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INDO-U.S. COLLABORATION IN RESEARCH AND TECHNOLOGY DEVELOPMENT: A TEN-YEAR DEVELOPMENT-ORIENTED STRATEGIC FRAMEWORK

NEW DELHI
SEPTEMBER 1983
REVISED AID/W: 11/83

PREFACE

This report was drafted by a team of AID staff from Washington and USAID New Delhi. The report is based on a review of documents prepared by the Government of India (GOI), Indian universities and research institutions; AID and other U.S. Government (USG) agencies; international institutions (e.g., the World Bank and International Crops Institute for the Semi-Arid Tropics - ICRISAT); and the writings of individual Indian and U.S. researchers, scholars and observers of Indian science and development. It is also based on extensive interviews conducted with Indian, U.S. and international officials, researchers, administrators and private sector representatives conducted in Washington, D.C., and in India during the period September 1-October 1, 1983.

The team wishes to express its gratitude to those individuals in the Government of India and in Indian research institutes, universities and private sector organizations who met with the team and accorded it a very positive reception. Special thanks for their generous commitment of time and hospitality are due Professor M. G. K. Menon, Member of the Planning Commission and Advisor for Science and Technology to the Prime Minister; Dr. O. P. Gautam,

Secretary of the Department of Agricultural Research and Education and Director General of the Indian Council of Agricultural Research, Ministry of Agriculture; Dr. S. Varadarajan, Secretary of the Department of Science and Technology; and Dr. Sukhdev Singh, Vice Chancellor of Punjab Agricultural University, Ludhiana. These visits and discussions demonstrated the strong ties that bind India and the United States in such areas as scientific research. The team also wishes to express its appreciation to Mr. Owen Cylke, Mission Director, USAID/New Delhi, and his staff, who were very supportive of the team's efforts, substantively and logistically. Particular thanks are due to Ms. Doris A. Withee and the FSN secretarial staff of the Mission for excellent logistical and typing support, and to Ms. Kit Holcomb of the Science and Technology Bureau, AID/Washington, for painstaking modifications of revised drafts.

The team appreciates the spirit of open inquiry and dialogue with a wide range of Mission staff. The team also benefitted from discussions with various members of the Embassy staff, especially with Dr. S. Ahmed Meer, Counselor for Scientific and Technological Affairs; Dr. Dennis Johnsen, his Deputy; and Mr. S.K. Dutt of the Science Counselor's office.

This report is but one step in what must be a process of dialogue. The team will have fulfilled its mandate if this report and the discussions that lie behind it accelerate that process, leading to significant implementation measures during the next twelve months.

A list of interviews and key documents reviewed are contained in annexes at the end of the report. Conclusions and recommendations are those of the team and do not constitute official positions of the Governments of India or the United States. Similarly, the team assumes responsibility for factual omissions and errors.

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EXECUTIVE SUMMARY

The following paragraphs summarize a report of discussions held in September 1983 between a team of USAID officials from Washington and New Delhi and officials of the Government of India. These discussions provide the basis for agreement on a ten-year strategic framework for the USAID program in India emphasizing support for development oriented research and technology development (R&TD). Both Indian and U.S. officials recognized that R&TD have been essential ingredients for sustained broadly-based development, that they have provided the new and adapted technologies capable of raising productivity and incomes, of reducing mortality and illness, of coping with economic and environmental stress; in a word, they have increased the effectiveness of development efforts.

A designated portion of the Mission's development assistance portfolio would be devoted to R&TD each year. This is projected to increase to $17.5 million or 19 percent of a $90 million portfolio by FY 1985, and to $32 million or 36 percent of the portfolio by FY 1988. These levels are over and above existing and planned support for research components in nutrition, family planning methods, social forestry and various irrigation and water management projects. Beyond FY 1988 the team recommends continued support of R&TD activities at a level of $25-30 million annually through the 1990s.

Objectives to be achieved over the ten-year period include increased effectiveness of Indian development efforts, of U.S. development assistance, and of development efforts in other countries. The great diversity of the Indian physical and biological landscape, and the impressive scientific talent that India can already count upon, suggest direct benefits to U.S. science and applied problems as well.

Main Features

-- support for basic and applied research in India focussed on development problems congruent with Indian and AID priorities and with the potential to improve the productivity and well-being of the Indian people;

-- research activities of varying duration will be undertaken within the ten-year time frame and will be subject to periodic monitoring and performance reviews;

-- social science research is an integral component of the strategy to ensure that the needs of intended beneficiaries are taken into account in the identification and design of research activities;

-- complementary support will be provided for professional interchange among Indian and U.S. working scientists, primarily in the form of relatively short-term meetings, workshops, study tours and selected longer-term assignments related to the research;

-- graduate and post-doctoral training related to the research will be supported, including training where needed of specialized technicians;

-- critical commodities, such as laboratory equipment and specialized supplies will be provided to complement the research;

-- a major objective of the above activities will be to utilize existing Indian research capacities more effectively, strengthening them where needed, rather than to create new institutions; thus, the performance reviews as well as workshops and studies will focus on research management and resource allocation;

-- the establishment (or re-establishment and strengthening) of relations between selected Indian and U.S. research institutions (or components of institutions, such as university departments) will be encouraged to promote continuity and long-term commitment;

-- the research and professional interchange will be conducted by highly qualified scientists of both countries and will be marked by a mature, collaborative style.

Sectoral Components

Sectorally-oriented research occupies a major place in the recommended strategy. Substantial increases in support for R&TD in five sectoral areas are projected:

-- agriculture: beyond the recently signed Agricultural Research Project, planned for $20 million, an additional $30 million is projected for FY 83-88 to support research on a number of priority topics (thirteen topics are suggested in the report, including management systems for lowland rice production); and an additional $15 million is projected over the same period for a joint program between U.S. and Indian agricultural universities to strengthen the research-teaching-public service capacities in selected areas of Indian agricultural universities and simultaneously enhance the breadth and experience of cooperating U.S. universities;

-- forestry and environment: a long-term R&TD program is recommended, emphasizing the role of trees and grass s in reversing ecological deterioration and expanding rural incomes, including baseline environmental research on natural resource degradation, results-oriented research on short-rotation and multi-purpose trees, and modest support for more basic research on genetic improvement of trees; initial funding is projected at $16 million between FY 1985 and FY 1988;

-- biomedical research: support would be provided for biomedical research on such priority diseases as: respiratory diseases, diarrheal and enteric diseases, reproductive immunology and the immunizable diseases, and nutritional anemia; the research will encompass research on diagnostic techniques, treatment modalities including new drugs, the development of improved or new vaccines, and applied research on health services; about $16 million for support of biomedical research and related training, professional exchange, selected equipment and reagents, and data management and information systems is projected for FY 1984-88;

-- energy: $8 million is projected for a Phase II Alternative Energy Resources Development Project for FY

1986-88, emphasizing R&TD on coal and biomass conversion and utilization;

-- industry/private sector: $5 million is projected for FY 1986-88 to strengthen R&D capabilities in the Indian private sector, perhaps emphasizing energy conservation, industrial pollution and the management of technological innovation; these activities could be linked with current proposals to establish a revolving fund of PL 480 generated local currencies in the form of a bilateral industrial research and development foundation or a similar mechanism.

In addition to support for research in India, each of the sectoral recommendations also includes support for professional interchange, training and selected equipment and commodities. Support for institutional development and strengthening could be more significant in some sectors (e.g., forestry) than in others. The recently signed Agricultural Research Project constitutes a potential model for all the sectors by providing a flexible mechanism for adding sub-projects as well as for periodic review of performance. While individual sub-projects would require close monitoring and some might well have a duration of less than five years, most or all sectoral umbrella projects could be viewed as ten-year programs.

"Innovative Research and Special Studies" Program

The report also proposes a ten-year program of "Innovative Research and Special Studies." This would have several components, including (1) support for research on a limited number of fundamental cross-sectoral topics (e.g., basic genetic engineering, surface and membrane phenomena, strength and fibre properties of biomass); and (2) support for consultants, studies, workshops and conferences involving Indian and U.S. experts on broader, cross-cutting topics related to science and technology and development (e.g., economics of technological change and resource allocation to research, the management of research, enhancing the role of the private sector in research, socio-economic analysis of the cost-effectiveness of alternative technology delivery systems, and science and technology in development information needs and exchange).

Support for basic research of a more generic rather than sectorally-oriented nature would be a departure for an AID bilateral country program. Both AID and the GOI's Department of Science and Technology (DST) would have to gain a better understanding of the nature of the research to be supported, especially in terms of its relationship to development problems. The consultants, studies and workshops should be useful to the DST and Indian Planning Commission in fulfilling their broad role of oversight of Indian science and technology and to AID in providing a mechanism for policy dialogue with the GOI on significant science and technology and research management issues.

One million dollars a year, or $4 million between FY 1985 and FY 1988, is projected for support of the program of "Innovative Research and Special Studies."

Implementation Considerations

The recommended strategy poses several implementation requirements.

-- Staffing Requirements

The strategy is relatively staff-intensive. The team recognized the limits on the Mission's ability to expand the number of direct hire staff. It recommends that a Joint Career Corps (JCC) Scientific Advisor be recruited from a U.S. university to coordinate the U.S. role in management of the strategy, to advise the Director and senior staff on performance and to manage directly the "Innovative Research and Special Studies" program. This advisor must be a respected, experienced scientist knowledgeable about science policy and administration, and about India and development. The advisor should be assisted by at least one and preferably two Foreign

National professionals. In the various sectors (agriculture, etc.) the team endorses efforts to reduce the workload on direct-hire staff through utilizing Indian consultants and consultancy firms.

-- Science Panel

The team recommends that a small group (3-5) of eminent scientists and science administrators be convened regularly (e.g., semi-annually) by the Mission Director to advise the Director and senior staff on the scope, content and performance of the strategy. They should be leaders in their fields, representing a mix of disciplines, including research resource allocation and management and the social sciences; they should also be knowledgeable about development and about India. In addition to reviewing strategy performance, the Panel would also provide a stimulus for effective implementation and an informal means of communication with senior Indian scientists and policy makers. The Mission Scientific Advisor and staff would serve as secretariat to the Panel.

-- Provision of U.S. Scientists

Timely participation of U.S. scientists in India is essential to the success of the strategy. Such

participation will for the most part be of a short-term, non-resident nature, including workshops, seminars and consultation with Indian researchers. Some longer-term participation of an expert advisory nature is also likely to be desirable.

The placement of expatriate technical assistance in India is a very difficult and protracted process. All such assistance must be included in the development budget of the requesting GOI organization, which must certify that the skills to be imported are not available from Indian sources (at a fraction of the close to $200,000 per work year for U.S. technical assistance -- $250,000 if acquired through an institutional contract with overhead). GOI officials have been very reluctant to accept U.S. experts under these circumstances, especially in a field like agriculture where the cadre of Indian professionals is relatively large.

The team recommends that the Mission seek at the highest GOI levels (e.g., the Prime Minister's Office) approval for expeditious provision of U.S. scientists from the resources of the USAID-India bilateral program. This element might be separated out from other projects into a

bilateral "technical support" project. Two considerations strengthen the case for establishing an improved procedure under the India program: (1) both the U.S. and India recognize the importance of timely participation of highly qualified U.S. scientists, and (2) the bulk of such expertise would be of a relatively short-term nature -- less than three months.

In the event that efforts to resolve the problem within the country program are not successful, an alternative mechanism funded from AID Washington should be explored. Under this approach, a portion of the bilateral program budget would be transferred to the S&T Bureau and/or Asia Bureau for the provision of U.S. scientists in response to requests from USAID and the GOI. Existing S&T Bureau projects could be drawn upon; an intermediary organization could be drawn upon to manage the recruitment process and to identify expertise unique to the India program. While such an arrangement would correspondingly reduce the size of the India program, it would also avoid inclusion of this element in the GOI budget. Several GOI officials proposed that the U.S. adopt such an approach, in effect providing U.S. experts "in-kind" (from the GOI perspective). UN experts are furnished to India in a similar manner, with funding provided from a UNDP account in New York.

-- Grant Funding Constraints

With an increased emphasis on institutional development, policy dialogue and technology transfer, the grant share of the DA budget has grown, from 10 percent during FY 1978-81 to 28 percent in FY 1983. An R&TD-oriented program would normally imply a high grant component in view of the emphasis on research and experimental activities, training and provision of scientific and technical expertise.

AID grant funds are extremely scarce and the current share of grant funding in the India program is probably near a maximum. The FY 1983-88 funding levels projected in this report take the grant constraint into account and assume that some portion of R&TD activities will be loan financed, i.e., all provision of commodities and equipment, as well as any construction costs, and some training, research and local technical assistance costs. The Mission is concerned that moving too far in this direction could reduce its leverage in seeking participation of U.S. scientists and in raising R&TD policy issues.

Other USG Activities in Science and Technology

This strategy does not imply a merger with other science and technology activities in India in which the U.S. Government is involved (e.g., local currency research programs, "Science and Technology Initiative" or "Senior Scientific Panel," and Indo-U.S. Joint Sub-Commissions). It should lead to more effective coordination or linkages among these elements, however.

Closer links might be possible between the AID program in India and certain elements of the Indo-U.S. "Science and Technology Initiative" (STI). This could occur in areas where there was a coincidence between AID-funded projects and the STI, such as biological nitrogen fixation, biomass and certain biomedical research topics. With the concurrence of the GOI, STI workshops in these areas might be supported. In addition, the AID program could provide extended support once the two-year STI initiative has elapsed.

Next Steps

The report recommends a series of actions to be taken over the next six months. First are presentation and review as soon as possible of the report and/or its recommendations in AID Washington and in India with the GOI. In addition to overall approval, explicit Washington approval should be sought for the creation of a Science

Panel, for the concept of an "Innovative Research and Special Studies" program and for recruiting a JCC Scientific Advisor. The Mission should seek high level GOI approval for timely participation of U.S. scientists.

Assuming AID Washington approval in principle, the members of the Science Panel should be identified and recruited by January 1984 and make their first visit to India in March 1984. Development of an "Innovative Research and Special Studies" PID should begin as soon as possible to ensure initial funding in FY 1985. The Scientific Advisor should be recruited to permit part-time involvement in the development of the PID and PP as well as in guiding the Science Panel. The Advisor should become full-time in the Mission by the beginning of FY 1985.

I. INTRODUCTION

The purpose of this report is to delineate a proposed "Research and Technology Development" strategic framework to serve as an integrative focus for a major share of the USAID program and relate effectively to other science-related U.S. Government-(USG) sponsored activities in India.

This framework is intended to broaden and extend the initiative set in motion by Prime Minister Gandhi and President Reagan during their meetings in Washington in August 1982. Those meetings launched a new dimension to Indo-U.S. cooperation in science and technology. This effort, first known as the "Blue Ribbon Group" or "Senior Scientific Panel" (SSP), and now referred to in the U.S. as the "Indo-U.S. Science and Technology Initiative" (or "STI" -- but still referred to in India as the "SSP"), is firmly underway. It remains a continuing and tangible manifestation of the announced desire of the two leaders to improve relations between the two countries. The linkages between the "STI" and the broader framework covered by this report will be discussed more fully in subsequent chapters.

The main objectives of the broader framework are to enhance, through support for the conduct of development-oriented research (and related professional interchange, training and commodities), (1) the effectiveness of India's development efforts in general, and of U.S. development assistance in India in particular; and (2) the effectiveness of development efforts and development assistance in other developing countries.

A subsidiary but not unimportant objective, recognizing the relatively mature state of India's science and technology capacity, and the great geographical, biological, ecological, demographic and ethnographic diversity in India, is to contribute to the advancement of scientific knowledge and its application to developed countries, including the United States. While the contribution to Indian development and to international development remains paramount for a development agency like AID, the potential significance of the subsidiary objective should not be underestimated. Both Indians and Americans with whom the team talked recognized the latter as an additional factor that could help attract high quality U.S. scientists.*

*Two examples of Indian research (being undertaken at Punjab Agricultural University) of importance to the U.S. as well as to India are work on (1) the "Karnal Bunt" blight affecting wheat and (2) rhizobium inoculation of non-leguminous crops, including major cereals.

Relationships between Indian and U.S. institutions, or components of institutions, such as university departments, would be established (or reestablished) and strengthened to help ensure the continuity and long-term commitment required for effective scientific endeavor. Support for a range of training and study-tour activities at the graduate and post-degree level as well as for critical commodi- ties such as laboratory equipment and specialized supplies, would complement the research. Exchanges dealing with broader questions could be supported, such as strengthening university research, teaching and links to application (e.g. extension or other delivery systems); research management; the economics of research planning and allocation and the role of economics and social science research. All these activities would be on the basis of a mature partnership between working scientists and their institutions.

These topics will be discussed in greater detail in subsequent chapters of the report. Brief discussions of five sectoral areas, with more extended treatments in separate annexes, are also included. The sectoral discussions cover agriculture; forestry and environment; energy; biomedical research; and industry/private sector. These analyses suggest a range of sub-sectoral topics, such as biological nitrogen fixation (to give only one of a number of examples), that appear to merit increased research effort. Further specification of these topics requires iterative discussion and refinement by Indians and Americans at both the policy and scientist levels. The design of research activities <u>within</u> these topical areas must of course depend heavily on the judgments of working scientists.

Although reproductive immunology and nutritional anemia are suggested among several priority topics in the section on "biomedical research," population and nutrition are not covered extensively in the main report or in the annexes. Support for research on the causes of low birth weight is already included in the existing Integrated Child Development Services project. A contraceptive research specialist from AID's Science and Technology Bureau is prepared to visit India in the near future to discuss in greater depth possibilities for support of contraceptive research and development in India.

The section (and Annex) on "Industry/Private Sector" does not explicitly discuss the proposals to establish a mechanism or mechanisms utilizing PL 480 generated rupees to stimulate joint R&D collaboration between Indian and U.S. private industrial enterprise. The team believes, however, that the analyses contained in this report raise a number of considerations of a policy and structural nature that must be weighed carefully in further development of these proposals.

A subsequent chapter (VI) briefly describes a possible program of "Innovative Research and Special Studies." This proposal has several attractive features, including support for broader, cross-sectoral aspects of development-oriented research. It also proposes support for basic research of a more fundamentally "upstream" character than AID has supported through its bilateral

country programs. This proposal and other implementation mechanisms and questions that are rather unique to the strategic framework proposed in this report are discussed in the following Chapter VII. Concluding chapters set out projections of estimated AID project funding to support the strategy during the FY 1983-88 period and propose a timetable for follow-up steps that should be taken over the next six months.

A. Rationale and Background

Basic and applied research, grounded in high quality scientific method and competence, has over the last three decades been a major source of far-reaching and lasting contributions to broadly-based economic and social progress in the developing countries. One has only to consider the impact of such accomplishments as the eradication of smallpox, reduction of malaria and expansion of basic food production in certain countries to recognize the veracity of this proposition. There are many less dramatic examples where research efforts undertaken in the developed and developing countries have made significant contributions to improving the productivity and well-being of the world's impoverished. These range from pharmaceuticals that reduce morbidity and infection, to techniques of irrigation and farm management that complement the "seed-fertilizer" revolution in agriculture, to modern family planning methods that improve maternal and child health. More recent developments such as oral rehydration therapy and potential and actual breakthroughs of a biotechnical nature in such areas as vaccines, fast-growing trees, and substitutes for petroleum-based fertilizer promise new advances of major portent.

