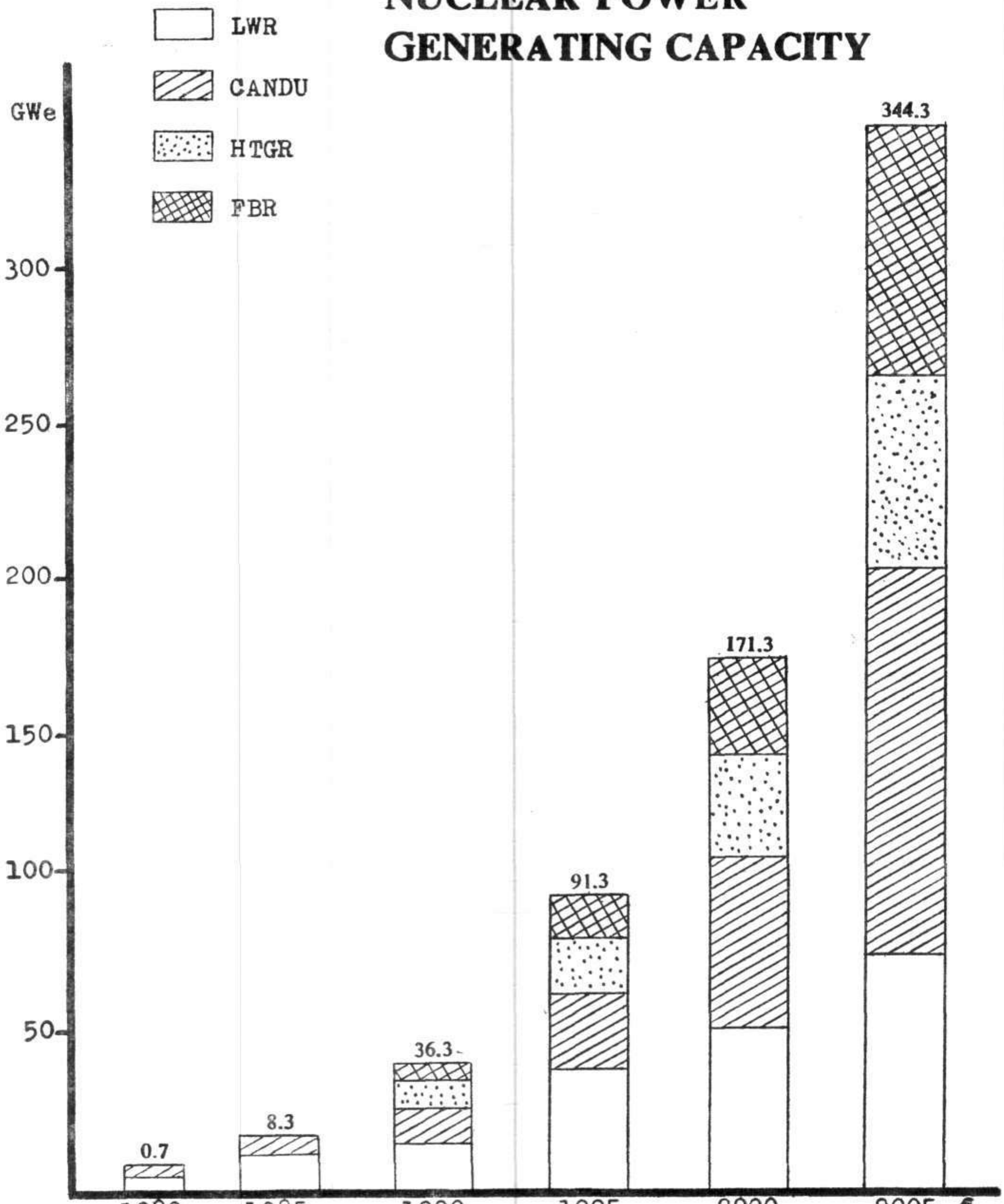


Table II

Number of Nuclear Reactors*
To Be Imported, Built and Exported By India
During the Next 25 Years

5-Year Periods	Type of Reactor	Imported	Built	Exported
1980-1985	CANDU	—	2	—
	LWR	5	—	—
1985-1990	CANDU	—	8	—
	LWR	11	—	—
	FNP	—	—	—
	HTGR	6	—	—
	FBR	3	—	—
1990-1995	CANDU	—	10	5
	LWR	7	—	—
	FNP	19	—	—
	HTGR	6	—	—
	FBR	8	—	—
1995-2000	CANDU	—	15	15
	LWR	—	—	—
	FNP	19	—	—
	HTGR	9	7	—
	FBR	10	5	—
2000-2005	CANDU	—	40	38
	LWR	—	—	—
	FNP	31	—	—
	HTGR	10	24	—
	FBR	16	15	—

*Indicate nuclear reactors completed and on-line.

LWRs, five land-based LWRs, 19 HTGRs, and 25 fast breeder reactors.

These projections are based on the fact that construction times for reactors can be held down to four to five years by using standardized design and mass production techniques and by intensive 24-hour-a-day construction timetables, which will necessitate rapid training of a large skilled construction labor pool in India.

Fueling of the reactors will be handled in two ways. For imported reactors, contracts will include importation of enriched fuels from the country of origin for at least the first few years of reactor lifetime. Since India does not have significant uranium resources, this dependence on imported uranium fuel will continue for some time. However, the large domestic thorium reserves can be utilized in LMFBRs to generate U-233 for later years' use in all types of reactors. Due to the difficulties involved in the isotope enrichment process, it is probably most effective for these materials to continue to be imported for the foreseeable future. However, India will build ten fuel fabrication plants and four spent fuel reprocessing facilities capable of handling both domestic needs in this area and orders arising from India's export of reactors. In addition, India will eventually need five heavy water plants to charge new CANDU reactors and maintain those already in operation. The accompanying Table III indicates capacities for these facilities and when they will come on line.

Table III

Fabrication and Production Plant Goals
For Nuclear Expansion Program

Year	Reactor Fabrication Plants	Fuel Fabrication Plants*	Reprocessing Plants**	Heavy Water Production Plants***
1980	0	0	0	0
1985	1	1	0	1
1990	2	3	1	2
1995	4	6	2	3
2000	4	10	4	5

*Capacity : 600 metric tons/year
**Capacity : 1500 tons/year
***Capacity : 800 tons/year

4. *Manpower and the Bill of Materials*

The nuclear energy development program envisioned here will have a significant effect on the skill level and employment profile of the Indian labor force. At the present time, there are about 8,000 skilled workers and 2,000 engineers engaged in the nuclear industry. By the year 2000, that figure should rise to the range of nearly 130,000 skilled workers and more than 32,000 engineers.

India has the capability to build up a massive engineering force with the nuclear industry. Tens of thousands of highly skilled workers are required for construction and manufacturing. These workers have to be intensively educated and trained on the job to build a mass production nuclear industry out of what is still today a highly specialized industry.

Engineering training should be focused in the area of design, construction and staffing of nuclear reactors, while industrial cadre must fill tens of thousands of highly skilled construction and manufacturing jobs.

Table IV shows the Bill of Materials and the manpower needs for the construction of a typical 1000 megawatt reactor for the types of plants in the Indian program, as well as for the ancillary fuel handling facilities and reactor fabrication facilities. In order to complete an imported plant, India must be able to supply essentially all of the concrete and cement requirements as well as about 80% of the steel and manpower. Most of the manpower for the imported plants will be in the skilled construction area, while most of the engineering manpower can be supplied by the exporting country. The stainless and specialty alloy steels, which are used in the construction of the reactor and turbine, will be supplied by the exporter as well.

As the program begins to take off, the demand for these materials will expand rapidly, necessitating construction of steel plants and cement factories capable of meeting the cumulative totals of production cited in Table V.

One serious bottleneck to the gear-up of basic industry is the machine tool and metal working equipment sector. At present, the lead time for delivery of the most advanced machine tools, such as a computerized boring mill, is two years. New capital goods production technologies need to be introduced to cut these lead times.

Quality control of reactor materials, especially the thick pressure vessels, is now time consuming and adds to the delay of reactor components fabrication. More advanced testing methods, such as x-ray techniques, ultrasonics and dye penetrants, can be applied to quality control in the nuclear industry. Other advanced methods, such as neutron radiography, are now under development.

Without the introduction of computerized and highly automated production technologies, it will be extremely difficult to meet the demand for qualified engineers and technicians for this program. Technologies, like those to be used in the Soviet Atommash facility to produce standardized reactors based on the concept of assembly-line production, will eliminate the one-of-a-kind engineering requirements currently used in the nuclear industry.