This is not to argue that research alone has produced these accomplishments or that research alone is a panacea for the future. Mobilization and commitment of domestic and international resources for physical infrastructure and delivery systems have also

been vital, along with a conducive economic policy environment that provides stable incentives and financial capital to the millions of small farmers and entrepreneurs for the adaptation and adoption of new technologies.

Research has nonetheless been an essential ingredient for sustained development; it has provided the new and adapted technologies capable of raising productivity and incomes, of reducing mortality and illness, of coping with new economic and environmental stresses; in a word, it has enhanced the effectiveness of development efforts.

These points have been recognized clearly in such documents as the GOI's Sixth Five-Year Plan which observes in the chapter on Science and Technology (p. 318):

> The crucial role of science and technology as an instrument of social and economic change has been appreciated and the rapid development of science and technology and of its application, accepted as a major objective of planning.

These observations were also mutually recognized when Professor M. G. K. Menon, Member of the Planning Commission of India and Advisor for Science and Technology to the Prime Minister, met in 1981 with Mr. M. Peter McPherson, Administrator of the Agency for International Development, and Dr. Nyle C. Brady, Senior Assistant Administrator for Science and Technology, AID.

AID Administrator McPherson, in view of the foregoing rationale, has concluded that AID should seek to increase markedly its support for the conduct of development-oriented research, focusing particularly on those countries where the scientific and institutional capacity already exists to undertake, with supplementary support, such research.

Among all countries in which AID supports bilateral assistance programs, India best meets these criteria. The Administrator asked that a long-term, ten-year strategy be developed that would emphasize support for development-oriented research. The Administrator envisions research results from this effort that will have widespread developmental impact not only in India but elsewhere in the developing world as well.

B. The Concept of Research and Technology Development

AID and most international development agencies have focused on the applied end of the scientific research spectrum. This is to be expected since these institutions are under a mandate to help bring about solutions to pressing, immediate problems that affect the lives and well-being of millions of people. Also, some of the most dramatic applications of research to development problems in the Third World, such as development of the new high-yielding varieties of wheat and rice, while involving years of painstaking effort, have nonetheless been goal-oriented or problem-driven and the results sought (i.e., shorter straw, higher yield) were envisioned at an early stage.

The range between basic and applied research is a spectrum, with several, not always easily distinguishable, intermediate stages between the two ends of the spectrum. AID, through its Research Priorities initiative, and in the proposed framework for the USAID program, is placing greater emphasis on support for somewhat more basic research than has been the case in the past. This is not intended to minimize the importance of applied and adaptive research, including operations and "action" research. Often the latter provide important information for the selection and design of more basic research. All of these are included in the concept of research and technology development.

Close to the basic end of the research spectrum are investigations that seek to expand knowledge of the fundamental properties and behavior of matter and of chemical and biological interactions. Although there may be an intuitive hunch that potential applications might be significant, the applications, or even the sectors or fields where pay-offs might accrue, may not be predictable in advance. Examples include research on surface interactions and membrane phenomena, and basic genetic research. The original creation in the laboratory of hybridomas would be an example of the latter. AID might support research on the modification of hybridomas for specific applications in agriculture, health, energy, etc., but it is less likely -- except perhaps through the program sponsored by the Science Advisor's office -- to support research of a

more fundamental nature. A unique proposal put forward under this strategy is to support some collaborative research of this more innovative and basic nature. This proposal is analyzed further in Chapter VI, below.

This latter proposal should not diminish the significance of the expanded research efforts recommended in each of the five sectoral areas summarized in Chapter V and reported more fully in Annexes A - E. These efforts would be both more basic as well as applied, but are driven by the need to solve specific sectoral problems (the "Karnal Bunt" wheat blight, for example).

C. Time Horizon

The ten-year time horizon of this strategy is a relatively long-term horizon for typical planning purposes -- both for developing country governments and for donor agencies. Ten years is not a long time horizon for a great deal of scientific endeavor, however. A decade was chosen to convey a sense of continuity and a sufficient period of time to undertake and anticipate results from some more basic or "upstream" problem-oriented research. Ten years is short enough, however, to convey the imperative of development; i.e., the need to bring technologies that increase productivity and well-being to the majority in greatest need.

The ten-year time frame is best viewed as the time horizon for a program or strategic framework. Within this framework, it may well be possible to phase some of the specific research efforts -- particularly those at the more applied end of the spectrum -- into two-, three-, or five-year segments. Some of the sectoral research under this strategy could be brought to completion within shorter time frames. But this will not be true for all research topics. The appropriate time frame will vary from problem to problem and topic to topic.

While a decade should be sufficient to strengthen individual and institutional collaborative relationships between India and the United States, many of these relationships should continue beyond this time horizon.

II. Research and Technology Development in Indian Development

A. Historical Trends

India's research and technology development capacity was already considerable at the time of Independence in 1947. The predecessor organizations of the three principal research coordinating bodies - the Indian Council of Medical Research (ICMR), the Indian Council of Agricultural Research (ICAR), and the Council for Scientific and Industrial Research (CSIR) - had been established in 1911, 1929 and 1942, respectively. India had 20 universities at the time of Independence, and an estimated 20,000 engineering graduates and 66,000 science graduates.

The rapid expansion of this research capacity has been a major government objective from the beginning of the development planning process in 1950 although "science and technology" did not become the subject of its own section of the Plan until the Fifth Five-Year Plan period (1974-79). The number of universities rose to over 120 by 1980. Scientific and technical personnel in engineering, science, agriculture and medicine increased at about 10 percent annually from 1950 onwards, with the result that there are

now over 2 million Indians with graduate or postgraduate degrees in these four fields. According to estimates prepared by the private Center for Monitoring the Indian economy (CMIE), total expenditures on research and development (R&D) increased from abut $10 million, or about 0.05 percent of India's GNP in 1950-57, to nearly $1 billion, or about 0.63 percent of GNP in 1982-83 (as compared with, e.g., 2.5% in the U.S. as of 1976 or 1.9% in Japan as of 1978). Although the central government accounted for over 90 percent of R&D expenditures until the mid-1960's, the share of state governments rose to nearly 10 percent by the early 1980's, and the private sector's share rose to over 15 percent. The government actively used administrative controls to channel private sector R&D efforts, and maintained tight controls over technology imports in the interest of technological self-reliance.

India's investment in research and technology development has achieved a number of notable successes, particularly in adaptation and rapid dissemination of high-yielding cereal varieties (HYVs), development of a broad manufacturing base, expansion of manufactured exports, and establishment of substantial indigenous capacities in space technologies, atomic energy and the manufacture of sophisticated armaments. Nevertheless, the overall payoff in terms of economic growth, employment generation and improved human welfare has not been as great as might have been expected. In agriculture, while self-sufficiency in foodgrains has been largely achieved -- no mean accomplishment --, the increase in productivity growth after the mid-1960's was not adequate to offset the decline in the rate of

growth of area planted with the result that the combined growth rate of foodgrains and non-foodgrains production declined. In industry, a recent study by Isher Ahluwalia indicates that overall levels of productivity in most sectors actually declined over the period 1959-60 to 1978-79. Moreover, the industrial technologies introduced have generally been imported and have been adopted with little modification, and are consequently excessively capital-intensive. Research has made almost no contribution thus far to improving energy efficiencies or developing alternatives to conventional sources of energy; this is critical to overcoming a major constraint to economic growth. In the health field, India has relied almost entirely on imported technologies, and has not been able to make modern health care available to more than a small fraction of the population.

B. Current Situation

1. Policy Framework

Research and technology development is affected by a wide range of policies, including those specifically directed at science and technology issues as well as those designed to affect development more broadly. Program policies for GOI research and technology development efforts are stated in the Sixth Five-Year Plan. The plan directs deliberate and sustained applications of science and technology to the economic and social problems of the country. Policy emphases include self-reliance for science and technology; more effective links among policy organization and application of technology to meet economic and social objectives; more

attractive incentives for young scientific talent; and attention to higher payoff opportunities for technological breakthroughs.

The most important recent development has been the promulgation of a GOI Technology Policy Statement (January 1983), the first such statement since the GOI Scientific Policy Resolution of 1958. Its primary significance lies in the government's commitment to simplify procedures further for technology imports in "areas of high national priority." (Electronics and computers are two areas that have subsequently been identified.) This reflects the realization that the highly restrictive approach to technology imports of the past thirty years has had an adverse impact, particularly in industries with export potential. The statement implies a more outward-looking environment for research and technology development in all fields, and has set the stage for increased allocations to science and technology under the Seventh Five-Year Plan (1985-1990) being prepared.

With respect to the impact of overall policies, there is a sharp difference between the experience of the agricultural and industrial sectors. In agriculture, the shift toward a more producer-oriented pricing policy which accompanied the introduction of HYVs in the mid-1960's, along with increasing reliance on the private sector for input supplies, has encouraged the rapid adoption of HYVs and improved inputs. This has in turn generated further support for R&D effort in both the public and private sector. Thus the policy environment has provided strong reinforcement for development-oriented research and technology development in agriculture.

In industry, on the other hand, the emphasis on protection, controls and administered prices has reduced competitive pressures and fostered an environment within which there is little incentive to develop and adopt productivity-increasing technologies. The trend of the past three years toward liberalization of industrial and trade policies and the reduction of price distortions should gradually increase the pressures for more aggressive R&D efforts, but this will be a slow process. Nevertheless, overall policies affecting the industrial sector are clearly moving in the right direction.

2. Institutional and Human Resource Capacities

India's institutional infrastructure for research and technology development is impressive. In addition to some 120 universities, five institutes of technology, 150 engineering colleges and 100 medical schools, there are now about 130 specialized research laboratories and institutes under ICAR, ICMR, CSIR, etc., as well as over 600 in-house R&D organizations in private and public sector enterprises and over 150 engineering consultancy organizations. While many of these organizations already have international reputations, their rapid expansion has required that resources be spread very thinly, and has necessarily resulted in a good deal of unevenness. Some of the attendant problems in the relevant sectoral areas are discussed in Annexes A through E attached.

Although India is said to have the third largest pool of technical personnel in the world, UNESCO data cited by CMIE indicate that India is actually fifth behind the USSR, Japan, China and the U.S. Furthermore, the numbers are quite low relative to India's population of 730 million. However, the high unemployment rates among science graduates and the existence of unemployment among engineering graduates suggest that India is now training adequate numbers of scientific and technical personnel. It is more difficult to assess the adequacy of India's research and technology development manpower base in qualitative terms. The GOI Sixth Five-Year Plan notes the need for "a considerable reorientation and upgrading of a large proportion of this stock of manpower through appropriate training programs," and points to the impact of inadequate university science and technology facilities on the quality of science and technology graduates.

3. Budget Allocation Process

As noted above, resources for public sector research and technology development activities are now allocated on the basis of detailed plans prepared within the overall framework of the five-year plans. General guidance regarding priorities is provided by a Science Advisory Committee to the Cabinet (SACC), and by the Planning Commission member responsible for science and technology

(currently the former Secretary, Department of Science and Technology). In order to be approved by the GOI, all donor-assisted activities must be in accordance with Plan priorities and allocations, and must be budgeted in the GOI's Annual Plans.

The Sixth Five-Year Plan (1980-1985) budgeted about $1.9 billion (or somewhat more than 2 percent of the total) for development expenditures on science and technology for the Plan period, along with $1.45 billion in recurrent expenditures. The largest single development expenditure allocation was for ICAR ($340 million in development expenditures); the other major allocations were for atomic energy ($249 million), space ($246 million), CSIR ($170 million) and conventional alternative energy ($167 million). ICMR received only $40 million for the five-year period, and the Forest Research Institute (FRI) $12 million.

4. Application of Results to Development

As was pointed out by F. A. Long in his brief study of science and technology in India (in Mellor's India, A Rising Middle Power), there are distinguishable models of the linkage of R&D to development which have been applied in India: the "private enterprise model," under which firms develop in-house R&D capacity to meet their own requirements; the "agricultural model," in which public sector research and extension organizations generate and convey technical information to private sector producers, who

purchase the necessary inputs; the "vertically integrated government department" model, which integrates the R&D and "production" activities in one public sector establishment (as in atomic energy, space or defence); and the "independent government R&D establishment," which must provide its results to public or private sector users such as industrial corporations.

The "agricultural model" has worked relatively well, as indicated by India's success in assimilating HYVs. This system includes the state agricultural universities, which are organized on the U.S. "land grant" model combining research, education and extension. In the industrial sector, the "private enterprise model" has been relatively unimportant until recently, and the "vertically integrated government department" model has applied primarily (apart from atomic energy, space and defence) to a few heavy industries such as steel. Thus the main emphasis has been on the "independent government R&D establishment," such as the laboratories run by CSIR. It is inherently difficult to forge adequate linkages with users under this model and in fact India's experience with this model has not been encouraging. CSIR has encouraged the establishment of research associations for various industries to overcome some of these problems, but thus far these associations have played a fairly minor role. As of the mid-1970's, the average annual R&D expenditures per association (for the nine for which data were available) were only $300,000.

5. Role of Private Sector

As noted above, the private sector now accounts for about 15 percent of R&D expenditures. Since there is little funding of public sector R&D by private firms in India (or vice versa), it is probable that the private sector also carries out about 15 percent of R&D activities. This contrasts sharply with the US, where according to F. A. Long the private sector financed about 45 percent of R&D as of 1975 and performed about 70 percent. Similarly, in Japan the private sector financed 74 percent of R&D in the mid-1970's and carried out 66 percent of all R&D.

III. RESEARCH AND TECHNOLOGY DEVELOPMENT IN INDO-U.S. RELATIONS

A. Background

During the 1950's and 1960's U.S. official and private agencies played a major role in strengthening India's human and institutional base for research and technology development. Official assistance for these purposes was interrupted in the early 1970's with the suspension of AID Development Assistance programs in India after FY 1972, but Rockefeller and Ford Foundation activities continued. As of 1971, Rockefeller and Ford assistance had totaled about $20 million and $100 million, respectively. AID grants under the Indo-U.S. Technical Cooperation Agreement (1952) had been about $450 million, and had financed the services of over 3,000 U.S. specialists (long-term and short-term) and participant training in the U.S. for over 6,000 Indians.

The most noteworthy examples of AID support for research and technology development were several major institution-building activities: the establishment of eight agricultural universities on the U.S. model (with assistance from a consortium of six U.S. land grant universities); the expansion of the All-India Institute of Medical Sciences (AIIMS) with major U.S. technical and financial

assistance inputs; and the establishment of the Indian Institute of Technology (IIT) at Kanpur, with assistance from a consortium of nine U.S. universities. AID also provided smaller amounts of research-related assistance to several of the laboratories under the Council of Scientific and Industrial Research (CSIR), and to other institutes involved in forestry, home science, irrigation, veterinary, medical and nuclear research.

Research and technology development activities were also supported from the late 1950's onward by counterpart rupees made available to various domestic agencies of the U.S. Government. The U.S. Department of Agriculture (USDA), the National Institutes of Health (NIH), the National Science Foundation (NSF) and other agencies have funded large numbers of Indian research projects involving varying degrees of collaboration by the U.S. side. GOI approval of new rupee-funded projects generally ceased after 1971, but the programs were revived after the negotiation in 1974 of the Indo-U.S. Rupee Agreement and the establishment of an Indo-U.S. Joint Commission (whose subcommissions act as the joint administrative mechanism for agreement on priorities for the rupee-funded programs).

B. Current Status

1. Subcommissions

There are currently four subcommissions under the Indo-U.S. Joint Commission: Economic and Commercial, Education and Culture, Science and Technology and Agriculture. The Subcommission on Education and Culture has generally been the most active, and is the only one with a U.S. secretariat (the Asia Society). The Economic and Commercial subcommission has served primarily as a forum for official exchanges of views, and has no associated programs.

The Subcommission on Science and Technology was set up in 1975 and has held six meetings. At the last meeting in December 1981 representatives of twelve U.S. agencies met with their Indian counterparts to discuss approximately fifty rupee-funded projects in energy; physical sciences; health, medical and life sciences; environment and ecology; and information sciences. No date has as yet been set for the next meeting. The Subcommission on Agriculture held its first meeting in September 1980 and its second in June 1982 (in Washington). The U.S. side is chaired by USDA at the undersecretary level, and has working groups on agricultural research, agricultural inputs and natural resources development. The next meeting is scheduled for January 1984.

2. Rupee-Funded Research Programs

At the present time twelve U.S. Government agencies draw on the equivalent of about $9 million annually in Special Foreign Currency Appropriation (SFCA) rupees to fund joint projects. These funds can be used only for rupee costs such as local costs of the Indian institutions, per diem in India of U.S. visitors, and international travel. They cannot be used for items requiring dollar funding such as U.S. equipment or per diem in the U.S. of Indian visitors. The major U.S.G. users are the National Institute of Health (NIH), the National Science Foundation (NSF), and the U.S. Department of Agriculture (USDA). USDA is represented in New Delhi through the far Eastern Regional Research Office (FERRO), which has approved 500 research grants since 1960 (of which 67 are now active). Other agencies are represented by the Counsellor for Scientific and Technological Affairs in the Embassy.

3. Indo-U.S. S&T Initiative (STI)

The Indo-U.S. S&T Initiative ("STI" -- also known, especially in India, as the Senior Scientific Panel -- "SSP") is firmly under way. The concept was first broached during Prime Minister Gandhi's visit to Washington in August 1982. A "Blue Ribbon Panel" of top U.S. science officials subsequently visited India to refine areas of mutual interest. This was followed in January 1983 by a high level task force of U.S. scientists and science administrators

who met with a group of their Indian counterparts and subsequently mutually agreed on seven areas in which to bring together individual Indian and U.S. scientists working on the same or similar problems. The objective is to encourage collaborative research (the "collaboration" could range from coordinated individual research to virtual joint research) leading to results in two-year time frame. The areas chosen are: nitrogen fixation, nitrogen fertilizer efficiency, fuelwood production, monsoon prediction, a range of diseases and epidemiology, and immunologic responses in human reproduction.

On the U.S. side in New Delhi, the Science Counsellor's Officer in the Embassy is responsible for coordination. On the U.S. side in Washington, a Senior Policy Group has been established. It is chaired by Dr. George Keyworth, the Shile House Science Advisor, and includes Dr. Nyle C. Brady, Senior Assistant Administrator for Science and Technology of AID (as vice-chairman); Dr. Frank Press, President of the NAS; Dr. Edward Knapp, Director of the NSF; the Director of NIH; the Administrator of NOAA; the Administrator of the Agricultural Research Service and other senior officials. NSF is coordinating agent and NAS is performing an oversight and evaluation function.

AID has lead program responsibility on the U.S. side for nitrogen; the Forest Service for fuelwood; NSF for monsoon; and NIH for health and population.

Initial meetings of panels of Indian and U.S. scientists have been held or are about to be held in each of the areas. One exception is a proposed panel on photo-voltaics which grew out of an initial proposal on materials science. Pending further mutual clarification of the focus of this proposed panel, its fate is uncertain.

NSF has provided $2 million for FY 84 funding of the international travel expenses of U.S. researchers and the per diem expenses of Indian researchers in the U.S. (the international travel expenses of Indian researchers and the per diem expenses of U.S. researchers in India are covered by India). Costs for which the U.S. is responsible are to be met in FY 1985 by the various program agencies, including AID. Providing the GOI concurs, it is possible that some nitrogen, fuelwood and perhaps biomedical research costs under the STI could be supported from the bilateral program in FY 1985 and beyond.