5. *The Role of the Nuplex*

India needs urbanization right now. Eighty percent of India's population lives in seventeenth-century conditions—totally shut out from education, technology, and realization of the potential for human creativity. Nuplexes, nuclear-centered agro-industrial complexes, must be the priority in India's industrial development program. This will enable the construction of at least 15 to 20 new major cities all over India in the next 25 years.

The cities will be powered by at least two 1000 MWe HTGRs each, around which an agro-industrial complex can be built. Along with on-the-job training, these complexes would provide for on-site classroom educational programs.

The nuplex and "integrated industrial complex" is the nuclear power plant of the future, providing energy as heat and electricity to power concentrations of industrial and agricultural processes. The nuplex concept is particularly important for the developing sector where the infrastructure for energy, industry and agriculture does not exist and must be built from the ground up.

A significant portion of the reactors, therefore, will be part of a much larger development package which could include an aluminum production plant,

Table IV

Materials and Labour Requirements Per Plant

Type of Plant	Materials (tons)				Man-Hours Labor
	Steel	Stainless Steel	Alloy Steel	Cement and Concrete	
HWR*	48,000	2,100	4,900	625,000	12×10^6
FBR*	31,000	1,700	3,600	350,000	$14\ 2 \times 10^6$
HTGR*	74,000	3,200	12,000	476,000	13×10^6
Reprocessing	51,500	4,600	7,100	835,000	16×10^6
Fuel Fabrication	22,000	200	300	30,000	1.3×10^6
Basic Component Fabrication	30,000 tons, basic structural steel			50,000	3×10^6
Floating Nuclear Plant Construction Facility	40,000 tons, basic structural steel			500,000	70×10^6

*for 1.0 GWe plant

Table V

Total Materials and Labour for Nuclear Construction Program

YEAR	STEEL (millions of tons)		CEMENT and CONCRETE (millions of tons)	MANPOWER		
	CARBON	ALLOY		TOTAL (mn.man yrs)	SKILLED WORKERS	ENGINEERS
1980	—	—	—	—	8,000	2,000
1985	0.95	0.02	12.4	0.14	36,700	9,200
1990	3.3	0.09	35.0	0.36	51,800	12,900
1995	6.4	0.27	60.0	0.70	77,600	19,400
2000	9.3	0.54	93.0	1.00	129,500	32,400

a steel production plant, a synthetic fuel production plant a chemical fertilizer production plant, and desalination plant, or a combination of these and other facilities. The design of the nuclcar reactor or reactor nuplexes will have to be tailored to the type of production facilities to be built and the entire nuplex design must be tightly integrated.

All current reactor designs—the LWR, the LMFBR, and the HTGR—can be used in nuplexes. But the reactor best suited is the HTGR. The most efficient and productive nuplexes can be designed and constructed if a cheap source of high temperature process heat is available with temperatures in the 1,400 to 2,000 degree Fahrenheit range. The HTGR is the only reactor that can meet these temperature requirements and has been featured in the most recent design of several nuplexes. The lower temperature reactors, like the LMFBR and the LWR, will be able to produce process heat or steam also, but at temperatures of 1,400 and 600 degrees Fahrenheit respectively. They can be effectively and economically used in certain types of nuplexes, but they are not as versatile for such applications.

In addition to the higher temperature process heat and steam applications and the production of electricity, the waste heat of all three reactor types can effectively be used in the nuplex as well. This low temperature process heat or steam can be used to desalinate water, heat entire cities, support aquaculture, provide year-round crops in cold climates, to mention a few applications.

The HTGR has been designed and is currently being developed for nuplex applications by General Atomic Company in the United States and by the West German government. Although these research and development programs have been underfunded during the past five years, it is estimated that given the appropriate funding levels, commercial-size reactors with temperatures in the 1,400 to 1,600 degree Fahrenheit range could be available for production within seven to ten years and could be used in nuplex designs in the 1990-2000 period and beyond.

In this program the first three nuplexes are discussed. Their locations have been chosen because of the ground work done by Oak Ridge National Laboratory and the Atomic Energy Commission of India on two of the three locations.

Location of Nuplexes

1. Kutch Gujarat

The Kutch site is located on the low-lying coastal plain of the Kutch portion of the peninsula between the Rann of Kutch and the Gulf of Kutch. The southern coastal plain of Kutch is classified as semi-desert. The density of population for the Kutch portion of the state is very thin. The Kutch area of Gujarat is generally lacking in major sources of both surface and groundwater, due to its climatic setting. Water being scarce, the success of agriculture depends on the careful husbanding of available water resources. Therefore, rather than an agricultural focus, the Kutch site is to be developed as an industrial complex. Kutch will emphasize industries producing aluminium from high grade bauxite (over 50% Al_2O_3) that exists in Gujarat, petrochemicals using natural gas that is available in Gujarat, and cement plants using gypsum that exists in Kutch and Halar districts. Gujarat also has about 17 million tons of 48% calcium oxide (CaO) for use in cement manufacturing.

Summary of Nuplex in Kutch

Commodity	Production Capacity	Power Consumed
Ammonia	3000 tons/day	100 MWe
Aromatics	13,000 bbl/day	
Methanol	3000 tons/day	60 MWe
Aluminum	1500 tons/day	650 MWe
Cement	1000 tons/day	500 MWe
Grid Electricity		600 MWe
Desalination	1000 mgd	100 MWe

2. Western U.P.

The project proposed for Western U.P. is based on nuclear power to produce fertilizers, pump subsurface water for irrigational purposes, and manufacture cement and steel. Water from subsurface, though cheaper than desalted water, is more expensive than surface water. The total annual pumpage of subsurface water in Western U.P. at present is approximately 6 million acre feet. The total area proposed to be covered under the agro-industrial complex is 3.8 million acres. In order to have a three-crop rotation over this area, annual water requirements for irrigation will be 13.3 million acre feet. The main basis for identifying water in sufficient quantity is to make intensive cultivation, with three crop rotations, possible. Fertilizer production depends on ammonia, obtained via electrolytic hydrogen, being oxidized to nitric acid, which in turn is used to acidulate phosphate rock to give nitric phosphate. Recent phosphate discoveries near Hardwar seem to be commercially significant; a multiple bonus would be forthcoming for northern India's agriculture via electric-furnace of rock phosphate.

Summary of Nuplex in Western U.P.

Commodity	Production Capacity	Power Consumed
Ammonia	3000 tons/day	100 MWe
Liquid H_2	100 tons/day	50 MWe
Finished steel	$3x10^6$ tons/year	300 MWe
Phosphate	700 tons/day	150 MWe
Pumping water	1.5 million acre-feet	150 MWe
Cement	1000 tons/day	500 MWe
Grid electricity		650 MWe
Chlorine	1000 tons/day	100 MWe

3. Madhya Pradesh

The Madhya Pradesh site is proposed because of the high bauxite deposit that exists in the Mandla, Jabalpur and Balaghet districts. Deposits of iron are found in Madhya Pradesh. There also exist large deposits of coal in the form of lignites. Presently, lack of electrical power is the reason why aluminum cannot be manufactured in large quantity.

Summary of Nuplex in Madhya Pradesh

Commodity	Production Capacity	Power Consumed
Aluminum	2000 tons/day	900 MWe
Finished steel	$4x10^6$ tons/year	450 MWe
Ammonia	3000 tons/day	100 MWe
Phosphate	700 tons/day	150 MWe
Grid electricity		400 MWe

The Development of India's Water Resources

India's Water is its Oil

One of the major resources India can rely on for its development is its immense water resources. Not only can a program for Water Management put an end to the cycle of droughts and floods which has plagued India for centuries, but properly harnessed, India's water resources can provide substantial amounts of power as well as irrigation for agriculture. India's water is its oil.

Power: At present approximately 28% of India's total installed generating capacity of 28,000 megawatts, or 8,000 megawatts, comes from hydroelectric power. The potential, even according to conservative estimates, is much, much greater. Most studies show that India can generate over 40,000 megawatts of electricity through hydroelectric dams.

In the section of this program dealing with energy, we have outlined a timetable for ensuring that this energy from our river systems is fully utilized.

The harnessing of our water resources to produce hydroelectric power must be integrated to an overall water management program aimed at simultaneously providing irrigation for our agriculture.