4. AID Activities

There are currently three existing and two planned bilateral USAID/India projects that are entirely devoted to research and technology development. The first, the FY 1978 Technologies for the Rural Poor project ($2 million), supports seven small joint research activities in solar energy, mini-hydro development, nutritional blindness and malaria control. All subprojects were

developed under the S&T Subcommission, and all involve the joint use of AID dollars and SFCA rupees. The second, the FY 1982 Alternative Energy Resources Development project ($5 million), supports collaborative research and professional exchange in coal technologies, energy conservation, and biomass production and conversion. The third existing project, Agricultural Research ($20 million), was signed in late FY 1983. It is designed to support five to seven subprojects on research problems identified by the Agricultural Subcommission. Detailed agreement has been reached on the first two topics (Post-harvent Technologies and Soybean Utilization).

The two planned activities are the FY 1984 Biomedical Support for Health Services project ($10 million) and the FY 1985 Forestry Research, Education and Training project ($16 million). In addition, the FY 1983 Integrated Child Development Services (ICDS) project includes $1 million for research on the determinants of low birth weights, and the FY 1983 Family Planning Communications and Marketing project may be amended in FY 1984 or FY 1985 to include approximately $1 million for professional interchange related to contraceptive research.

IV. A TEN-YEAR STRATEGY FRAMEWORK

A. Objectives and Criteria

The objectives and criteria for a research and technology development strategy will be based upon GOI and USG program policies, and resource and management constraints.

Program policies for U.S. Development Assistance programs derive from the Foreign Assistance Act. Development Assistance programs require demonstrable economic and social development benefits, especially for low income families. This strategy proposal reflects conviction among AID's leadership that support for research and technology development is essential for sustained improvement of productivity and well-being of the poor. Consequently, AID is giving more systematic support to research and technology development. This strategy for India will also help pioneer approaches for other bilateral programs.

The issue of funding impinges upon operation of the R&TD program in two ways. The first and most obvious is the level of grant financing available for the program over and above the demands of the existing AID program. Careful determination of priorities and selection of topics, and judicious use of U.S. expertise will be necessary to stretch scarce grant resources far enough to mount a significant collaborative effort. Second, the programming approach for using the AID funds in R&TD activities should depart from the traditional donor-recipient relationship. The R&TD program is premised on collaboration between senior U.S. and Indian scientists, where both sides bring resources to bear on a problem of mutual interest and from which each side expects to draw benefit. AID must be prepared to deal with the implications of this different type of relationship in the way it programs funds and implements the resulting programs.

As noted in the Introduction, the proposed ten-year time frame for the R&TD strategy provides continuity and an adequate time horizon for longer-term development-oriented research efforts and institutional relationships. Individual research activities will often be of shorter duration. Indian scientists who establish the policy for and administer R&TD programs feel strongly that a joint program needs to show results to sustain financial support. Some Indian scientists feel the rather short two-year time frame for the STI program has introduced a useful discipline to define clear, achievable objectives. The definition of research efforts should permit measurable results within an agreed time frame as a basis for assessing performance.

AID management capacity in India is limited by constraints on staff size. It is obvious that AID cannot expect to manage an R&TD program in the conventional way it manages assistance projects. The R&TD program, by its design, will rely on joint management and substantial delegation of implementation responsibility to entities outside of the USAID Mission. The Mission's management energies can be most appropriately brought to bear on the design of R&TD activities and setting up a flexible framework for S&T exchange.

Considering these factors the following strategy objectives and criteria are proposed:

1. Impact: research results that when applied in India and other developing countries, promise:

   -- increased employment, productivity and incomes for the poor majority of the population;

   -- conservation and more efficient use of natural resources and energy;

   -- reduced infant mortality and/or fertility.

The set of areas for research, oriented to India's development problems, should be screened in terms of how the likely research results will change the development process. For example, choices of biomedical research areas should be based on the potential for reducing infant mortality and/or fertility. Some research areas under study through the Science and Technology Initiative would not be included in this program, i.e., filariasis and blindness. Similarly, some research projects supported by the Special Foreign Currency Program would not be included, e.g., leprosy, cancer, biofeedback, hepatitis. The procedures for selection of research topics and review of research results should be structured to permit screening in terms of the above impact criteria. The only exception to this principle might be some of the research supported under the "Innovative Research and Special Studies" program (discussed in Chapter VI) where it would be difficult to predict impacts with certainty although a range of possible impacts could be suggested.

2. Linked to Application: as noted in Chapter I, some of the research to be supported will be closer to the basic end of the spectrum than normally supported by AID, but will for the most part be driven by the need to solve a particular applied problem in a sector, such as increasing the yield of a given crop or developing a new vaccine. Only in the proposed "Innovative Research and Special Studies" program might research be supported at an even

more basic level where the field or fields of potential application cannot be predicted in advance. The bulk of the research to be supported in this strategy would, however, be expected to take the needs of users into account in research design. Application of research results would be expected as soon as possible, but not longer than ten years.

Operations research is also an important applied research tool. This includes research on the technology transfer or dissemination process itself. A powerful basic technology may be on the shelf for a number of years without being applied for want of a demonstration of its applicability or for lack of a cost-effective delivery system. For example, the basic technology for ORT (oral rehydration therapy) had been known for some time but not widely applied until the International Centre for Diarrheal Disease Research/Bangladesh, and its predecessor, the Cholera Research Laboratory, did additional applied research that both refined the basic technology and conclusively demonstrated its scientific principles and its applicability. Similarly, millions of Indian children have not yet received "DPT" injections, but additional resources devoted to operations research could lead to a more cost-effective delivery system capable of reaching those children. To take an example from agriculture, millions of additional Indian farmers might be reached with irrigation water if more resources were put into "action research" on alternative approaches to delivery systems and on-farm water management.

3. Mutual Participation and Quality of Research: India's science policy-makers observe that research capability has progressed much more rapidly than overall economic growth in India. The research establishment is a modern segment of the society linked to the international networks of scientists and research institutions. The challenge is to utilize this capacity more effectively, strengthening it where needed. As noted in Chapter II, however, Indian scientists and other observers caution against overestimating this capability by simply tallying up the number of research scientists and technologists in India. A large portion of the research establishment entered their professions during the past decade, when the opportunities for interaction with scientists in the developed countries were very limited (especially with U.S. scientists, as USAID funds for interaction dried up).

Indian scientists feel the need for more interaction. Nevertheless they recognize that many of their experienced scientists have world-class ability and many of the younger scientists have the potential to be in these ranks. They do not want to interact through a traditional assistance mode, with its implications that Indian scientists need to be developed. They know that they will function most productively as equal partners in joint research endeavors. They want full participation and mutual effort throughout the research process. Quality researchers and quality research are strong desiderata for both sides.

At the same time, Indian science administrators recognize there are weaknesses that require strengthening. The strategy therefore recommends support for selective training and commodities and equipment as well as professional interchange. And while well-established Indian institutions, such as the Department of Science and Technology and selected councils of research, institutes and universities, would be expected to assume major management responsibilities, the USAID Mission -- through the proposed Science Advisor and Science Panel as well as special studies and workshops -- will conduct a continuing review and dialogue with the GOI on the management of research.

4. Continuity: the current programs which foster interaction between Indian and U.S. scientists do not offer permanent support. The special Local Currency Program may expire in the next few years unless an endowment fund can be arranged. The Science and Technology Initiative is limited to a two-year period, although this program could be extended. Experience shows that continuous interaction requires continuous financial support. Neither the U.S. nor Indian science establishments have authorities or funds to foster interaction, because the interaction is not considered necessary for specific research results.

The ten-year time frame for the R&TD program proposed here can foster individual and institutional relationships for a new

generation of U.S. and Indian scientists. This interaction is an explicit objective of the USAID program, to accelerate scientific contributions to development in India by joining the efforts of U.S. and Indian scientists. Even so, the USAID program will eventually end. It should be possible to demonstrate the value of interaction to both U.S. and Indian science establishments leading to continuing and self-sustaining relationships.

5. Management Effectiveness: During the team's discussions, Indian science administrators requested that the proposed program be structured so that research results would be produced during the life of the program. They wanted to be able to measure the value of the research investments. They also urged that adequate procedures be established and resources provided for program monitoring and evaluation. The team agreed with the importance of these aids to management and stressed the importance of careful selection of research topics that can produce measurable benefits related to India's development problems. These management systems should be in the hands of experienced scientists who also understand the policy and management objectives. As noted above, the USAID Mission will conduct a continuing review and dialogue with the GOI on research management effectiveness.

6. Role of Social Science: Dr. O. P. Gautam, head of the Indian Council for Agricultural Research, eloquently described the relationship between research and applications of improved

technology on farmers' fields. He noted that the effectiveness of extension services would affect the rates of application, but he stressed the importance of developing technologies that were really appropriate to the farmers' needs. Dr. Menon, Member of the Planning Commission responsible for Science and Technology, stated the need for lower cost delivery systems to accelerate the utilization of research results. To ensure that appropriate technologies are developed and that there are affordable methods of delivery, researchers must take a broad approach to defining their research task, comprehending the economic and social dimensions of technology use. The team believes that social science should be harnessed to these problems, as part of development-oriented research efforts. Social science needs to be integrated into problem solving efforts.

The team found a relative lack of awareness and/or interest among some Indian science administrators about the opportunities for social science to make a contribution, not withstanding the existence of a number of social science research institutes throughout the country. There were some exceptions: for example, an active Agricultural Economics and Rural Sociology Department at Punjab Agricultural University that interacts with other departments; and an effective use of social scientists in the technology development work sponsored by the new GOI Department of Non-Conventional Energy.

Those instances where lack of enthusiasm was apparent may reflect concern about the involvement of foreigners in social science research. This is an area requiring sensitive encouragement by the Mission.

There are two challenges: (1) strengthening the social science components of existing research institutions and enhancing their integration with the work of other scientists; and (2) encouraging linkages (through workshops, contractual ties, etc.) between social science and other research institutions.

B. A "Research and Technology Development Strategy"

The following section outlines the main features of for a ten-year "Research and Technology Development Strategy" for the USAID program in India. This strategy would pursue the objectives and criteria set forth above. This section also discusses the rationale employed by the team in arriving at the recommended program mode after considering a range of factors and options.

1. Main Features

- Identification of a development-oriented research and technology development strategy as a hallmark of the U.S. Government's relationship with India for the next ten years. AID financing and the

Agency's mechanisms for gaining access to senior U.S. scientists will make the USAID Mission the key actor in promoting this strategy.

- Integration of an R&TD strategy with the current sectoral approach of the USAID program (e.g., agriculture, forestry, natural resources management, health, population, nutrition, etc.).

- Forum for discussing, with GOI science policymakers, R&TD opportunities related to mutually agreed problem areas within the sectors in which the USAID program is involved. This will provide the basis for establishing a more broadly-based science relationship which permits dialogue, exchange and application of the human and financial resources of both the U.S. and India to both macro "science-cum-development" and research management issues as well as specific field--oriented technological constraints.

- Recruitment of an advisory panel of eminent scientists and science administrators to lend institutional legitimacy to the broader set of science/development issues and to review performance of the overall strategy.

- Related professional interchange to enhance economic and systems analysis of research opportunities and to consider alternative approaches to research management.

- Facilitation of professional interchange and informal networks, especially across sectors and in areas where breakthroughs in technology are needed, e.g., in biotechnology and in social science applied to delivery of technology.

- Facilitation of U.S. researchers' participation on-site in Indian research and in strengthening research capability, primarily of relatively short-term duration, and through careful selection and rapid and simple procedures. Funding and arrangements would be handled through one of several alternatives, involving the USAID Mission, S&T Bureau and/or Asia Bureau (see Chapter VII for further discussion).

- Expansion of post doctoral professional exchange and selected graduate, post-doctoral and specialized technical training opportunities of varying duration related to research efforts.

- Funding for other research-related costs on a selective basis, such as laboratory equipment.

- A sharply expanded program of sectoral funding by AID for research and technology development, reaching over $16 million a year by FY 1985 and averaging almost $25 million a year between FY 1985 and FY 1988, if program budget levels are maintained.

- Mission oversight of the broad S&T framework by a JCC Scientific Advisor, a respected scientist and expert in science policy and administration.

2. Rationale

The team initially considered two broad alternative "modes" for the R&TD strategy. The first, or Alternative I, would essentially be a continuation of AID's current mode of operation in India. Alternative II would represent a major modification of AID's mode of operation and would be based on the establishment of an institutional locus of technical collaboration and professional interchange outside the AID Mission. This could take a number of forms, such as a foundation, an institute, a permanent secretariat to the Indo-U.S. Joint Commission, an in-country office for the

Indo-U.S. Science and Technology Initiative (STI), etc. Broadly speaking, under Alternative I the implementation of the research and technology development activities would be internal to the AID Mission, while coordination with other USG or private agencies on research collaboration or professional interchange would be an "external" matter for USAID, and the bulk of the GOI's contacts would be with AID as the USG's "donor agency" arm. Under Alternative II, on the other hand, implementation of the R&TD program would be "externalized" in terms of USAID's role, but much of the coordination of the program with other USG or private activities could be "internalized" by bringing them under one institutional umbrella. The bulk of the GOI's contacts under this alternative would be with a joint secretariat or foundation of some kind, which would give substance to the concept of a relationship of "mature collaboration" rather than that of "donor" and "recipient."

Alternatives I and II therefore differ with respect to the extent to which they meet the various objectives and criteria outlined above. The recommended alternative is an intermediate one, including some features of Alternative I and some of Alternative II. The factors which led to this recommendation are summarized in the chart below, which assigns a plus sign to the alternative which is more likely to meet various objectives and criteria more fully (and a minus sign otherwise):

	Alternative I	Recommendation	Alternative II
R&TD Program Emphasis	-	+	+
Joint Effort Likely to Endure Beyond the Program	-	0	+
Rapid Implementation	+	+	-
Opportunity for Policy Dialogue	-	+	+
USAID Management Burden	-	-	+
Coordination of USG Programs	-	-	+
Linkage to AID Programs	+	+	-

a. R&TD Strategic Emphasis: The current USAID program allocates a large portion, approximately 25%, for R&TD activities, including in irrigation and water management. The Agricultural Research Project is the most notable among the 16 active or proposed projects which include R&TD activities. Despite the existence of these activities, AID and the GOI have not highlighted their importance as a basic objective of the program. In the past, Agency policy emphasized the delivery of technology in bilateral programs, giving lower priority to investment in research and technology development. In a few countries with AID programs, such as India, there is well developed scientific capability to contribute better technology to the development effort.

The AID Mission in India, the Embassy, and Indian policy-makers, in both the science and economic development spheres, now wish to emphasize R&TD opportunities for AID's program. The emergence of this interest is timely, it builds upon the dialogue between Indian and U.S. scientists created by the Indo-U.S. subcommissions for Science and Technology and for Agriculture, and the Indo-U.S. Science and Technology Initiative guided by the Senior Scientific Panel. The Administration of AID and the leadership of the Asia Bureau and Science and Technology Bureau have requested this R&TD proposal.

In operational terms, emphasis on R&TD in the USAID program requires going beyond the current program mode in the following ways: a strategic framework for R&TD with a long-term commitment as a program priority, allocations of staff, increased attention by Mission management, project mechanisms tailored to the flexibility required for scientific endeavor, and a forum for discussing R&TD policy, and management and program issues with the GOI. The recom- mended mode can provide these requirements, with somewhat less visi- bility and attention than the institution embodied in Alternative II. Alternative I would only provide better project mechanisms.

b. Joint Effort Likely to Endure Beyond the Program:

During the past ten years there has been a gap in AID-supported exchange between U.S. and Indian scientists. During the fifties and sixties, many Indian scientists were trained in the U.S. and worked with U.S. scientists in India. Although institution building is no longer a primary objective, Indian and U.S. scientists still feel the need for interaction. The Special Local Currency Programs for agriculture and science and technology have enabled interaction; however, the funds have been insufficient for Indians to be trained in the U.S. and for U.S. scientists to work with their colleagues in India. The Science and Technology Initiative (STI) accelerated these efforts, but with limited funds and a tight two-year time period for research.

Alternative II envisages a joint Indo-U.S. R&TD institution or foundation that would manage a rupee endowment fund and AID Development Assistance funds. Such an institution could provide resources and mechanisms that would continue beyond the AID R&TD program proposed here. The recommended mode does not at the outset link AID's program to a new R&TD institution and, therefore, falls short of ensuring permanent mechanisms for scientific interaction. The recommended mode does strengthen Indo-U.S. scientific relationships, both personal and institutional, and harnesses them to economic development objectives. These relationships and experience with methods of interaction may endure beyond the AID program if other funds become available in the future, perhaps through an endowment fund and evolution toward a joint R&TD institution. The current effort initiated by the Ambassador to establish a scientific and cultural endowment fund composed of PL 480-generated rupees could well provide such an opportunity.

c. Rapid Implementation: All the scientists, Indian and U.S., associated with existing programs urge rapid, simple, responsive procedures. The major drawback to Alternative II is the time and effort needed to negotiate participation in an institutional mechanism outside the AID structure. The variety of mandates and modes of operation of the U.S. and Indian institutions which might be involved creates a challenging series of obstacles to agreement on the nature and functions of a comprehensive R&TD institution.

Implementation would likely be delayed for two years or more. The recommended mode involves more modest initial steps, with the implementation obstacles restricted primarily to internal AID systems.

From the team's viewpoint, a major obstacle to implementing any of the alternative modes is an AID mechanism to fund and to process requests for U.S. technical experts. Such a mechanism is likely to be seriously delayed if it must be channeled through the Indian budget review process; all bilateral funding is subject to such review, without exception. Several approaches to mitigating this problem are proposed in Chapter VII-B.

d. Coordination of USG Programs: Indian science administrators are perplexed by the relationship among the current U.S. initiatives in science and technology. Objectives, mechanisms, personalities, time frames, and funding levels differ among the U.S. programs. The Indians feel their own administrative structure is integrated and constant for all the programs; they would prefer a simpler structure on the U.S. side. At the same time, the leadership of DST feels the STI should be allowed to develop or mature before it is changed, or melded with other programs.

More effective coordination among the U.S. programs could have the following benefits: more coherent approaches to particular scientific or technical problems; more effective use of

existing, limited resources by pursuing broader or multiple objectives; less administrative burden on the Indians and less administrative cost for the U.S.; more effective, visible role for the U.S. in its scientific collaboration with India by joining the forces of the various programs. On the other hand, the complexities of differing authorities and procedures among USG agencies and the conflicts of different institutional viewpoints present a daunting challenge to those who would coordinate. Without an attractive drawing force, such as the establishment of an Indo-U.S. foundation or institute, any formal coordination is probably beyond the capability of USAID to encourage at this time.

e. Linkage to Other USAID Development Assistance Programs: The current relationship between USAID and Indian research institutions in particular sectors should not be undermined. Now that the difficult, protracted negotiations for an Agricultural Research Program are completed, the Mission has an effective, reasonably flexible vehicle to support agricultural R&TD over the time frame of this strategy. The USAID is developing a project for biomedical research which has direct links to application in primary health care systems at the State level. The new nutrition project includes research on the causes of low birth weight. A forestry research project is planned.

The overlay of a formal institutional framework which intervenes in the above mentioned project-supported R&TD programs could be detrimental to the Mission's R&TD effort. The recommended mode tries to preserve the integrity of arrangements for each of the sectoral programs, and to enhance the R&TD effort through: a complementary cross-sectoral program to be administered by DST; more opportunity for dialogue about R&TD policy and management issues; and timely provision of U.S. scientists to participate in the programs. The formal structure and authorities inherent in the separate institute or foundation proposed in Alternative II could risk detrimental intervention in the sectoral programs already underway.

f. Opportunities for Policy-Dialogue: The current USAID program does not provide an adequate basis for addressing problems or issues encountered by policy-makers concerned with research and technology development. The recommended mode proposes three bases for addressing such issues: a Science Panel of U. S. scientists and science administrators to advise the Mission on R&TD issues related to AID's program; a working relationship with the Department of Science and Technology (DST) which formulates S&T policy for and advises the Planning Commission, supports research on new technologies, and coordinates research throughout the public sector; and, finally, a project mechanism for innovative research and studies. Funds for studies by DST or the Planning Commission

could be used to examine alternative approaches to analysis of research investments and improved methods of research management and to assess benefits of research investments.

Under the recommended mode, the Science Panel would consist of a small number (3 to 5) of eminent U.S. scientists to beconvened by the USAID Director for internal AID program reviews. A more formal arrangement under Alternative II would be a joint Indo- U.S. Panel to review and discuss joint R&TD programs. This joint Panel might be given more authority in terms of recommending or determining budget allocations and research priorities; the recommended mode leaves these authorities with AID.

g. Management Burden for USAID: The recommended program mode probably places the greatest management load on the USAID Mission. An important relationship must be developed with the Department of Science and Technology. A science panel must be supported. An additional project, involving complex research programs and difficult policy studies, must be managed. An expanded volume of visits by U.S. scientists and graduate and post-doctoral training of Indian scientists must be administered. An enhanced AID role in R&TD must be orchestrated, involving interaction with science and development policy makers in India and the U.S. These tasks must be carried out at various levels, with heavy involvement of USAID executive staff. This management burden is the major drawback of the recommended mode. With Alternative II, much of this burden, not all of it, could be shifted outside the USAID to a new institution.

There are ways of reducing this burden under the recommended mode, including the use of JCC's, FSN staff and utilizing Indian consultants and consultancy firms that work closely with the Mission. These options are being actively pursued or explored by the Mission. However, the longer range answer to integrating the management requirements of an R&TD program lies in AID's ability to catalyze working relationships between Indian and U.S. universities, and between various government departments of both countries (e.g., NIH, USDA, Embassy Science Counsellor, NSF, etc., with relevant GOI counterparts) without taking a lead role in most instances.

Additional discussion of the above topics is found in Chapter VII, "Implementation Mechanisms."

V. SUMMARY OF SECTORAL COMPONENTS

The following sub-sections summarize longer analyses of each of five sectoral areas: agriculture; forestry and environment; energy; biomedical research; and industry. The complete analyses are contained in five annexes. These sectoral analyses were prepared by the sectoral specialists on the team: Dr. Anson Bertrand on agriculture; Dr. George Curlin on biomedical research; and Dr. Robert Ichord on forestry and environment, energy and industry/private sector.

Certain common features tend to emerge from these analyses. They comprise some of the main features of the overall strategy as described in Chapter IV: support for collaborative research and professional interchange; selected graduate, post-doctoral and specialized training; provision of critical research-related commodities; concern with relevance and application to major development problems; and establishing -- or re-establishing -- relationships between selected Indian and U.S. institutions or units of institutions (e.g., university departments). Some of these findings tend to vary from sector to sector. For example, institutions are relatively well-established in agriculture, so that institutional relationships and strengthening efforts would be more selective in this sector. In forestry, however, there could be significantly broader support for institutional development related to support for development-focused research.

An operational conclusion for USAID that emerges, particularly from the agriculture sectoral analysis, merits special attention. A long-term effort in collaborative research and technology development, characterized by continuity and commitment, requires a long-term, flexible support instrument. The team believes that the Agricultural Research Project (ARP) recently signed by the GOI and the U.S. has the potential for becoming such an instrument. The ARP envisions about six sub-projects to be mutually agreed on over time by the Indian implementing institution, the Indian Council for Agricultural Research (ICAR) and the USAID Mission in New Delhi. The team believes the ARP should be extended, with additional funding as warranted, as long as mutually desirable. The team would expect this time horizon to last ten years and perhaps longer. Reviews of performance involving Indian and U.S. scientists would occur at regular intervals over the life of the project. This approach has been mutually agreed to by ICAR and USAID for the ARP. The team believes such a procedure should obviate the need for new or amended ARP Project Papers, thus permitting GOI and Mission staff to give attention to the development and monitoring of workable frameworks within which R&TD collaboration, implemented by entities other than AID, can take place.

The team believes the ARP, as described above, could constitute a model to follow in other sectors. The proposed biomedical research and forestry research projects are obvious candidates for this approach. This approach is facilitated greatly if there is a central implementing institution on the Indian side, such as the ICAR.

A. Agriculture*

The continued stability and sustained improvement in the productivity and well-being of the Indian nation and its people are dependent upon continued development of Indian agriculture. Agriculture contributes over 40% of India's Gross Domestic Product, and food grains dominate, accounting for 70% of total crop production.

India's agricultural policies over the past thirty years have aimed at accelerating production, reaching self-reliance and enhancing equity. The first phase emphasized reforms in the institutional environment and changes in attitudes of farmers. Both objectives were partially achieved. The second phase of agricultural development in India began in 1965-66 with the development of a "new agricultural strategy" with the objective of rapidly increasing agricultural production and rural employment through the use of

*See Annex A for complete section on Agriculture.

largely externally derived technology including high-yielding varieties (HYVs), fertilizers and pesticides, as well as the expansion of irrigated area and the maintenance of adequate incentives to adopt the new technologies and expand production. At the same time India was making major efforts to enchance its agricultural education, research and technology development and transfer capability. This strategy paid handsomely and has permitted India to become largely self-sufficient in food grains. India has not had to resort to massive imports of food grains since the mid-70's (with the exception of about two million tons of wheat imported in 1981-82 -- and a lesser additional amount in 1983 -- to replenish stocks depleted during the 1979-80 drought).

Many analysts have concluded that prospects are good that India can reach its ambitious goals of about 4% annual growth if the GOI continues to give high priority to the agricultural sector and provides the necessary technical inputs and maintains agricultural markets that are attractive to farmers.

Because most of India's cultivable land is cropped, future growth in production must largely come from increased productivity (increases in production per unit of input). There is opportunity for increased productivity in most areas. With the exception of rice and wheat in the Punjab, crop yields in India are not on a par with many other areas of the world with similar soil and climate resources. The challenges and opportunities in the future appear to lie in closing the gap between predominant yields obtained in India and the biologic potential.

Research and technology development, linked to effective extension and other forces of technology diffusion, and complemented by sound pricing and marketing policies, must continue to play a leading role in Indian agricultural development. Carefully selected research and technology development and implementation activities offer unique opportunities for GOI and AID collaboration to accelerate agricultural development.

Identification of problems and selection of areas for specific collaboration in research is difficult because the spectrum is so broad and the needs so great. Emphasis must be placed on those areas of high importance to India's future food needs, keeping quality of the scientific effort in mind at all times.

Since India's agricultural universities and ICAR (Indian Council for Agricultural Research) institutes are mature and staffed, for the most part, with capable scientists, selected areas for future efforts should build on strength in science where a collaborative effort will have a high probability of making significant progress in solving constraints to production and utilization of agricultural produ

Regardless of the Mission management mechanism adopted, it is visualized that the pattern of R&TD activity in agriculture in India supported by AID will largely be implemented through a mode established by the existing Agricultural Research Project.

Opportunities for research in agriculture that will be mutually beneficial to India and the U.S. are numerous and it is anticipated that many of these collaborative research efforts will be launched during the next ten years. The need is great and the absorptive capacity is sufficient, given an adequate programming mechanism, to accommodate research activities during the next five years requiring at least $30 million in addition to the $20 million already allocated. In addition there is a great opportunity to strengthen the Indian agricultural universities and at the same time enrich the U.S. universities by development of a joint program to increase the capabilities of Indian agricultural universities. It is estimated that $15 million at a minimum could be effectively used for this purpose during the next five years.

Specific agricultural subject matter areas that appeared to merit increased R&TD effort and to present potential opportunities for Indo-U.S. scientific collaboration during the period 1983-1988, are:

1. Integrated plant nutrient management systems, to maximize efficiency and adequacy.
2. Management systems for lowland rice production including fertilizer efficiency and varietal improvement.
3. Biological nitrogen fixation.
4. Agroforestry research and development of silvi-food crop and silvi-pastoral systems for food, fodder and fuel.

5. Energy research in agriculture concentrating on alternative energy sources such as solar and wind.
6. On-farm water management including drainage and use of irrigation water.
7. Soil-water-crop management systems for rainfed agriculture.
8. Animal breeding including ova transplant and other techniques to accelerate animal improvement.
9. Bio-technology including cell and tissue culture and other techniques.
10. Disease and pest control for pulse and oilseed crops.
11. Weed control for both dry farming and irrigated areas.
12. Socio-economic studies in areas such as irrigation, farm-forestry and farming systems.
13. Small watershed management.

These areas are not presented in priority order and should be viewed as recommendations for subsequent GOI and USG discussion and review. If a decision is made to initiate and foster collaborative research efforts in these areas during the next five-to-ten years, the progress of Indian agriculture should be enhanced as each has been identified as a major constraint. While it is beyond the scope of this paper to justify each recommended area, one which does merit special attention is on-farm water management (no. 6).

Assuming that the high priority areas identified above will be addressed in the period 1983-1988, the period 1988-1993 will require continuation of most of them to pursue second and third generation problems. This will be necessary because much of the research is agro-ecological zone-specific, and the biological system is so dynamic that new challenges are presented constantly; i.e., plant breeding for resistance to diseases and insects is never done. Several additional research areas for 1988-1993 are suggested in Annex A below.

India's agricultural universities were developed with assistance from U.S. land grant universities and most are organizationally and functionally similar to land grant universities. This teaching-research-public service model should be perpetuated and strengthened in India's agricultural universities and at the same time specific programs in specific universities should be strengthened.

It is recommended that AID launch a major program aimed at strengthening the teaching-research and public service capacity of selected agricultural universities. Such a program might be funded for the next five years with provision for extended support if evaluation shows continuing needs and that the existing program has accomplished its objectives. Types of activities that might be included in this program are post-doctoral fellowships, support for

research to be conducted by an Indian scientist in a U.S. university, short-term educational visits to U.S. universities by Indian university administrators, purchase of equipment for research and other types of activities found to be needed to strengthen the agri- cultural universities.

The presence of ICRISAT (the International Crops Research Institute for the Semi-Arid Tropics) in India presents both opportunities and problems. Since AID is supporting twenty-five percent of the core program at ICRISAT, it behooves AID to ensure that ICRISAT's work is supportive of Indian development needs.

ICRISAT is working on crops of special significance to India: sorghum, millet, groundnuts and edible legumes. The breeding material and new varieties produced by ICRISAT are readily available and are moving quickly to Indian farmers through ICAR and the state extension programs. Research being conducted at ICRISAT in farming systems is less readily taken up by the extension system and the farmers for several reasons, the principal one of which appears to be the cost incurred by the farmer in making the transition from traditional methods of tillage, water management and cropping to the new improved system. There is a tendency for the All-India Coordinated Agricultural Research Project personnel to view the ICRISAT farming system for the vertisols (black soils) as merely a water harvesting technique instead of a farming system. Until the concept is sold as a farming system that will earn the farmer more

income and the credit system available to the farmer permits him to make the shift, adoption of the improved farming system will continue to lag.

The Director of ICAR is a Member of the Board of ICRISAT and is in a position to influence its program. It is recommended that the USAID work with both ICAR and ICRISAT to increase the dialogue between ICAR and ICRISAT.

B. Forestry and Environment*

Pressures on India's natural resource base are intensifying as the population moves towards the one billion mark and as agriculture and industrial development demands larger volumes of land. energy and raw materials. The result is a rapid deterioration of India's forest, soil and water resources. Of central concern is the process of deforestation and land degradation that threatens gains in agricultural production and poses a major future constraint to achieving the projected minimum requirement of 225 million tons of food production by 2000. The Indian Ministry of Agriculture estimates that 175 million hectares of agricultural and non-agricultural lands are suffering degradation from various causes: ; serious

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*See Annex B for complete section on Forestry and Environment.

water and wind erosion, waterlogging, salinity and shifting cultivation. The growing fuelwood crisis and the diversion of organic residues and dung to energy uses will further the nutrient drain and soil erosion processes.

The GOI has launched sizable social forestry programs in most states and has recently moved to create 12 biosphere reserves to supply wood needs, protect watersheds and preserve biological diversity. On the research side, the GOI is in the process of formulating national research programs in the forestry and environmental areas. A World Bank/USAID/ODA Sector Team has recently recommended a substantial program to strengthen forestry research, education and extension and has recommended five broad areas for research:

(1) fuelwood biomass research;

(2) fodder trees;

(3) watershed land use management;

(4) forest product utilization;

(5) wood-based energy technologies.

Some forestry and environmental research is underway at the FRI (Forest Research Institute at Dehra Dun); CSIR (Council for Scientific & Industrial Research); institutions such as the National Botanical Research Institute and the National Chemical Laboratory; ICAR (Indian Council for Agricultural Research), the Central Grasslands and Fodder Research Institute in Jhansi, the Central

Soil and Water Conservation Research and Training Institute, the Central Arid Zone Research Institute, and the National Institute for Agricultural Research; and other institutions, e.g., Madurai Kamraj University. AID is currently providing about $4 million in research for forestry under energy and social forestry projects and provision is made in the Agricultural Research project for forestry research. India recognizes its need to strengthen research and technical capabilities in the forestry and environmental areas. AID has a unique opportunity to make a critical input at the formative stage of a national program for building a national capacity, similar to our contribution in the agricultural area.

The team recommends a long-term R&TD program emphasizing the role of trees and grasses in reversing ecological deterioration and expanding rural incomes. The sectoral program would have three major elements:

(1) Baseline environmental research on the nature, determinants and consequences of land, forest and water degradation.

(2) Early results-oriented research in short-rotation and multi-purpose trees (fuelwood, construction materials, medicinal products, fruits and nuts, nitrogen fixation, etc.), including species identification and trials, agroforestry and silvi-pasture potential, yields of minor forest products, soil nutrient balances,

preferences and impacts on the poor and landless for different trees and afforestation schemes, nursery techniques, and selection and mass propogation of genetically superior trees.

(3) A more basic but modest research effort aimed at genetic improvement of trees through the creation of new hybrids for clonal propogation.

The establishment of an Indian Council on Forestry Research, as is being considered by the GOI, including ICAR, CSIR, FRI, and the Department of Environment, if widely endorsed and implemented, would provide a framework for the development of an umbrella research project similar to the current agricultural research project with ICAR. Such a project should be linked to the new joint program in forestry and bioresources being developed by the Asia Bureau and the S&T Bureau.

An FY 85 project of $40-60 million over ten years may be attainable.

C. Energy*

Energy is a vital input to agricultural and industrial development; per capita GNP is closely correlated with per capita

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*See Annex C for complete section on Energy.

commercial energy use. If India is to achieve by 2000 the same GNP per capita as in Thailand in 1980 ($670), it will need to increase its commercial energy consumption from 105 million tons of oil equivalent (TOE) to 250 million TOE. This prospect represents a formidable task. But new oil and gas discoveries hold promise of significant reductions in oil import dependence.

India remains over 50% dependent on traditional or "non-commercial" energy. Price increases for commercial fuels have put these fuels out of the reach of the lower income groups and population pressures and shortages of fuelwood have pushed up fuelwood prices in urban markets. The poor have increasingly been forced to use dung and agricultural residues.

GOI policies give high priority to energy and close to 40% of India's budget expenditures are for energy, fuelwood, and related fertilizer and transportation. Nevertheless, shortages of power are occurring in virtually every state and are seriously affecting industrial and agricultural output.

The GOI supports a broad-based program of R&D in the energy sector with a general emphasis on:

- improvement and adaptation of existing technologies with emphasis on conservation;
- development of more efficient technologies for utilizing indigenous conventional sources of energy;
- development of renewable energy technologies.

Areas for research and technology that are key for meeting both centralized and decentralized development needs are coal and biomass. India has the largest coal resources in the developing world with over 100 billion tons of probable reserves. The coal is, however, of poor quality and India is keenly interested in technologies for the benefication, transport, and utilization of high ash coal. R&D on biomass production and conversion is also of high priority and Prime Minister Gandhi stressed R&D on biotechnology at the recent World Energy Conference in New Delhi.

Competent research and development programs in new coal technologies exist at Bharat Heavy Electricals, the Central Fuels Research Institute and the Regional Research Laboratory at Hyderabad. In biomass conversion, IIT Delhi, the National Chemical Laboratory, and Jyoti Ltd., a private company, are carrying out substantial programs on combustion, gasification and liquefication of woody and non-woody biomass.

USAID has an Alternative Energy project that is promoting collaborative research and professional exchange in coal and biomass with these institutions. Research activities are being developed in fluidized bed combustion, coal and biomass gasification, coal mixtures, and coal benefication. The U.S. technical manager for the program is the Pittsburgh Energy Technology Center of the Department of Energy. Substantial U.S. private company involvement is anticipated.

If this new activity proves effective, plans for a larger and longer-term (i.e., seven year) follow-on project in FY 86 should be pursued. A reasonable cost estimate for a ten year program of collaborative research and professional exchange is $15-25 million.

D. Biomedical Research*

Biomedical research in India is a vigorous field. Although the biomedical research field is relatively small, it is of relatively high quality. Good coordination exists between the established medical research programs undertaken through the Indian Council of Medical Research (ICMR) and the newer DST (Department of Science and Technology) research programs. The overall amount of GOI support available for R&TD is said to be adequate, although availability of funds may limit the acceleration of development-oriented biomedical research. The ICMR budget is apparently better funded than the DST budget because it is an older, more well-known program.

The DST list of priorities is so basic that the question of relevance to development is difficult to assess. Many of the diseases are not major killers of children. The best insurance for

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*See Annex D for complete section on Biomedical Research.

agreement on the areas for health research is a careful, iterative process involving development and technical experts. In the National Biotechnology Board of DST, the initial priority-setting process was a lengthy (five year) exercise which effectively reached a consensus and involved a large number of groups. There appears to be widespread support in the biomedical research community for the DST list of priorities for biotechnology.

Policy appears to encourage broadly the acquisition of foreign technology in the biomedical research area as in other areas. Foreign exchange will reportedly be made available to acquire the technology. However, there is a lack of coordination between the relevant GOI administrative units and actual operations. For instance, customs is seldom persuaded to facilitate import of even short-lived biomedical reagents. An active private sector in research reagents and supplies would greatly enhance development of useful technologies.

There are several excellent biomedical research professionals in India. Most work alone; there are few relatively larger concentrations of professionals although there appears to be fairly good communication between investigators. Facilities are adequate but certainly not lavish. For example, equipment appears to be adequate at best. There is every indication that productivity cannot increase dramatically in most productive laboratories without additional, improved equipment.