Irrigation: It is no exaggeration to say that India's agricultural potential is enormous. No other region in the world is best-suited for large-scale cultivation than the Ganges-Brahmaputra river basin. While India today produces 120 million tons of grain per peak monsoon year experts estimate that we could be producing *over 1, and perhaps 2 billion tons of grain per year*! If provided with the necessary inputs of fertilizer, mechanization and, most important, water, India can become the breadbasket of the world within 15-25 years. At present 43 million hectares are irrigated. According to the water management program we propose, we can irrigate at least three times that area.

The central focus of any water development program for India is the need to build a grid of canals linking the major river systems so that water can flow from surplus areas to deficit areas at the same time that groundwater storage recharge and extraction sites are developed.

The details of this massive water management plan —which incorporates some of the outlines of the National Water Grid put together by former Irrigation Minister K. L. Rao—can be worked out by the experts in the field. In this program we propose the following two-stage approach and timetable. For summary of Irrigation Development Program see Table I.

Stage I—1980-1995

(1) *Diversion Canals:* The first stage of the program should concentrate on constructing a major diversion canal from the Brahmaputra River—which carries a surplus of water, especially during the monsoon season —near Dhubri, to the Ganges River, near Patna. The canal would include outlets for irrigation releases to Bangladesh enroute.

A second diversion canal should also be built from the upper Ganges and Yamuna Rivers in Haryana (north of Delhi) with groundwater recharge and extraction facilities enroute to convey surplus water

Table 1

Proposed Irrigation Development of India

River	Surface Runoff (BCMY)	Arable Land (MHa)	Land Under Irrigation			
			Potential (MHa)	Existing (MHa)	Proposed (MHa)	
					Stage I (1980-95)	Stage II (1995-2010)
Sutlej	32.5	9.6	3.2	6.3	8.0	8.0
Ganges	365	60.2	36.5	19.5	40.0	48.0
Brahmaputra	600	6.1	51.0	0.8	5.0	5.5
Sabarmati	3.2	1.5	0.3	0.3	0.5	1.0
Mahi	8.3	2.2	0.8	0.3	0.8	1.5
Narmada	40.7	5.2	4.1	0.3	2.0	4.0
Tapi	18.7	4.3	1.9	0.4	1.0	3.0
Subernarekha	7.9	1.2	0.8	0.1	0.5	1.0
Brahamani	18.3	2.4	1.8	0.3	1.0	1.8
Mahanadi	66.6	8.0	6.7	1.6	3.0	6.0
Godavari	105.0	18.9	10.5	2.3	5.0	14.0
Krishna	67.7	20.3	6.8	3.5	5.0	15.0
Pennar	3.2	3.5	0.3	0.5	0.8	2.5
Cauvery	21.0	5.5	2.1	1.8	2.5	4.0
Others	322	10.4	32.2	5.0	6.0	7.5
Bangladesh	100	8.8	10.0	—	5.0	6.5
Total	1.680	160.0	168.0	43.0	81.1	122.8

Stage I (1980-95):—Divert Brahmaputra to Ganges and Yamuna **to** Rajasthan Canal. Initiate intensive groundwater recharge and extraction systems and local dams and canals. Construct Bangladesh Seawater Barrier & Flood Embankments.

Stage II (1995-2010):—Divert Brahmaputra-Ganges Southerly by Link Canal and Regulating Reservoirs, Complete groundwater, dam and canal development.

into the Sutlej Basin for delivery into the Western Desert through an enlarged Rajasthan Canal. (see map) Near Bikaner in western Raiasthan, a pump-lift canal facility would convey Himalayan water to the porous sandstone aquifers about 105 km. north-east of Jodhpur as a regulating storage facility. The dam, canal and groundwater systems of each individual river basin will be developed in coordination with the anticipated facilities of Stage II.

(2) *Groundwater Recharge and Extraction Systems*. A crucial aspect of the water management program is the improvement of groundwater recharging and extraction systems. About 65 percent of India's runoff flows through the Ganges Delta. Because the storage capacity of dams in the steep Himalayan Rivers is limited, the key to effectively impounding surplus runoff during the July-October monsoon season is the extensive development of these groundwater recharge and extraction systems.

Two methods are proposed for the rapid development of groundwater storage and extraction on a major inter-regional scale. In pre-selected areas small nuclear explosive devices can be used to fragment impervious geological formations both to increase the vertical percolation from natural streambeds and new canals and to increase the horizontal transmissibility between natural groundwater aquifers. Nuclear devices can also be used for constructing delivery and navigation canals, as proven feasible in studies carried out by the Tata Institute of Fundamental Research in the 1960s.