Training is one area in which there was virtual consensus. All of the Indian investigators mentioned the need for greater access to short to mid-term training or visiting scientist opportunities for themselves and their younger colleagues. Most mentioned post-doctoral, non-degree training as a need.

In summary, key features of the Indian biomedical research field are:

-- Success is associated with a few bright and productive individuals who are located in a variety of laboratories.

-- There are few concentrations of productive investigators; groups are rare.

-- A few are acknowledged researchers in the U.S. and elsewhere; they are part of a network.

-- By and large, the acknowledged leaders are not active in areas to be considered of top priority from a development perspective.

-- Historically, support has come from the ICMR programs; indeed, many of the leaders in biomedical research work in the ICMR network of laboratories.

-- With the exception of the All India Institute of Medical Science, the Christian Medical College at Vellore, the Post-Graduate Institute at Chandigarh and a few others, produc- tive biomedical researchers are not associated with medical colleges.

-- Funding is only one of several potential constraints, and it is probably not the most serious one.

-- Indian biomedical researchers cherish the thought of true collaboration with U.S. investigators with whom they are familiar.

-- There is a felt need for younger members of the research staff to train at the post-doctoral level in the laboratories of U.S. scientist-collaborators.

With these points in mind, the possibilities for activities and estimated budget levels are as follows:

AID support to biomedical research in India should be disease-oriented and based on the priorities of the Government of India with which AID priorities are congruent. Shared overall objectives to be achieved are: reductions in infant, child and maternal mortality; in fertility; and in morbidity of the labor force. Major biomedical research subjects that constrain achievement of these objectives are, in order of priority: respiratory diseases including tuberculosis; diarrheal and enteric diseases including typhoid; reproductive immunology and the immunizable diseases; and nutritional anemia.

The support of priority disease-based research will encompass research on diagnostic techniques, treatment modalities and the

development of improved or new vaccines. Thus, biotechnical research with particular emphasis on biochemistry and genetic engineering in the expanding hybirdoma technology for identification of antigens and antibodies are basic. The use of these newly derived antigens and antibodies for rapid diagnostic techniques will lead to the next level of research to be supported, the field trials. Field trials of diagnostic techniques discovering morbidity patterns should lead to additional research into treatment modalities. This applied research activity needs constant support of bench laboratory research to disclose new drugs and new vaccines. The field trials research should enable bench research to modify advanced diagnostic techniques to the point of making available simple, rapid diagnostic techniques which do not depend upon microscopes and expensive equipment for use in primary health centers. The support of biomedical research must be comprehensive, from the bench to health services.

The tools for biomedical research must be strengthened. First in priority is the training of junior level researchers and of laboratory technicians through the collaboration of the American and Indian scientific communities. The Indian community should be enabled to take full advantage of the numerous American laboratories (university, NIH, private institutions) that are vigorous in the hybridoma/recombinant D&A-genetic engineering-antigen-antibody complex. The return visits of American investigators and lab technicians to Indian laboratories for planning conferences and for scientific councils and seminars should be facilitated.

Beyond training, the essential tools of equipment and reagents must be made available initially by access through foreign exchange but ultimately by the support of local production. Doubtless, local production will spontaneously surface with the increase in demand that should result from extensive training.

The final tool to be emphasized is that of data processing and management information systems; data processing, so essential to extensive bench laboratory work, and management information systems, so essential in field trials and applied research for health services. Management information systems constitute an important link between biomedical research and effective application through health services.

The approaches outlined above would require about $1.5-2.0 million a year in AID funding over a ten year period to fund 15-20 investigators. Additional funds would be needed for training expenses, workshops of collaborators, and selected equipment and specialized supplies.

E. Industry/Private Sector*

Sustained industrial growth is vital for India if the standard of living of its massive population is to rise in the coming decades. Yet the average annual rate of increase in the index of value added from the industrial sector has declined from 6.4% in the 1950's to 5.8% in the 1960's to 4.9% in the 1970's. The industrial sector provided only 25% of GDP in 1982.

The Sixth Five-Year Plan recognizes the importance of technology to industrial development. India has placed heavy emphasis on self-reliance in science and technology and the January 1983 "Technology Policy Statement" sets out basic principles that permit only selective import of technology and related foreign investment.

At the center of regulatory decision-making on technology imports is the Director General for Technology Development (DGTD) in the Ministry of Commerce. This office of over 700 technical staff examines proposed investment projects and technology licensing/R&D arrangements from the standpoint of (1) the economic impact of the investment; (2) the foreign exchange requirements; and (3) the

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*See Annex E for complete section on Industry/Private Sector.

availability and comparative quality of domestic technology. Major cases or disputes over the third point are reviewed by the technology Evaluation Committee, composed of DGTD, the Department of Science and Technology, the Council for Scientific and Industrial Research, the National Research and Development Corporation and sometimes outside experts. Neither private industry nor public industry is formally represented on the TEC.

Total expenditures on industrial R&D by public and private groups totaled Rs. 1,937.6 million (about $194 million) in 1980-81, with the private sector accounting for about 55% of the total. Private sector R&D expenditures were concentrated in chemicals, electrical equipment, drugs and pharmaceuticals. In the public sector, the Council of Scientific and Industrial Research plays a key role in R&D, commanding 18% of Central Government R&D resources in 1980-81. CSIR has 38 laboratories, 100 extension centers and regional stations, 4,300 scientists and 10,000 support technicians. It represents a powerful interest group in support of technological self-reliance. CSIR in general tends to be viewed by private industry as ineffective and sometimes as an obstacle to obtaining superior foreign technology. This generalization does not hold, however, for several CSIR institutes that have good reputations, such as the National Chemical Laboratory and the Central Fuels Research Institute.

Several large coprorations in India, such as BHEL in the public sector, and Jyoti Ltd. and Tata Research in the private sector, carry out considerable R&D in the energy, electrical and transportation areas. Industry research institutes, such as in the U.S., are limited in number and capability. The largest ones are in textiles, tea, jute and wool. The Association of Indian Engineering Industries (AIEI) with its 1,617 members has an active R&D committee. USAID is beginning a project that includes work with AIEI in energy conservation.

India has paid a tremendous price for its policy of technological self-reliance. It is beginning to realize this fact more sharply as advances in countries such as the U.S. and Japan in electronics and computers widen the productivity gap even further. Although the number of licensing agreements has increased in recent years, many constraints exist to increased technology imports and a larger, more effective industrial R&D effort. Important barriers include: (1) the protective, sometimes monopolistic economic environment; (2) the low returns to investment due to government price controls; (3) the unreliability of power and infrastructure bottlenecks; (4) the small size of most Indian companies; (5) non-restrictive licensing provisions; (6) the low ceiling on allowable licensing fees; (7) some feeling that duration of patent protection (as short as three-to-seven years) limits R&D investment; and (8) the prohibition against majority foreign ownership.

The basic conclusion of this general overview is that India needs to institute policy changes to allow easier access to imported technology and to create a more effective infrastructure for the adoption of imported technology. A U.S. program approach to support these objectives would focus on: (a) identifying the research and technology needed to improve productivity and requisite policy reforms to promote their adoption at both the macro and specific industry level; (b) improving capacity to manage technological innovation and R&D at the firm and plant level; (c) improving R&D development capabilities in the private A&E (Architectural and Engineering) community; and (d) reform and rationalization of the CSIR system so it is more responsive to industry needs. (Prime Minister Gandhi recently ordered a review of the CSIR system.)

Two areas of possible concentration in this regard are energy conservation and industrial pollution. U.S. companies may be interested in tie-ups with Indian private companies for R&D and technology transfer. A program in the management of technological innovation might also be pursued through AIEI. A program of $5-10 million is recommended.

These options could be linked to, or combined with, current proposals to establish a revolving fund of PL 480-generated local currencies in the form of a bilateral industrial research and development foundation or a similar mechanism.

VI. INNOVATIVE RESEARCH AND SPECIAL STUDIES

In addition to sectorally-oriented research, this strategy proposes a program of "innovative research and special studies." The program would have two components: (1) support for collaborative research on a limited number of fundamental, cross-sectoral topics and (2) a program of workshops and conferences dealing with broader, policy-oriented science and technology issues.

In the first component, research and professional interchange with U.S. scientists working in the same areas would be supported for a limited number of defined topics agreed to by AID and the GOI. Research support in these areas could be provided through a competitive research grants mechanism along the lines of that employed by the U.S. National Science Foundation (NSF). The following kinds of topics were suggested as possibilities:

- genetic engineering of a more basic character;
- surface and membrane phenomena (plant nutrient and therapeutic agent absorption -- by animals and humans --, and desalinization technology are examples);
- strength and fibre properties of different forms of biomass (wood types, textiles, thatch, etc.); and
- photosynthesis.

The multi-sectoral aspects and potential applications are perhaps most easily envisioned for genetic engineering, which has potential applications in animal and human health, crop production, forestry, energy and certain biological-industrial processes. The GOI National Biotechnology Board, serviced by the Department of Science and Technology (DST), might serve as a mechanism to facilitate the development of a network of Indian research institutions with capabilities in genetic engineering as well as to coordinate professional interchange with U.S. scientists working in this area.* This would facilitate the cross-sectoral and disci- plinary interchange that is highly desirable in this field.

A new center for certain elements of biotechnology research is in the process of being established at Chandigarh. The team has heard concern expressed that this, or other new biotechnology centers, would deprive existing institutions of the best people working in this area. For this reason the team prefers that USAID provide support for a network approach rather than encourage establishment of additional centers.

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*See the brochure issued by the DST, "National Biotechnology Board and Its Committees" (New Delhi: Technology Bhavan, April 1983) for further information on the Board.

The second component of this program envisions a number of small efforts, such as seminars, workshops, studies and consultants, dealing with policy-related, cross-sectoral topics related to science and technology and development. Recommended topics include:

-- economics of technological change and resource allocation to research;

-- socio-economic analysis of the cost-effectiveness of alternative technology delivery systems;

-- alternative approaches to improved research management; and

-- enhancing the role of the private sector in development-oriented research, including improved linkages to public sector research institutions.

A possible third component would be support for enhancing the exchange of development-related scientific and technical information. The team did not have an opportunity to investigate this topic beyond observing that such U.S. resources as the U.S. National Agricultural Library might be more effectively linked to the libraries of Indian agricultural research institutes and universities. A related topic that could be explored through conferences or workshops is technologies for development information and analysis, including applications of microcomputers. A development information activity limited to agriculture could be supported through an Agricultural Research or Agricultural Universities project.

The resources required for support of innovative research and related studies would be relatively modest. Support for basic research of a more generic rather than sectorally-oriented nature, would be a departure for an AID bilateral country program. Such research is closer to that supported centrally by the AID Science Advisor's Office or by the U.S. National Science Foundation and National Institutes of Health. In the Indian context, however, a bilateral program of this nature could provide a mechanism for policy dialogue with the GOI on significant science and technology issues.

VII. IMPLEMENTATION MECHANISMS

The strategy features outlined in Chapter IV can be implemented through the following mechanisms: sectoral programs such as the Agricultural Research Project which can be extended over the ten-year time frame; a funding mechanism for providing U.S. scientists; a modest Innovative Research and Special Studies project; and an advisory panel to the USAID of eminent scientists. These mechanisms pose two issues which must be resolved by AID if the recommended approach is to be successful: (1) requirements for sufficient USAID grant funds for U.S. technical experts; and (2) requirements for adequate staff in USAID New Delhi to manage the R&TD program.

A. Sectoral R&TD Programs

The recommended strategy implies a primary role for sectoral research. Each sector has different needs and institutional capabilities. The Mission has valuable relationships with sectoral agencies. The team concluded that direct separate programs would help respond to the different situations and would strengthen these relationships. The alternative, channeling funds for all R&TD activities through a central agency like DST, would reduce the management burden on the Mission. However, DST is not organized or staffed for such a role. Even if it were, such an arrangement could well undermine the effectiveness of sectoral programs.

The Agricultural Research Project with the Indian Council for Agricultural Research (ICAR) is now underway. Preparation of this project took five years of discussions with the ICAR beginning in 1978. A sound, strong relationship has developed between USAID and ICAR's leadership. The project provides a structure for joint determination of research priorities and for regular reviews of performance, as well as a flexible instrument for funding. This arrangement could be extended for the duration of an R&TD program strategy.

For health, population and nutrition research, the Mission has had good working relationships with the Indian Council for Medical Research (ICMR). The recently approved Integrated Child Development Services (ICDS) Project finances research through ICMR on the causes of low birth weight. The proposed Biomedical Support of Health Services Project may establish a funding arrangement which can be used for the duration of an R&TD program. The project will link research to application in primary health care systems. More investigation is needed to determine whether there are opportunities for AID support for contraceptive research.

For forestry research, the recent multi-donor review with the GOI produced recommendations to establish an Indian Council on Forestry Research and Education. As part of a broader effort to develop forestry research, training and extension, the R&TD program could finance activities through the proposed ICFRE. For energy and

industry, sectoral projects might work with the Ministry of Energy, the Department of Non-conventional Energy, selected CSIR laboratories and/or universities and industrial enterprises.

These sectoral programs would finance the conduct of research in India, related short-term professional interchange, training of Indian scientists in the U.S. and scientific equipment.

B. Provision of U.S. Scientists

Throughout the Indian research establishments visited by the team, scientists expressed interest in working directly with U.S. scientists in the U.S. and India. Participation by U.S. scientists in India was generally envisioned as being on a relatively short-term, non-resident basis. There is consensus in India that long-term resident advisors were valuable during the era when Indian institutions, such as the agricultural universities, were being established, but that era has passed. Resident advisors are too expensive and too visible to be accepted easily in India now.

By Indian law, all components of foreign donor financed aid programs must be incorporated into the development plan of the Government of India. This was done to bring the various donor programs under control and to assure that each contributed to achievement of development plan objectives. The effect is to require that every unit of foreign currency spent on development

assistance for India be accounted for within the Indian budget process. In other words, equivalent rupees must be appropriated by Parliament totaling the value of each foreign aided project. Administratively, this requirement brings budgetary discipline to the technical ministries responsible for various aid programs. A very difficult set of obstacles is created, however, in the case of financing for expatriate technical assistance. The average cost for a work-year of expatriate assistance now approaches $200,000. Acquired through an institutional contract which includes stateside support, this figure can reach $250,000. A project technician in, for example, the Ministry of Health or the Ministry of Agriculture, must justify devoting the rupee equivalent of this sum from within the Ministry's established budget and in so doing must certify that the skills to be imported are not available from Indian sources at a fraction of the cost. National sensitivities are exacerbated by this requirement, and the provision of technical expertise which would otherwise be sought eagerly is constrained by patriotic as well as fiscal considerations.

At the same time, Indian scientists and policy-makers stress their need for high quality U.S. scientists, who clearly have something to offer the already well-qualified Indian scientists in joint research efforts. The USAID Mission feels strongly that special efforts and perhaps special arrangements will be needed to identify and to attract high quality U.S. scientists to this program. The

Indians are hoping that the very nature of the research opportunities in this program will attract America's best scientists. The high quality of U.S. investigators recruited for the low birth weight research program gives confidence that this quality standard can be achieved.

It is imperative to the success of this strategy that some arrangement or mechanism be devised to permit selection of qualified U.S. scientists that match with Indian needs and to provide them in a timely manner. Failure to do this will ensure failure of the strategy.

There are several alternative approaches that might be pursued. An option that is attractive to Indian officials -- and was in fact proposed by several -- is to furnish technical assistance and experts from AID Washington. The cost of such assistance would not show up in the bilateral country program and therefore would not be part of the GOI development budget. From the GOI perspective this would be assistance "in-kind." In fact, the UNDP furnishes expatriate assistance in this manner. Under the UNDP arrangement, requests for specific experts or commodities are made by GOI line agencies and channelled through the New Delhi UNDP Resident Representative to New York headquarters where physical and financial arrangements are secured. If AID were to adopt this approach, a portion of the bilateral program budget would be transferred to the S&T Bureau and/or Asia Bureau for the provision of U.S. scientists in response to requests from USAID and the GOI.

A problem with this approach is that even though the impact is still in India, in budgetary terms the India program looks as though it is being reduced and a Washington account increased. Also, it may be necessary to include in the Washington account all technical assistance in the India program, not just that related to research and technology development.

Before the above approach is considered further, an approach that would represent a major departure for AID, the team recommends seeking at relatively high levels in the GOI approval for expeditious provision of U.S. scientists from the resources of the country bilateral program. Two main points to be established are that: (1) both sides recognize that the timely provision of qualified U.S. scientists is essential to the success of the proposed R&TD strategy; and (2) the bulk of such expertise would be of a relatively short-term nature -- less than three months. High-level agreement on these principles could be communicated to relevant GOI line ministries, thereby facilitating the provision of U.S. scientists. The selective provision of long-term experts might still be a stumbling block -- and is in fact subject to delays even through the UNDP -- but may, if the above principles are accepted, constitute a smaller problem that it does now. A variant of the above approach that might expedite the provision of technical assistance would be to separate this element out from all bilateral projects into a separate, bilateral "technical support" project.

The team recommends that the above concerns and proposals be raised at high levels with the GOI (e.g., the Prime Minister's Office) at the earliest opportunity.

If further efforts to resolve the problem within the bilateral country program are not successful, then the team would recommend serious exploration of the AID-Washington approach. Two alternative implementing mechanisms might be considered: (1) adding increments of funds to the wide range of S&T Bureau projects already set up to provide field services, or (2) setting up a separate project to provide India and other countries with U.S. scientists for R&TD programs. A combination of the two may be desirable. Use of existing S&T Bureau projects would be the easiest method, but the choice of scientists and institutions may sometimes be too restricted, and the separate purposes of the USAID R&TD program and the existing S&T Bureau projects may not always adequately converge. A new, separate project for R&TD program services would take some special effort to establish quickly, but would offer the opportunity to hire an intermediary agency to recruit and screen scientists. Such an arrangement would relieve AID staff of an onerous continuing burden, and could create an entity in the U.S. to focus on India's needs.

C. Innovative Research and Special Studies Project

The program of innovative research and special studies described in Chapter VI would be financed through a project under the direction of the Department of Science and Technology. In addition to the support of research, the project would also provide a means of financing small efforts -- seminars, workshops, studies, consultants -- useful to DST and the Planning Commission in fulfilling their broad role of oversight of Indian science and technology. For example, DST is currently formulating the science and technology elements of the Seventh Five-Year Plan. On a continuing basis, DST advises the Planning Commission and the Prime Minister's office on S&T matters. In developing a PID, the Mission and DST will have to develop a better understanding of the nature of the innovative research to be supported, especially in terms of the relationship to development problems. It is premature to put a price tag on this type of activity, since the terms of its authorization will likely evolve over time. Resources should be proposed initially that are sufficient to demonstrate tangible results from support of work on science policy problems and on innovative research.

D. Science Panel

The team recommends that a small group (4-5) of eminent scientists and science administrators be convened regularly by the Mission to advise the Director, the Mission Scientific Advisor and

other senior staff on the scope, content and progress of the strategy. The purposes are: to obtain the assessments of experienced scientists, who also know India and understand development, on the performance of the total program; to provide some stimulus for implementation; and to provide another informal means of communication with Indian policy-makers. The scientists should be well-respected by both scientists and development experts in India and the United States; they should commit themselves to periodic meetings, perhaps semi-annually at the outset, over a span of several years; they should represent a mix of disciplines including social science, research management and economic analysis of research investments. The Mission will need to define clearly the terms of reference for the panel before the Agency could consider candidates.

E. Grant Funding Constraints

Since the reopening of the AID program in India in 1978, the grant component of each year's development assistance budget has grown from an average of 10% annually in FY 1978-FY 1981 to 28% in FY 1983. This increased importance of the grant component in USAID-India's portfolio reflects a greater emphasis on technology transfer, institution building, policy dialogue and private sector initiatives. As their activities in these areas increase, the Mission

is requesting with increasing urgency that even greater proportions of grant funding be permitted. Traditionally, loan funding has been used for financing construction, imported procurement, recurrent costs and similar items; grant financing has been reserved for technical assistance, training, research and experimental or pilot activities.

Chapter VII projects annual funding levels, sector-by-sector, for an R&TD strategy through FY 1988. The Mission's existing portfolio and grant constraints were taken into account in making these projections. These estimates assumed that some portion of R&TD activities would be loan-financed. This implies that the Mission will need to redefine with the GOI the types of project components which may be grant financed (e.g., some training and research costs, and locally procured TA as well as any provision of commodities, equipment or construction costs). This may be both feasible and desirable as well as necessary. To the extent, however, that the Mission pushes to expand loan-financing of R&TD activities early in the implementation of strategy in each of the sectors, it may reduce the important leverage that grant financing provides to introduce U.S. scientist collaboration and to test new approaches to implementation.

F. Mission Management and Staffing

The pattern of USAID/India's current staffing was set in 1978 when the AID program reopened. At the time a very small Mission was deemed sufficient to manage a large, primarily resource transfer program. Although the nature of the program has shifted away from relatively simple resource transfer to more complex programming modes, and although DA program levels have reached $90 million a year, the Mission staff has grown only marginally since 1978. Both USAID and other units of the American Embassy in New Delhi have some experience in management of science and technology-oriented programs. USAID has managed since 1978 a $2 million grant project entitled Technologies for the Rural Poor. This project involves seven separate applied research sub-projects in applications of solar technologies, micro hydroelectric generation, nutritional blindness and malaria research. A senior Indian project officer is occupied full time in the management of this complex effort. A project for "Alternative Energy Resources Development," signed in fiscal year 1982 and totaling $5 million, is yet to get fully underway. When it does, it is clear that at least one additional senior professional will be required on a full-time basis to

manage its implementation as well. The staff will spend most of their time preparing and reviewing program documents and operations, corresponding with co-investigators, arranging meetings with scientists, facilitating travel and accommodations and reviewing financial documents.

Irrespective of who implements the research, USAID must expect for itself a style of involvement that will be staff-intensive on an intermittent basis. The areas of involvement will include: definition of research program direction and providing the conceptual linkages to a development orientation; developing and testing new "fast response" methods of procuring personnel and supplies to support the program; and guiding the implementing entities who will actually manage the activities. Although the precise structure of individual activities under the new strategy is yet to be defined, the staff-to-dollar ratio could be quite high, particularly during the early years of the strategy. The team believes the Mission should continue to assume that additional U.S. direct-hire staff related specifically to new R&TD programs will not be available, and only minimal, if any, relief can be expected on FSN direct-hire levels. The Mission should also assume that staff composition will not radically change in the next three-to-five years. This means an even greater workload on an already clearly overloaded staff, augmented with Indian talent under personal services contracts (and limited by OE constrants).

This burden can be minimized to the extent to which some of these functions are externalized to outside contractors (e.g., logistics arrangements). Nonetheless, any new S&T initiatives will have to build on existing workforce levels and skill mixes for the most part, and will have to fit within the current strategic directions of the Mission's portfolio. This will prevent "R&TD," per se, becoming a separate front in the Mission's portfolio development and causing "scatteration" in both strategic focus and staff energies.

The team recommends that a scientific adviser be recruited from outside the Agency to advise the Mission Director and senior staff, and to coordinate the overall strategy. This officer would also be directly responsible for managing the proposed "Innovative Research and Special Studies" project. The program and the relationships with DST and Indian scientists require an experienced, respected scientist who understands India and the development process. We realize this is a tall order and may not be possible; however, we think the JCC recruitment system is the best source of candidates. A minimum of one, and preferably two, Indian FSN scientists should assist this officer. The Advisor and his staff would serve as secretariat to the Science Panel.

G. Relationship to Other U.S. Government-Sponsored Science and Technology Related Activities and Functions in India

The team does not envision a merger of AID-supported R&TD activities with other science and technology activities

sponsored by the U.S. Government in India. Each program has its separate character that should be maintained.

The frameworks envisaged in this report should, however, lead to improved coordination on both the Indian and U.S. sides between the two sets of programs.

As noted in other sections of the report, elements of the STI (Science and Technology Initiative) might with GOI concurrence be extended and broadened with USAID support, particularly for more widespread applied and adaptive research in various locations of India. The STI activities in biological nitrogen fixation, nitrogen efficiency and biomass would appear to have such potential. STI workshop expenses in these areas in both India and the U.S. could, with GOI concurrence, also be supported. Once the proposed biomedical research project is underway, elements of STI health research activities could similarly be supported.

The joint subcommissions could be encouraged to take a more active part in reviewing the various sectoral elements of the USAID-supported R&TD stragegy.

VIII. Project Funding by Sector, FY 1983-FY 1988

The Mission has already initiated research and technology development projects in alternative energy (FY 1982) and agriculture (FY 1983) and is designing projects in biomedical research (FY 1984) and forestry research and education (FY 1985). The team's review of various sectoral research and technology development opportunities indicates that the Mission should begin to plan now for several major project initiatives for the period FY 1986 and beyond. For the five-year period, FY 1983-88, in agriculture, the team has recommended $30 million in additional funding for research carried out by ICAR and its institutes beyond the $20 million already planned for the Agricultural Research Project, and $15 million for improvement of research capacity in the agricultural universities. In forestry and environment the team has recommended $16 million for FY 1983-88 and $40-60 million over the ten-year FY 1983-93 period. For energy $8 million is recommended for FY 1983-88 and $15-25 million during FY 1983-93. In biomedical research, the team recommended $16 million over the FY 1983-88 period or about $3 million a year for the ten-year period. The team also recommended limited support for industrial research, and for innovative research and special studies.

The table below provides the team's estimates of the amounts which could be obligated for research and technology development projects during FY 1983-FY 1988, taking into account constraints imposed by the existing portfolio and by the availability of grant funds and Mission staff.

Project Funding by Sector, FY 1983 - FY 1988

($ Millions)

Sector/Sub-Sector	Fiscal Year 1983	1984	1985	1986	1987	1988	Total
Agricultural Research	6.5	3.5	5.0	10.0	10.0	15.0	50.0
Agricultural Universities	-	-	-	5.0	5.0	5.0	15.0
Sub-Total:	6.5	3.5	5.0	15.0	15.0	20.0	65.0
Alternative Energy	-	-	-	2.0	3.0	3.0	8.0
Forestry Research	-	-	5.0	4.0	4.0	3.0	16.0
Sub-Total:	-	-	5.0	6.0	7.0	6.0	24.0
Biomedical Research	-	2.1	6.5	1.2	3.0	3.0	15.8
Industry/Private Sector	-	-	-	1.0	2.0	2.0	5.0
Innovative Research and special studies	-	-	1.0	1.0	1.0	1.0	4.0
Sub-Total:	-	2.1	7.5	3.2	6.0	6.0	24.8
TOTAL:	6.5	5.6	17.5	24.2	28.0	32.0	113.8

The amounts shown for FY 1983-FY 1985 are based on the Mission's projections of obligations for the research and technology development projects already initiated or being designed. However, the team recommends that the Mission also move ahead with the Innovative Research and Special Studies project to allow initial funding in FY 1985. With this addition, the obligation levels increase from an average of $6 million per year in FY 1983 and FY 1984 to $17.5 million by FY 1985, or slightly above the AID/Washington FY 1985 target of $15 million.

The amounts shown for FY 1986-FY 1988 assume that the Mission would amend the Agricultural Research Project in FY 1986 and would provide initial funding for an Agricultural University Development Project in that year. Obligations during FY 1986-FY 1988 would total $30 million for agricultural research (in addition to the $5 million available from the Phase I project) and $15 million for agricultural universities, much of which should be provided on a loan basis. For alternative energy and forestry, the amounts are based on likely obligation schedules for a $10 million Phase II Alternative Energy Resources Development (FY 1986) project and for the FY 1985 $16 million Forestry Research, Education and Training project.

In the other areas, the projections assume a Phase II Biomedical Support for Health Services project in FY 1987, an FY 1986 start in industrial and private sector research, and the FY 1985

start noted above for the Innovative Research and Special Studies project (to be carried out under the GOI's Department of Science & Technology). Based on these projections for the various sectoral programs, the level of funding for research and technology development activities increases to $24.2 million in FY 1986, $28.0 million in FY 1987, and $32.0 million in FY 1988. The total for FY 1985-FY 1988 is $101.7 million, or an average of about $25 million per year.

In addition, there are research and technology development components in several other projects in USAID/India's portfolio. For example, the FY 1983 Integrated Child Development Services project includes $1 million for research on the determinants of low birth weights, and the Family Planning Communications and Marketing project may be amended to include nearly $1 million on research related to the immunology of contraception. There are also research components under the two state-level social forestry projects, and significant amounts of technical and social science research are being supported under various irrigation and water management projects.

We have not attempted to extend the funding projections beyond FY 1988. However, based on the team recommendations for the various sectors, AID should probably plan continued support of Research and Technology Development activities at the level of $25-30 million annually through the mid-1990s.

IX. Next Steps

There are a series of action steps that flow out of this report. The following are measures that the team believes should and can be taken over the next six months.

1. First, the Mission and Embassy should present a brief summary document to the GOI. This summary would outline the basic strategy, its main features and implementing mechanisms. Concurrence in principle should be sought from the GOI focal points that will be critical to effective implementation of the strategy. These include the Department of Economic Affairs (DEA) as well as the Planning Commission and Department of Science and Technology (DST). The Mission may wish subsequently to present the summary document to the key sectoral institutions with which it interacts, such as the Indian Council of Agricultural Research (ICAR). These steps should be taken as soon as possible.

2. The AID/Washington members of the team, under the leadership of the team leader, should present the report to the SAA for S&T and to the AA for Asia as soon as possible. It will probably be desirable to follow this up with a submission of the report (or a summary) to the Administrator, possibly accompanied by an oral presentation and discussion.

3. In pursuing step 2 above, the AID/Washington team members should seek approval of the overall report and specific approval of two critical implementation mechanisms:

(a) creation of a panel of 3 to 5 eminent American scientists and science administrators to advise the USAID Mission on its R&TD strategy; and

(b) the initiation of an "Innovative Research and Special Studies" program.

4. As the AID/Washington reviews are being undertaken, the Mission should simultaneously seek high-level GOI understanding and concurrence on an expeditious arrangement for the provision of U.S. scientific expertise through the bilateral program. It should also give further consideration to the composition, funding mechanism, frequency of visits and terms of reference for the Scientist Panel.

5. If the Mission is not able to reach agreement with the GOI on a mutually satisfactory arrangement for the provision of U.S. scientific expertise through the bilateral program, the S&T and Asia Bureaus should, in collaboration with the Mission, devise an appropriate AID/Washington funding mechanism or mechanisms for the provision of U.S. expertise to be effective as soon as possible, but not later than the beginning of FY 1985.

6. As soon as the Scientist Panel concept is approved in Washington, and as soon as guidance is received from the Mission on the Panel's terms of reference, the Mission and the S&T and Asia Bureaus will agree on a slate of candidates and proceed to recruit a panel. This should be completed by January 1984, with the objective of having the panel make its first visit in March 1984.

7. Upon approval in principle from Washington, the Mission will initiate discussions with the GOI to develop a PID and PP for an "Innovative Research and Special Studies" project for initial funding in FY 1985.

8. Assuming that AID/Washington approves the overall report, the Mission will begin recruiting as soon as possible a JCC Scientific Advisor to the Mission, with the objective of having someone in place by the beginning of FY 1985 at the latest. Once identified and approved, this person could hopefully visit India as a consultant before his or her JCC appointment is approved, in order to join R&TD-related discussions, especially in connection with development of the "Innovative Research and Special Studies" project. The Asia and S&T Bureaus will do everything possible to facilitate and expedite this critical JCC recruitment.

The Mission will also begin as expeditiously as possible to recruit one or two (certainly two if energy is to be included in their responsibilities) professional FSN staff to backstop the Scientific Advisor.

9. A contraceptive research specialist from the S&T Bureau Office of Population will be made available before the end of Calendar 1984 to visit the Mission and discuss in depth the possibilities for AID support of contraceptive research and development in India.

ANNEX A: AGRICULTURE

I. Overall Development Context

For the stability and well being of the nation and its people, India must continue to develop the potential of its agricultural sector. This potential can be achieved only if India maintains its natural resources that are required for agriculture and enhances the productivity of these resources.

The importance of agriculture to India is exemplified by the fact that agriculture contributes 41% of India's GNP. Food grains dominate India's agriculture, accounting for 70% of total crop production and approximately 77% of the cropped land. Forty-one percent of food grain production in 1980-81 was rice. Wheat contributed 28%, "coarse grains" (sorghum, millet, maize) contributed 22%, and pulses added 9%. The predominance of food grains is not likely to change in the forseeable future, nor is the relative mix of food grains likely to change. India is deficient in edible oils; therefore, expansion in oilseed production is a priority for Indian agriculture.

India's agricultural policies over the past thirty years have emphasized the growth of production and the attainment of self-reliance (equity has also been an objective -- at times more rhetorical than real). The first phase focused on reforms in the institutional environment and changes in attitudes of farmers. Both objectives were partially achieved. The second phase of agricultural development in India began in 1965-66 with the development of a "new agricultural strategy" with the objective to rapidly increase agricultural production and rural employment through the use of largely externally derived technology including high-yielding varieties (HYVs), fertilizers and pesticides, as well as the expansion of irrigated area, and the provision of adequate incentives to adopt the new technologies and expand production. At the same time India was making major efforts to enhance its agricultural education, research and technology development and transfer capability. This strategy paid handsomely and has permitted India to become largely self-sufficient in food grains. India has not had to resort to massive imports of food grains since the mid-70s (with the exception of about two million tons of wheat imported in 1981-82 -- and a lesser additional amount in 1983 -- to replenish stocks depleted during the 1979-80 drought).

To meet its current objectives for improvement in per capita food supplies and overall growth in employment and personal income, the Government of India (GOI) has given priority to agriculture and has established production growth rate goals of 3.9% per annum for food grains and 3.5% per year growth in employment in the agricultural sector. To keep the momentum and to meet future challenges, the Seventh Five-Year Plan, beginning in 1986, will undoubtedly require similar ambitious goals for agriculture.

Many analysts have concluded that prospects are good that India can reach its ambitious goals of about 5% annual growth if the GOI continues to give high priority to the agricultural sector and provides the necessary technical inputs and maintains agricultural markets that are attractive to farmers. The technical inputs required include an affordable and reliable supply of HYVs, irrigation water, fertilizer, pesticides and improved soil, water and crop management techniques.

India's spectacular progress in agricultural production has been derived from the use of HYVs, and the consequent technology; and also from an increase in the amount of land used for crop production. Because most of India's cultivable land is cropped, future growth in production will largely come from increased productivity (increases in production per unit of input).

There is opportunity for increased productivity in most production areas. With the exception of rice and wheat in the Punjab, crop yields in India are not on a par with many other areas of the world with similar soil and climate resources. The challenges and opportunities in the future appear to lie in closing the gap between predominant yields obtained in India and the biologic potential.

Research and technology development, linked to effective extension and other forms of technology diffusion and complemented by sound pricing and marketing policies, must continue to play a leading role in Indian agricultural development. Carefully selected research and technology development and implementation activities offer unique opportunities for GOI and AID collaboration to accelerate agricultural development.

Subsequent sections of this annex discuss GOI objectives and policies, major research institutions and programs, current USG-supported activities, and constraints to more effective research. A concluding section recommends the elements of a ten-year program of support by USAID for research and technology development in India.

II. GOI Objectives, Priorities and Policies for Research and Technology Development (R&TD)

India has made major progress in agriculture during the past thirty-five years. In food grain production India has moved from 56 million tons in 1949, to 108 million tons in 1970-71, to 131.4 million tons in 1978-79, to an estimated 142 million tons in 1982-83. The average rate of increase for the past ten-year period is down from the two previous decades; 1950-51 to 1960-61 the average rate of increase was 3.5%, 1960-61 to 1970-71 it was 2.6%, and during the period 1970-71 to 1982-83 it was 2.2%. Although overall production continues to increase, the trend toward lower average annual increases is cause for concern and signals a need for continued attention to the forces that drive agricultural production in India.

"India has evolved a set of agricultural policies since the mid-60s which are strongly production oriented."[1] The GOI's current strategy for food production and rural employment includes "efforts to consolidate and spread the agricultural gains of the 'green revolution' with targeted rural development programs aimed at raising incomes above the poverty level."[2]

GOI official policy recognizes that overall agricultural growth requires expansion of the agricultural infrastructure and increased inputs, especially irrigation, HYVs, fertilizer, pesticides and other agricultural technology. Chief among the goals of the GOI is increasing food grain yields or closing the "yield gap" throughout India. It is recognized that to close the yield gap will require continued emphasis on research, technology development and education on use of the improved technology. The U.S. agriculture establishment has major strength in research and technology development and transfer. It is logical to conclude that opportunities exist for mutually beneficial collaboration in agricultural research and technology development.

Since independence it has been GOI policy to support science-based development for the agricultural sector. The Sixth Five-Year Plan (1980-85) continues the emphasis on increased

productivity and also identifies stability and diversification of production as major goals. It also identifies goals to conserve India's natural resources, to generate rural employment and enhance consumption by increasing the purchasing power of people.[3] The Plan also emphasizes the need to identify the constraints responsible for the gap between potential and actual yields. Causes of slow technology transfer continue as major concerns. The Plan calls for research efforts directed at conservation of plant, animal, soil and water resources, evaluation and stabilization of production trends in unirrigated areas evolving technology to suit marginal and small farmers, improvement of animal and fisheries resources and development of integrated farming systems. The Plan also indicates that measures for effective transfer of technology to the field and providing research support to the farming community will receive special consideration.

In the forestry sector the Plan also calls for particular attention to be paid to three sets of needs: (a) ecological security; (b) fuel, fodder and other domestic needs of the population; and (c) the needs of village, small scale and large scale forest-related industries.

Objectives in irrigation aimed at optimizing development and use of water resources will require research on on-farm water management as well as research on irrigation system design and operation.

India's goals in meteorology include development of an integrated weather service for agricultural operation and planning, application of remote sensing techniques to agricultural meteorology and extension of the soil moisture observational network. These goals have high potential to contribute to agriculture and present many opportunities for research and technology development.

Goals in energy development and utilization are of major significance in agriculture and present many research and technology development opportunities. The thrust of the research effort for energy in India will be on "improving the efficiency of production, distribution and utilization of all forms of energy, improvement of energy efficiency in processes and equipment, recycling of waste for augmenting energy supply and development of new and renewable technologies."[4] Development of solar, wind and biomass sources of energy are of particular interest for agriculture.