A second method utilizes the radial well concept that originated in ancient West Asian countries and which has been improved by an American company. Such wells consist of a vertical concrete caisson of about 15 feet in diameter and up to 200 feet deep. From the central caisson, horizontal perforated collector pipes of about 8 inches in diameter and up to 300 feet in length are hydraulically jacked into the water bearing formation in a multiple "radial" pattern. These wells have ten to twenty times the yield of simple vertical or "tube" wells, have substantially less drawdown or well interference effects and utilize much more efficient pumps which can be maintained more easily in an accessible central enclosure. The unique feature of this type of well is that in addition to being able to extract water from the well, water can also be efficiently recharged into the same well. (The recharge water must be sufficiently filtered and treated by conventional aggregate media and chemical methods to prevent clogging by encrustation sediment or biological organisms).

The proper use and location of nuclear explosive devices and radial wells along river and canal systems can be reasonably estimated to double the useful groundwater storage capacity throughout India. As more of the cultivated land above the plain of rivers becomes irrigated by the proposed features of this plan, even more accrual to the groundwater basins can be expected since about 60 percent of the applied water percolates below the crop root zone. Most of these new irrigated lands will be situated on relatively pervious soils upstream of the groundwater basin where impervious strata are less prevalent.

The approximate quantities of water which should be made available according to this program are summed up in Table II.

Table II

Water Extraction for Irrigation

Program Stages	Extraction from River Flow	Ground Water Extraction		Total Water Extraction
		By Deep and Shallow Tube Wells	By Radial Wells	
Present	222 BCMY	85 BCMY	—	307 BCMY
End of Stage I	222 BCMY	85 BCMY	380 BCMY	687 BCMY
End of Stage II	447 BCMY	85 BCMY	575 BCMY	1107 BCMY

3) *Seawater Barrier at the Mouth of the Ganges.* The third aspect of the water development program which must be viewed as a priority is the construction of flood control embankments and other measures to improve the navigability of the lower Ganges and Brahmaputra Rivers. This can be accomplished by using the river training techniques developed by the U.S. Army Corps of Engineers on the lower Mississippi River. A competent master plan for Bangladesh was prepared by an engineering company in the U.S. in 1964, portions of which are being slowly implemented by the Bangladesh government.

However, we propose a crucial addition to this plan: the installation of a seawater barrier at the mouth of the Ganges, replete with saltwater-clearing navigation locks and sediment sluiceways similar to the Zuider Zee reclamation project in Holland. This feature—although difficult considering the copious discharge, annual fluctuations and numerous distributaries of the Ganges Delta—is necessary to fully utilize the fresh water potential of the river system, especially during the low flow season. The seawater barrier will also alleviate the expressed concerns of the government of Bangladesh over the effect of upstream diversions from the Ganges and Brahamputra on increasing the intrusion of seawater into the waterways of the Ganges Delta.

As a first step we propose that feasibility for this massive engineering project be initiated immediately in collaboration with the Bangladesh government.

Stage II—1995-2010

After about ten years to complete design and construction and five full years of operation, the Stage I facilities will be augmented by the beginning of construction of Stage II. The two major aspects of Stage II will be :

(1) *Completion of the groundwater recharge and extraction as well as the river diversion plan outlined in Stage I.* (Table II gives a more detailed breakdown of the timetable for this).