India's new thrust in environment which is aimed at environmental quality improvement and preservation presents many research opportunities of importance to agriculture because plant and animal production systems are environmentally sensitive systems whose requirements must be understood and preserved.

The Plan's goals in education relate directly to the needs of agriculture. India intends to provide selective support for "high caliber but broad-based scientific research and thereby to improve the quality of the educational system."[5] The University Grants Commission (UGC) provides support to universities to support selected university science departments, thereby establishing the infrastructure for training of agricultural scientists. The UGC working through the Indian Council for Agricultural Research (ICAR) has developed and continues to support the agricultural research infrastructure and specific research activities essential for development of future agricultural scientists and for both the short- and long-term science-based information needs of agriculture.

India's plans in rural development include science and technology oriented activities related to community infrastructure essential to meet the needs of agriculture for supplies required for production, labor and access to markets.

It is anticipated that the Seventh Five-Year Plan (1985-1990) will continue most if not all of these areas of emphasis and will present many opportunities for research and technology development which would be of mutual interest to the Indian and U.S. science community.

III. Major Current R&TD Institutions and Programs

India's agricultural production sector is almost entirely private, being composed of over seventy million farm households. Individual land holdings are very small, averaging only two hectares per household. Subsistence farming is the norm. Income is derived from selling that which is excess to the needs of the farmer and his family.

Market channels available to the farmers are mostly private except for rice, wheat and a few special crops with manufacturing or export potential. The GOI provides a market channel for rice and wheat which is of major importance to farmers in the Punjab where these two commodities are normally surplus to local needs.

Production inputs such as unimproved seed, fertilizers and pesticides are normally provided for farmers through private sector channels. Seed of high-yielding varieties (HY"s) is usually made available to farmers through state seed corporations.

Research, technology development and extension education are a public responsibility. India's agricultural research and technology development system is a large and complex one. It has changed greatly during the past thirty-five years. The earliest institutions were founded during the 1880's and 1890's. Prior to independence, research activities focused mainly on commercial crops such as sugarcane, cotton, coffee, tea and jute. Organizationally, the Ministry of Food and Agriculture included various central research institutes and central commodity committees on such crops as sugarcane, tobacco, oilseeds, jute and coconut. These institutes and committees had little central supervision and the emphasis was on commercialization. In addition, several states operated small research stations during the pre-Independence period.

Since Independence, the GOI has been very conscious of the need to develop an effective agricultural research and technology development system. Successive changes have resulted from the many studies and reports that have been prepared. Most of the changes were recommended by high level committees which reported in 1955, 1959, 1962 and 1963. The reorganizations resulted in two major actions: (1) The Indian Council of Agricultural Research (ICAR) was revamped in 1964 bringing under its aegis the various research institutions operated by the commodity committees and all of the central research institutes; (2) additional agricultural universities have been established and all have been strengthened and given responsibility for teaching and major segments of research including participation in the All India Coordinated Research Schemes. These universities also have responsibility for assisting the state agricultural extension programs by providing information and participating in extension activities.

Currently the agricultural education, research and technology transfer functions in India are carried out by a network of agricultural universities with responsibility for teaching, research and extension education under the overall authority of the State Government in which each is located; the Forest Research Institute at Dehra Dun, National Research Centers, Agriculture Research Institutes, and All India Coordinated Agricultural Research Projects. The latter three are under the authority of ICAR.

ICAR [6] has overall coordinating responsibility, serves both as the principal funding source and carries out most of the program planning, supervision and evaluation activities related to agricultural research and technology development. The Minister for Agriculture and Irrigation in the GOI is the President of ICAR. The Minister of State in the Ministry is the Vice President of ICAR. The Director General of ICAR is the principal executive officer of the Council. He is currently Secretary to the Department of Agricultural Research and Education of GOI. He also functions as the principal advisor to the GOI on all matters connected with agriculture, animal husbandry and fisheries research and education.

Support for the Director General of ICAR, on the technical side, is provided by four Deputy Directors General for (a) Crop Sciences, (b) Soils, Agronomy and Agricultural Engineering, (c) Agricultural Education and (d) Animal Sciences. The Deputy Director Generals are assisted by other technical officers. On the administrative side, the Director General is assisted by the Directors of Finance, Personnel and other appropriate support.

The ICAR is responsible for the coordination and promotion of higher education for agriculture in India. To accomplish its objectives ICAR provides assistance to agricultural universities (1) for their development programs; (2) improvement of salaries; and (3) scholarships, fellowships and teacher training programs. This central coordinating point for agricultural research and education provides an effective means to identify priority needs and opportunities and channel resources to meet the needs. It also provides a means to insure efficient use of funds and technical manpower and to ensure quality of output. ICAR provides an almost ideal channel through which AID can impact upon India's agricultural research system and thereby facilitate development.

India supports agricultural research efforts through a number of organizational and programmatic efforts. The present system of twenty-three agricultural universities in seventeen states has been developed over the last twenty years to provide scientific education to meet the needs of the nation. ICAR provides 40-80% of the support for agricultural research at these universities and the balance is provided by the respective state governments.

The ICAR provides management and 100% of the financial support to two National Agricultural Research Centers, thirty-five agricultural research institutes and seventy-two All India Coordinated Research Projects which have been established to ensure in-depth research on a wide range of commodities and scientific problem areas. These institutes are for specific scientific research and are located throughout India. This network of institutes enables the problems of agriculture to be viewed comprehensively.

The All India Coordinated Research Projects encompass research schemes on commodities and on problems of wide-spread interest. These projects operate through ICAR institutes as well as through agricultural universities and, therefore, provide a link between Center and State level institutions. The ICAR institutes and agricultural universities undertake research on fundamental and applied aspects of production, preservation and utilization of agricultural products, whereas the coordinated projects conduct applied research on specific commodities or problem situations. The coordinated projects complement the work of the universities and ICAR institutes. The basic format for these coordinated projects includes a project coordinator and several subprojects which are

geographically dispersed and located both at ICAR institutes and agricultural universities. For example, the All India Coordinated Dry Land Agriculture project has its coordinator at Hyderabad with specific research at eighteen other locations.

Major advances have been achieved through this coordinated research approach.[7] Most notable is new genetic material for several crops which have superior yield and/or disease resistance qualities and better adaptation for specific ecological zones.

The ICAR has joined with sister organizations in India to create a National Biotechnology Research Center. This center will be the future location of major efforts in basic research aimed at biological nitrogen fixation, photosynthesis enhancement and genetic engineering of improved plants. Future plans for joint research undertakings in this area between India and the U.S. would seem to be worth preserving. ICAR also conducts operational research projects in specific areas of the country to gain insights into the socio-economic constraints affecting adoption of research results.

In general, the quality of the scientific staff at the institutes and universities is high and the level of financial support reasonably adequate. Equipment is needed in many locations and funds for travel and professional development are less than desired by the scientists. However, the conclusion is that India is supporting its objectives to meet food needs by continuing to provide for agricultural R&TD.

IV. Current USG-Supported R&TD Efforts in the Sector

Agricultural research initiatives involving Indian and U.S. resources consist of the USAID Agricultural Research Project (Project No. 386-0470), PL 480 projects administered by the Far East Regional Research Office (FERRO) of USDA and the activities currently being planned under the Science and Technology Initiative (STI) stemming from the 1982 meeting of Prime Minister Gandhi and President Reagan. The Science Attache's Office in the Embassy also manages competitive research grants on Indian agricultural and related topics funded by such U.S. organizations as the Smithsonian Institute and the National of Science Foundation. The irrigation and forestry programs currently sponsored by the Mission contain research elements closely related to or involving agriculture. Although a certain degree of compatability exists with respect to some of the topics being addressed, funding mechanisms and institutions involved are not the same. Consideration must be given to the manner in which funding and administrative responsibility are handled as efforts move forward to unify the USG's R&TD efforts in India.

The USAID Agricultural Research Project has been designed based on priority topics identified by the Indo-U.S. Agricultural Subcommission. The project, which has been agreed to by the GOI and will be executed by ICAR, provides a $20 million grant to ICAR for specific subproject activities. Thus far three subprojects have been designed: soybean processing, post-harvest technologies for fruits and vegetables and groundnut research. Implementation of the groundnut project has been deferred for approximately one year. The three subprojects approved to date account for $10.5 million of the total $20 million grant.

It is anticipated that additional subprojects will be identified and designed to utilize the remaining funds within a relatively short period and that additional funds would then become available. Subproject topics appearing in the project paper include biological nitrogen fixation, energy management for agriculture, agroforestry research and on-farm water management. Other areas identified by the Indo-U.S. Subcommission which could be included as subprojects would likely be: livestock breeding, pest management, management of agricultural research and education and biotechnology. It is estimated that within the currently funded $20 million project three more subprojects can be initiated. The specific topics chosen will be by agreement between ICAR and USAID.

The STI (Science and Technology Initiative, or Senior Scientific Panel) for agriculture includes three topics: biological nitrogen fixation, nitrogen fertilizer efficiency and biomass (fuel-wood) production. These three areas are of high priority for India and are compatible with possible future subprojects under the agricultural research project.

The current PL-480 program in agricultural research being carried out by the USDA (Far Eastern Regional Research Office - FERRO) utilizes rupees equivalent approximately to $2 million annually. Currently fifty (50) specific research activities in India are supported by this mechanism including projects in plant production and protection, animal production and protection, agricultural product processing and utilization, land and water management, agroforestry and agricultural economics. The specific topics are chosen based on potential interest of U.S. domestic agriculture in the research results. Complementarity between the PL-480 program elements and the USAID program or the STI program is accidental. It is reasonable to believe, however, that the program elements could be harmonized and complement each other. For example, under the land and water management category, nitrogen fertilizer efficiency for lowland rice is an element in the PL-480 and in the STI programs. If agreeable to the ICAR, this topic could be included as a subproject for the Agriculture Research Project.

USAID's irrigation activities are many and varied. Currently $210 million is committed and another $100 million will soon be allocated to support irrigation. Although almost all irrigation projects have elements of R&TD activities in them and all irrigation is of importance to agriculture, four irrigation projects merit discussion because of their direct effect on agriculture. They are: (1) Irrigation Management and Training, (2) Maharashtra Irrigation Technology and Management, (3) Rajasthan Medium Irrigation, and (4) Madhya Pradesh Minor Irrigation.

The overall Irrigation Management and Training Project is a large ($10 million loan, $41 million grant) seven-year project with the overall goal of increasing irrigated agricultural production through improved delivery of water to desired locations (farmers' fields) and more efficient use of water delivered. About 50% of this project, or $25.5 million ($4.2 million per year), will be development-research oriented. The project addresses the full range of concerns, from the use and management of irrigation water by farmers for crops, to river basin planning for multiple use. This project includes "action research" studies aimed at finding solutions to principal problems of irrigation systems including system design, farming systems, system operation, and institutional arrangements. This project also includes special studies on topics such as development of improved farm management methodologies for more effective use of water delivered, behavioral analysis of farmers, improved information systems and others of special interest to agriculture.

Each of the state-specific projects, mentioned above, is designed to strengthen institutions and develop human resources for improving India's capacity to design, implement and operate more efficient irrigation systems. Each contains major elements of special studies aimed at improving coordination of agriculture and irrigation in regard to water supply and use on farms.

It is estimated that the research component of each irrigation project is as follows:

(a) Maharashtra: 15% ($1.2 million per year),
(b) Rajasthan: 5% ($0.3 million per year) and
(c) Madhya Pradesh: 15% ($1.2 million per year).

It is absolutely essential to increase the end use of on-farm soil and water management research results if the investments currently being made in irrigation are to be good investments.

The Science and Technology Bureau, through S&T/AGR, has a portfolio of project activities through which technical assistance is provided to the USAID's agricultural program. Excluding ICRISAT,

for which AID provides 25% of the core budget support, S&T/AGR provided technical assistance estimated at $1.1 million for India in FY 1983, 52% of which was in support of irrigation. S&T/AGR projects included in this total are: Fertilizer Development, Water Resource Economics, Improved Soybean Varieties, Nitrogen Fixation, Soil Management Support Services, Sorghum/Millet CRSP, Storage and Processing of Fruits and Vegetables, Fishery Development, International Bench- mark Soils, Tissue Culture, and Water Management Synthesis.

Forestry activities supported by the USAID are currently confined to two major projects: (1) Madhya Pradesh Social Forestry ($24 million loan and $1 million grant) and (2) Maharashtra Social Forestry ($25 million loan and $5 million grant). A PID for $16 million for a proposed Forestry Research, Training and Extension Project is being developed in conjunction with the $50 million project proposed by the World Bank. In addition, there are 24 other interventions involving the USG to a lesser extent in forestry research and training in India. These include activities by the S&T Bureau, STI and the National Science Foundation. It is imperative that these separate forestry interventions be coordinated and directed to objectives agreed to by GOI. The present fragmented program leads to confusion and wasting of esources.

The current and future USAID-supported R&TD program in India will be compatible both with GOI priorities and with the priority research concerns AID has identified for Asia. The priority of sustaind, high productivity in relatively favorable natural resource areas, particularly in irrigated agriculture with emphasis on irrigation management will continue to be addressed as a new part of the irrigation program of the Mission. When a new subproject under the overall Agricultural Research Project concerning on-farm irrigation water management is initiated, this priority area will be adequately addressed.

The priority of sustained production in less favorable natural resource areas is being addressed by the All India Dry Farming Project. It is anticipated that this topic will be addressed by the Mission's program through a new subproject on dry land agricultural management.

The priority related to food and agriculture policy, including nutrition, food self-reliance, food security and equitable growth, is being addressed by India's current program of research and all work contemplated under the new agricultural research project will impact on these concerns.

The fourth priority of crop and animal protection (pre- and post-harvest) by most cost-effective and environmentally acceptable means is addressed by the new agricultural research subprojects on soybean processing and utilization and the subproject on post-harvest technology of fruits and vegetables.

Other priority research areas identified by the Asia Bureau include: (1) development of minimum purchased inputs systems, (2) livestock in mixed farming systems and (3) development of institutional capability to generate suitable technologies and get them applied. The USAID's current agricultural R&TD program does not contribute directly to these priorities; however, there will be ample opportunities to design subprojects in the future that address these issues, if found appropriate to Indian conditions and priorities. Both the Mission and the GOI are interested in strengthening institutional capability, particularly in agricultural universities, through collaborative research and professional interchange. It is anticipated that future projects developed by the USAID in India will continue to emphasize enhancement of institutional capability in R&TD.

The presence of ICRISAT (the International Crops Research Institute for the Semi-Arid Tropics) in India presents both opportunities and problems. Since AID is supporting twenty-five percent of the core program at ICRISAT it behooves AID to ensure that ICRISTAT's work is supportive of Indian development needs. It might also be noted that over two-thirds of the technical staff at ICRISAT are Indian citizens, including the Deputy Director General for Research.

ICRISAT is working on crops of special significance to India: sorghum, millet, groundnuts and edible legumes. The breeding material and new varieties produced by ICRISAT are readily available and are moving quickly to Indian farmers through ICAR and the state extension programs. Research being conducted at ICRISAT in farming systems is less readily taken up by the extension system and the farmers for several reasons. The principal one appears to be the cost incurred by the farmer in making the transition from traditional methods of tillage, water management and cropping to the new improved system. There is a tendency for the All-India Coordinated Agricultural Research Project personnel to view the ICRISAT farming system for the vertisols (black soils) as merely a water harvesting technique instead of a farming system. Until the concept is sold as a farming system that will earn the farmer more income and the credit system available to the farmer permits him to make the shift, adoption of the improved farming system will continue to lag.

The Director of ICAR is a member of the Board of ICRISAT and is in a position to influence its program. It is recommended that the USAID work with both ICAR and ICRISAT to increase the dialogue between ICAR and ICRISAT.

V. Constraints to More Effective R&TD in the Sector

Given the desire of both the USG and GOI to effect development through R&TD and given the fact that both countries have many highly trained and competent agricultural scientists, it is reasonable to conclude that the most effective mode for accomplishing the overall objective is through a collaborative approach. The desired collaboration would have organizations and scientists from both countries with mutual interests working toward common objectives. Such collaboration could take many forms and be played out at a variety of levels. For example, there could be university-to-university collaboration on topics of institution-wide concern. There could be collaboration between institutes or departments with common subject matter concerns and finally there could be research collaboration of the type initiated by STI where one or more Indian scientists working on specific problems collaborate with one or more U.S. scientists who are also working on similar problems, e.g., biological nitrogen fixation by rhizobium.

A. Policies and Procedures

Constraints to effective use of R&TD for development exist on both sides. The inability of the USG to provide dollar costs for collaborative R&TD through mechanisms other than grants to GOI will continue to hamper development of effective programs. On the Indian side, the GOI's unwillingness to expend grant funds for dollar costs for technical support will continue to be a deterrent. Streamlining the process whereby the USAID can provide assistance, perhaps through "buy-ins" to central S&T projects, for technical support would be of considerable advantage to development of R&TD for agriculture in India. In order to provide such assistance, the funds may have to be channeled through a Washington account rather than the India bilateral country program, so as not to show up in the GOI budget.

The absence of effective mechanisms for supporting collaborative research and scientific interchange, including professional development, within existing AID procedures constitutes a major deterrent.

B. Institutional Capacity

Although $20 million has been provided for support of agricultural research, India has the institutional capacity to effectively use much more. As stated earlier funds available will permit development of approximately three more subprojects. These funds are likely to be committed within a year. The Joint Commission, STI and the current team have identified thirteen additional areas (mentioned earlier; also see following Section VI). A conservative estimate of funds needed to support these

potential initiatives would be approximately $40 million. If India and the U.S. should undertake a major effort to strengthen the twenty-three agricultural universities through support for research and technology development, an additional $20 to 25 million could be used effectively.

Funds for salaries and easily obtainable supplies and equipment are reasonably adequate in most agricultural universities and research institutes; however, there is need for foreign currency for purchase of certain specialized equipment and for travel for professional development. These needs could largely be met if the funds indicated above are provided and if the dollar funding problem is solved.

The current mode of operating USAID projects requires a project manager for each major project. Hiring restrictions within AID will preclude hiring the staff required to carry out an expanded R&TD program in agriculture in India. This personnel constraint must be overcome or a different mode of operation that requires fewer technical people must be developed and implemented.

C. Donor Involvement

Because India is so large and has so many well-developed agricultural research institutions, multi-donor involvement is not a major constraint to development of meaningful Indo-U.S. collaborative efforts in agriculture. It is, however, a major job for the USAID staff to keep current on other donor involvement and thereby take advantage of mutually supportive activities while avoiding conflict and overlap.

Major donors in the agricultural field include the World Bank which is supporting work in numerous areas, i.e., watershed development, forest resource development and training, irrigation and agricultural research. The Ford Foundation's program relates to socio-economic issues that affect agricultural and rural development. Specific emphasis is being given forestry, energy and water development. UNDP, operating through FAO, is providing technical support in the form of expert consultants to many projects including irrigation, forestry and numerous areas related to agricultural production and natural resource management.

VI. Sector Elements of a Ten-Year R&TD Program

The role of agriculture in the overall development of India is paramount and the important role of R&TD utilization in agriculture is unquestionable. Science and technology must continue to impact heavily on agriculture in India if India is to meet the food requirements of the future. It can be concluded, therefore,

that India will continue to emphasize science and technology for agriculture and that collaboration and interaction between Indian and U.S. scientists should be fostered. Therefore, the AID program in India over the next ten-year period must include a major agriculture R&TD element.