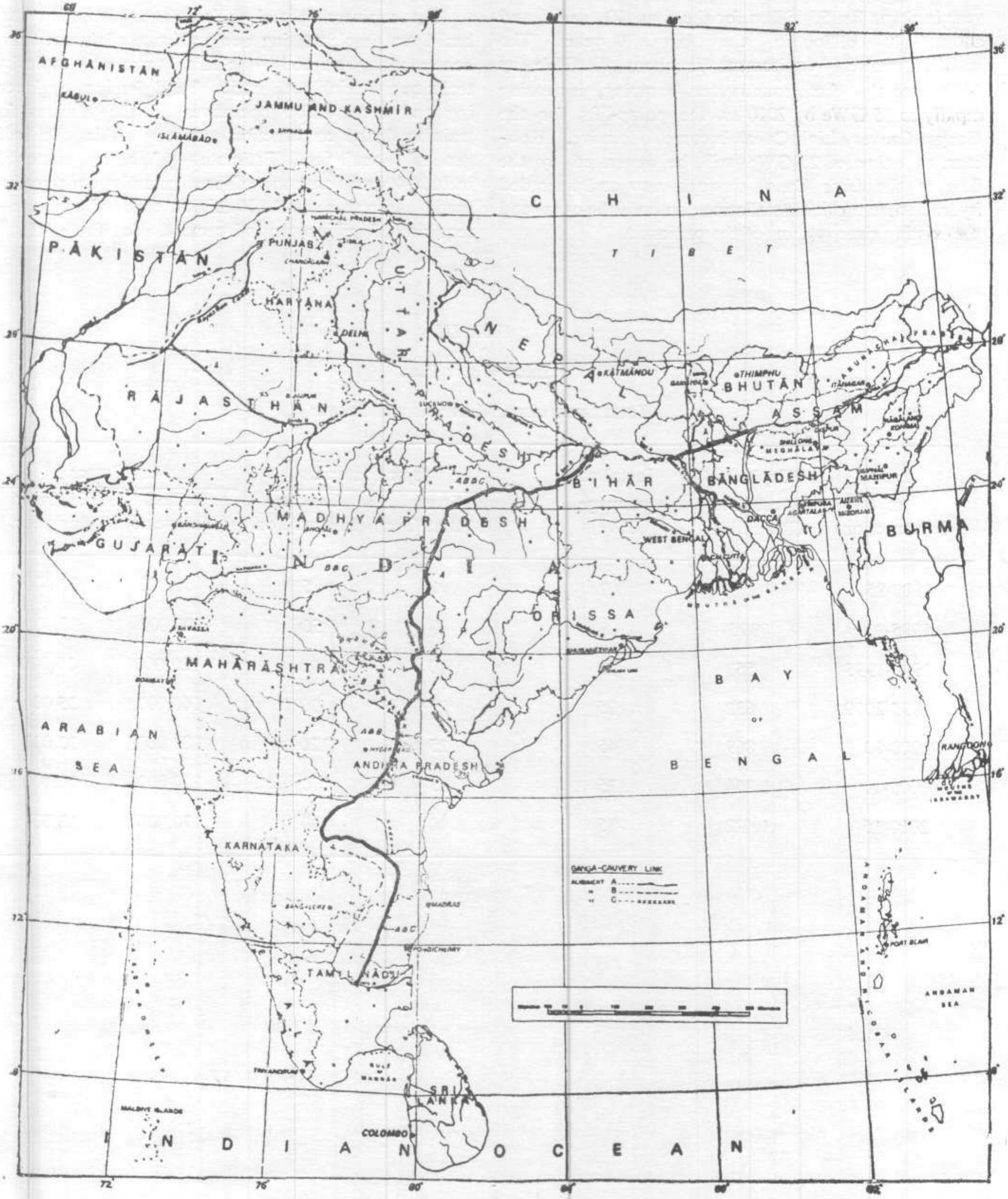
(2) *Ganges-Cauvery Link Canal.* This canal, which would stretch from Patna to the Cauvery River in the South, was originally proposed by Former Irrigation Minister K.L. Rao. However, the ultimate capacity of the canal we propose will be 24 BCMY, ten times greater than the maximum size estimated by Mr. Rao. There are two reasons why it is possible to substantially expand Mr. Rao's plan through this program. First, the Rao estimate assumed that pumping would be allowed only during the four months of the monsoon season. Second, the energy for pumping lift was presumed to be a function of the potential hydroelectric power from new dams in Nepal. However, in this program, the provisions for groundwater storage and extraction together with salinity control in the Ganges Delta with the seawater barrier, will allow for the pumping of both surface water and groundwater throughout the year. In addtiion, as outlined in the section of this program dealing with energy, nuclear plants in addition to hydroelectric stations will provide the large amounts of energy needed for pumping. For the Rao plan an estimated 16 Gigawatts of electrical power would be needed to lift 24 BCMY in a 4-month period. In this program about 54 gigawatts will be needed to lift 240 BCMY during a 12-month period.

The Ganges-Cauvery Link Canal connects the major river basins of most of the states in the Southern peninsula into a nationally regulated economic unit—rather than disparate states in competition for regionally limited resources. The canal would be about 60 feet deep and 1,500 feet in average width at the start, tapering down to 60 deep and 350 feet wide below the Krishna River outlet. For a total length of 1,640 miles, 440 miles are in pump lift reaches of national rivers and 1,200 miles are in gravity-flow canals or rivers. Approximately 120 billion cubic meters of storage is necessary for delivery regulation which will be supplied in the canal or adjacent streams. One of the major purposes of the canal will be to provide inexpensive barge transportation for ores, grains and bulk products from the south to the north. Patna will become a bustling seaport.

As shown in Table I, about 27 percent of the total arable land in the country is presently irrigated. In Stage I and II this will increase to 50 and 77 percent, respectively. In the Godavari and Krishna Basins of the central peninsula, for example, we can irrigate twice the amount of land through this full-scale program.

Costs and Power Requirements

The estimated cost of construction is about 632 billions rupees for Stage I facilities and 790 billion rupees for Stage II, including pumping power plants. Since facilities will be constructed over a continuous period of 30 years, the average capital requirement per


AFGHANISTAN
KABUL
ISLAMABAD
JAMMU AND KASHMIR
PAKISTAN
PUNJAB
HIMACHAL PRADESH
CHANDIGARH
HARYANA
DELHI
UTTAR PRADESH
LUCKNOW
RAJASTHAN
JAIPUR
CHINA
TIBET
NEPAL
KATMANDU
BHUTAN
THIMPHU
ARUNACHAL PRADESH
ITANAGAR
ASSAM
SHILLONG
MEGHALAYA
KOHIMA
IMPHAL
MANIPUR
BIHAR
BANGLADESH
DACCA
AGARTALA
TRIPURA
AIZAWL
MIZORAM
BURMA
WEST BENGAL
CALCUTTA
MOUTHS OF THE GANGES
MADHYA PRADESH
BHOPAL
GUJARAT
GANDHINAGAR
INDIA
ORISSA
BHUBANESWAR
MAHARASHTRA
BOMBAY
SILVASSA
ARABIAN SEA
BAY OF BENGAL
ANDHRA PRADESH
HYDERABAD
RANGOON
MOUTHS OF THE IRRAWADDY
KARNATAKA
BANGALORE
MADRAS
PONDICHERRY
TAMIL NADU
TRIVANDRUM
GULF OF MANNAR
SRI LANKA
COLOMBO
MALDIVE ISLANDS
INDIAN OCEAN
ANDAMAN AND NICOBAR ISLANDS
PORT BLAIR
ANDAMAN SEA
ABBC
BBC
ABB
ABC
68°
72°
76°
80°
84°
88°
92°
96°
36°
32°
28°
24°
20°
16°
12°
8°
GANGA-CAUVERY LINK
ALIGNMENT A
" B
" C

year is about Rs. 55 billion for the first 10 years and about 40 billion in the last 20 years. The installed power requirement is about 13 GWe by 1990, mostly for groundwater pumping, increasing rapidly to 85 GWe by 2010 as the pump-lifts for the Ganges-Cauvery Link Canal become operative. However, an estimated 25 GWe will be generated by the flow of the Link Canal through new and upgraded hydroelectric turbine installations on both the canal and the existing river systems of the peninsula.

The engineering and skilled labour estimates are based on implementing new and state of the art heavy construction methods—including nuclear explosive techniques—using both national and foreign engineering and construction operatives as the nucleus for training skilled construction workers within the indigenous population. Estimates of basic materials include 40 million tons of predominatly construction grade carbon steel and 190 million tons of concrete—requiring 23 million tons of cement. (See Table III)

Table III

India Water Plan

Total Investment, Materials and Labour

Year of Construction	Capital Investment (Rs. Bill)	Installed pumpage (GWe)	Major Materials		Man Power	
			Steel (Million Ton)	Concrete (Million Ton)	Skilled (Man years)	Engineer (Man years)
1980-85	79	2	1	5	60,000	20,000
1985-90	395	6	6	50	100,000	25,000
1990-1995	553	13	10	70	120,000	30,000
1995-2000	632	25	15	90	140,000	35,000
2000-05	869	45	25	120	180,000	30,000
2005-10	1,264	75	35	170	200,000	20,000
2010-15	1,422	85	40	190	170,000	12,000