Since agriculture does not operate in a vacuum, it must be considered as one important element in the spectrum of science generators and users. Science concerns in energy, irrigation, forestry, animal and human health, watershed management, environmental management, industrial development and basic sciences impact heavily on agricultural development. For this reason, it is recommended that an overall R&TD initiative be developed within the USAID. Such an initiative should provide for oversight over the science-based portfolio of the Mission. It could take the form of a high level board of advisors for the Mission made up of both Indian and U.S. scientists or just U.S. scientists. It is also suggested that this board include respected scientists in agriculture as well as in other fields such as energy, health, etc. The Secretariat of this Board of Scientific Advisors could be a Scientific Advisor on the Mission staff (a position that is essential for the future science-based program of the Mission in India).

It is recommended that the Mission identify a portion of its annual budget for support of science-based activities and that the Board of Scientific Advisors give advice as to allocation of these funds to the various sub-sectors such as agriculture, health, energy, etc.[8]

These programs should be designed to facilitate institutional concerns and specific areas for scientific collaboration. Institutional concerns relate to facilitating collaboration and to strengthening institutional capacity and quality. Indo-U.S. collaboration in this area should facilitate those activities that will build and maintain quality of research, teaching, and public service capability of the university or institutes involved.

Identification of problems and selection of areas for specific collaboration in research is difficult because the spectrum is so broad and the needs are so great. Emphasis must be placed on those areas of high importance to India's future food needs, keeping quality of the scientific effort in mind at all times.

Since India's agricultural universities and ICAR institutes are mature and staffed, for the most part, with capable scientists, selected areas for future efforts should build on strength in science where a collaborative effort will have a high probability of making significant progress in solving constraints to production and utilization of agricultural products.

The current modes for scientific interaction are several. These may be sustained, terminated, or others developed. The hallmark for future research collaboration should be facilitation of interchange of scientists and scientific information.

Decisions concerning use of funds allocated to each subsector could be made by the USAID based on advice by a Technical Advisory Committee (TAC). The Secretariat for this Technical Advisory Committee could be the Chief Technical Officer in the USAID for the sector, i.e., the Chief of Agriculture and Rural Development for the Agriculture TAC. It is not impossible to conceive of an arrangement whereby the Joint Subcommission for Agriculture would serve as the TAC for agriculture. One advantage of this might be to harmonize the PL 480 activities with the USAID activities.

Regardless of the superstructure adopted it is visualized that the pattern of R&TD activity in agriculture in India supported by AID will largely be implemented through a mode established by the existing Agricultural Research Project. Opportunities for research in agriculture that will be mutually beneficial to India and the U.S. are numerous and it is anticipated that many of these collaborative research efforts will be launched during the next ten years. The need is great and the absorptive capacity is sufficient, given an adequate programming mechanism, to accommodate research activities during the next five years requiring at least $30 million in addition to the $20 million already allocated. In addition there is a great opportunity to strengthen the Indian agricultural universities and at the same time enrich the U.S. universities by development of a joint program to increase the capabilities of Indian agricultural universities. It is estimated that $15 million at a minimum could be effectively used for this purpose during the next five years. More specific recommendations concerning universities will be given later.

Specific agricultural subject matter areas that appeared to merit increased R&TD effort and to present potential opportunities for Indo-U.S. scientific collaboration during the period 1983-1988 are:

1. Integrated plant nutrient management systems, to maximize efficiency and adequacy.

2. Management systems for lowland rice production, including fertilizer efficiency and varietal improvement.

3. Biological nitrogen fixation.

4. Agroforestry research and development of silvi-food crop and silvi-pastoral systems for food, fodder and fuel.

5. Energy research in agriculture, concentrating on alternative energy sources such as solar and wind.

6. On-farm water management, including drainage and use of irrigation water.

7. Soil-water-crop management systems for rainfed agriculture.

8. Animal breeding, including ova transplant and other techniques to accelerate animal improvement.

9. Bio-technology, including cell and tissue culture and other techniques.

10. Disease and pest control for pulse and oilseed crops.

11. Weed control for both dry farming and irrigated area.

12. Socio-economic studies in areas such as irrigation, farm-forestry and farming systems.

13. Small watershed management.

These areas are not presented in priority order and should be viewed as recommendations for subsequent GOI and USG discussion and review. If a decision is made to initiate and foster collaborative research efforts in these areas during the next five-to-ten years, the progress of Indian agriculture should be enhanced as each has been identified as a major constraint. While it is beyond the scope of this paper to justify each recommended area, one which does merit special attention is on-farm water management (item 6). Given the rapid growth of irrigation in India, it can be predicted in the years ahead that many new soil and crop management problems related to management of irrigated areas will loom as very important. Examples are water logging and salinity control. Plans should be made to initiate research in these important topics in many places in India before the problems become unmanageable.

Assuming that the high priority areas identified above will be addressed in the period 1983-1988, the period 1988-1993 will require continuation of most of them to pursue second and third generation problems. This will be necessary because much of the research is agro-ecological zone-specific, and the biological system is so dynamic that new challenges are present constantly, i.e., plant breeding for resistance to diseases and insects is never done.

In addition to these areas requiring continued research in the second five-year period, it is recommended that collaborative research be undertaken in such fundamental areas as:

1. Plant biochemistry and breeding to insure quality.

2. Photosynthetic enhancement.

3. Genetic engineering of plants, animals and products for support of agriculture.

4. Overcoming effects of salinity by both biological and physical-chemical means.

5. New uses for plant and animal products.

6. Chemistry and physics of soil-plant-water systems.

7. Agricultural meteorology and related fields. Support for agriculture-related elements of a possible monsoon research center that has been floated recently might be a possibility.

These investigations need not be massive undertakings, but they must involve the most capable scientists in both India and the U.S. and they must be permitted to interact freely and frequently.

India's agricultural universities were developed with assistance from U.S. land grant universities and most are organizationally and functionally similar to land grant universities. This teaching-research-public service model should be perpetuated and strengthened in India's agricultural universities and at the same time specific programs in specific universities should be strengthened.

It is recommended that AID launch a major program aimed at strengthening the teaching-research and public service capacity of selected agricultural universities. Such a program might be funded for the next five years with provision for extended support if evaluation shows continuing needs and that the existing program has accomplished its objectives. Decisions on use of the funds should be made by USAID and ICAR based on an analysis of the needs of each university. Types of activities that might be included in this program are post-doctoral fellowships, support for research to be conducted by Indian scientists in a U.S. university laboratory, short-term educational visits to U.S. universities by Indian university administrators, purchase of equipment for research and other types of activities found to be needed to strengthen the agricultural universities.

Activities such as those described in the previous paragraph should be included as normal parts of collaborative research activities carried out by institute scientists as well as by university scientists.

The STI in agriculture includes activities in BNF (Biological Nitrogen Fixation), fertilizer efficiency and fuelwood production. Since each of these areas has been agreed to by GOI and USG as areas of mutual interest, and since these areas are compatible with priority areas for research identified earlier, it is recommended that the STI activity stand alone for two years (the STI agreement period). At the end of that period, activities could, where warranted, be assumed by an appropriate on-going subproject under the Agricultural Research Project, or the planned Forestry Research, Education and Training Project. This will require early action by USAID to have in place research activities in each of the areas currently included in STI.

Program management and funding concerns in the USAID are great. To launch and supervise all the activities identified as needing effort using the current project management mode would require more staff than the USAID can expect to acquire. A mode of operation that requires less technical supervision by USAID staff must be found and implemented. Given the stage of maturity of the ICAR and its institutes and universities, it is recommended that the USAID make grants to ICAR for work in specified fields that include collaboration or interaction with U.S. scientists working in the same field and a periodic peer review mechanism involving both Indian and U.S. scientists.

Because funds granted to the ICAR cannot be readily used to effect scientific collaboration by U.S. scientists in India, it is essential to find improved methods for paying costs incurred in providing technical assistance or collaboration by Americans in India.[9] The Agency must address and solve this problem soon if research interaction with India is to expand. If a Washington-based approach is adopted (see discussion in Chapter VII-B), the procedure of "buy-in" into S&T/AGR (and other S&T Bureau offices) projects might be used. S&T/AGR could then supply the technical or collaborative assistance required "in-kind." S&T/AGR already has or could develop projects in all areas suggested for future collaboration. This procedure has the added advantage of increasing the collaborative research effort by the amount of S&T/AGR support that is added to the project above the buy-in level. This could be substantial in major projects. Other possible mechanisms exist but it is beyond the scope of this annex to suggest all of them. However, it is important to emphasize that this problem must be solved.

Increased involvement of the private sector in India will develop slowly. The private sector is currently supplying fertilizer, seed, pesticides, fuel and machinery. As India's agriculture becomes more science-based and as farmers' incomes increase, opportunities for the private sector to provide inputs will increase. However, during the next ten years there do not appear to be opportunities for great involvement of the private sector in agricultural R&TD beyond that which develops spontaneously.

In summary, it is recommended that a major component of the USAID's agricultural program in India be R&TD oriented. "R&TD is the engine that drives development in agriculture." The program should be an integral part of the USAID's overall R&TD program. It should not stand alone. It should be carried out through ICAR and involve the research institutes, the All India Coordinated projects and the agricultural universities in collaborative research efforts with U.S. institutions and scientists. It should have elements which support research schemes, research institutes and universities. The program must be "development-problem driven," concentrating on high priority areas of mutual interest that are predicted to remove obstacles to development and to areas of science predicted to make breakghroughs in a reasonable period of time. These activities should be conducted in such a way that will facilitate interaction between Indian and U.S. scientists. In order to effect this program, AID must modify procedures to remove administrative and fiscal barriers.

Notes

[1] See John R. Westley and M. C. Gupta. "Agricultural Growth in India: Policies, Performance, Impact," USAID/India, May 1982.

[2] See Project Paper No. 386-0470, "Agricultural Research," USAID/India, June 1983.

[3] Sixth Five-Year Plan for India.

[4] Ibid.

[5] Ibid.

[6] For a more complete description of ICAR and its functions, see Annex B to Project Paper No. 386-0476, "Agricultural Research," USAID/India, June 1983.

[7] Annual Report of ICAR, 1982-83.

[8] See Chapter VII of the main report for further discussion. The main report favors a Science Panel for the Mission that, at least to begin with, would be composed only of U.S. scientists. The main report recommends the Panel periodically review the performance of the various research projects.

[9] See Chapter VII of the main report for further discussion.

ANNEX B: Forestry and Environment

I. Overall Development Context

Pressures on India's natural resource base are intensifying as the population moves towards the one billion mark and as agricultural and industrial development demands larger volumes of land and raw materials. The result is a rapid deterioration of India's forest, soil, and water resources. A recent report by the Center for Science and Environment on The State of India's Environment 1982 provides an overview of these trends and calls for urgent government action on a wide number of fronts.[1]

Of central concern is the process of deforestation and land degradation that threatens gains in agricultural production and poses a major future constraint to achieving the projected minimum requirement of 225 million tons of food production by 2000.[2] ESCAP figures suggest an annual deforestation rate of 250,000 hectares, although some estimates go as high as one million hectares out of a total estimated accessible and productive forest area of 30 million hectares.[3] It is generally agreed that although approximately 23% of India's total land area of 328 million hectares is classified as forest, only about 10% has adequate forest cover.

Deforestation is a central contributor to the larger process of land deterioration that has reached tremendous proportions. Destruction of forests in the upper Himalayan watershed areas is particularly critical for the downstream Ganges basin.[4] The GOI Ministry of Agriculture estimates that 175 million hectares of agricultural and non-agricultural lands are suffering degradation from various causes: serious water and wind erosion (85.75%); waterlogging (3.4%); saline soils (2.6%); shifting cultivation (1.7%); alkaline soils (1.4%); dairy land (1.4%); and wasteland fit for reclamation (3.8%) (see Appendix A). In fact, the Chairman of the National Environmental Planning Commission considers only 61 million hectares as reasonably good forest, pasture and agricultural land.[5] (see Appendix A).

Dr. M. S. Swaminathan and others have long warned of the nutrient drain from soil erosion and the diversion of organic residues and dung to energy uses. The fuelwood crisis in India will result in further pressures on these resources in the future as discussed in the section on energy.[6] Despite the economic costs of this soil degradation (damage from floods in 1978 alone is estimated at almost 11 billion rupees [7]), the Sixth Five-Year Plan allocates only 5 billion rupees for forestry programs and 400 million rupees for environmental programs. A tree planting target of 2,144,000 hectares is set for the Plan period (1980-85) with 70% of that being in "social forestry" programs of the individual states. This level is over twice the estimated plantings under the Fifth Plan.[8]

A tree planting is also underway by the Department of Environment in critical watershed and catchment areas using army officers. Recently, the GOI has moved to establish 12 biosphere reserves, in addition to the current 44 national parks, 207 natural sanctuaries and 166 forest reserves, to protect India's environment and preserve its biological diversity (see Appendix B).[9]

II. GOI Objectives, Priorities and Policies in R&TD

The GOI is currently in the process of formulating national research programs in the forestry and environmental areas. A Task Force chaired by the Secretary of Environment has prepared a report for the Cabinet Committee on Science and Technology with recommendations on organization and programs in the forestry research sector. A World Bank/USAID/ODA Sector Team has recently endorsed the recommendation of the Task Force on a substantial new program to strengthen forestry research, education and training in India. The following five broad areas are suggested for research: (1) fuelwood biomass research, (2) fodder trees, (3) watershed land use management, (4) forest product utilization, (5) wood-based energy technologies.[10] Topics within these areas are contained in Appendix C. Based on Prime Minister Gandhi's speech at the recent World Energy Conference in New Delhi, a top research priority will be "the application of new biological advances on biomass production (e.g., tissue culture, protoplast fusion, genetic engineering, nitrogen fixation, improved photosynthesis, etc.), particularly on lands not suitable for agriculture."[11]

The Department of Environment has prepared a profile for its overall program that calls for research on topics that will enable the development of programs and environmental legislation related to biosphere reserves, protection of grazing lands, protection of wetlands and sanctuaries, prevention of overfishing in coastal waters, protection of catchment areas, and protection of endangered species. The Department has an Environmental Research Committee that advises on research programs.

III. Major Current R&TD Institutions and Programs

Research and technology development in forestry and environmental sciences is scattered throughout the country and is carried out under the auspices of various bodies.

A. Department of Agriculture

The Forest Research Institute at Dehra Dun is the focal point for forestry research in India. FRI and its regional branches in Coimbatore, Bangalore, Jabalpur and Burnyhat are focusing principally on silvicultural, entomological, pathological, and wood utilization research on commercial timber species (long-rotation). Coimbatore has, however, carried out field trials, on short-rotation eucalyptus species. Some state forestry departments are developing research programs; Kerala State has a particularly strong forestry research institute.

B. Council for Scientific and Industrial Research

Several institutions under the CSIR network are engaged in relevant research. In 1981, the Department of Science and Technology established the National Botanical Research Institute as one of two Biomass Research Centers. The program has since been transferred to the Department of Non-Conventional Energy of the Ministry of Energy.[12]. The main objectives of the Center are:

(1) to assess the potential of plant species of proven adaptability to soil alkalinity for biomass production;

(2) to standardize agro-techniques;

(3) to study photosynthesis in relation to plant productivity and nutrient cycling of selected species and nitrogen economy;

(4) to survey the land and water potential of the area and formulate programs on the utilization of municipal and agricultural wastes for energy conservation;

(5) to concentrate on energy crops of terrestrial and aquatic nature;

(6) to undertake feasbility studies on more efficient uses of biomass for obtaining maximum energy and on developing appropriate technology for energy crops, production systems, harvesting and collecting, pre-treatment and conversion.

To assess the biomass production of 12 fuelwood species tolerant to sodic soils, NBRI together with the U.P. State Forestry Department has set up a block trial replication experiment. For each species, 1,875 saplings replicated 3 times have been planted at 1.5m x 1.5m spacings on 36 plots.[13] Measurements of growth, yield in response to fertilizer and other conditions are underway. Analysis of coppicing characteristics will be performed after several more years of growth. Samples have been sent to the Punjab Agricultural University for fuelwood characterization analysis. Trials are also underway on selected high starch and sugar crops and hydrocarbon producing plants. NBRI also has unique experience at the Banthra Research Station in the reclamation of a small wasteland area and its conversion into a "natural" forest over a twenty-year period. Tissue culture work involving some woody biomass is also being conducted.

The National Chemical Laboratory in Pune has one of the largest tissue culture groups in the world. They have had success applying tissue culture methods to teak, eucalyptus and several other tree species.[14]

The Central Salt and Marine Chemicals Research Institute in Bhavnagar is experimenting with jojoba and other drought-resistant plants and shrubs. The National Environmental Engineering Research Institute in Nagpur is conducting research on water and air quality and sedimentation.

C. Indian Council for Agricultural Research

The Central Grasslands and Fodder Research Institute in Jhansi is carrying out research on silvi-pasture and the role of grasses in helping to stabilize soils. The Central Arid Zone Research Institute at Jodhpur, the Central Soil and Water Conservation Research and Training Institute at Dehra Dun and the Central Soil Salinity Institute at Kemal are involved in research on desertification, soil erosion and soil salinity problems. CAZRI has apparently given some effective advice on trench planting for trees on wastelands in Gujarat to a PVO group.[15]

The Indian Institute for Agricultural Research has recently established an Agro-Energy Center that will work on agroforestry, biological nitrogen fixation, tissue culture and organic recycling.[16] Several state agricultural universities, e.g., Punjab Agricultural University, are creating similar units.

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D. Department of Environment

The Botanical and Zoological Surveys of India both fall under the supervision of the Department of Environment. This Department coordinates the Indian National MAB Committee which collaborates with UNESCO on studies, research and demonstration activities on the ecological impact of human activities. The Department plans to establish a Himalayan Institute of Environment and Development to undertake research on the ecosystem in the Himalayan region.

E. Other Institutions

Madurai Kamraj University at Madurai has been designated with NBRI as a National Biomass Research Center. It has a School of Biological Sciences with a major emphasis on the physiological side. Photosynthesis research is a major theme. The Indian Institute of Sciences in Bangalore has an emerging interest in environmental issues and in 1982 hosted a meeting on Conservation and Management of Biological Diversity in India. In Hyderabad, the Administrative Staff College of India has a Center for Energy, Environment and Technology and has conducted several studies on social forestry and biomass energy. UNESCO and the Department of Environment are sponsoring a Regional Workshop in "Biomass Energy Management in Rural Areas" in December 1983 at the college.

IV. Current USG Programs

USG programs to date in forestry and environment have been limited. Under the Special Foreign Currency Program, USDA has supported forestry research activities with Coimbatore and Dehra Dun. USDA is coordinating the forestry research component of the STI program and a U.S. team visit to India to develop collaborative research projects is proposed for late October. USAID is providing about $2.0 million for fuelwood production research to NBRI and Madurai Kamraj University under the Alternative Energy Resources Development Project. Silviculture and plantation management research on fuelwood species is included in both the Madhya Pradesh and Maharashtra State Social Forestry projects. A Research, Training, and Extension project is under design for FY 85, which would be the Agency's only separate country forestry research project.

Some collaboration has taken place with India in the land management and land reclamation area, through NSF and EPA. NSF is planning in early 1984 a workshop at CAZRI on Arid Zone Research priorities. The U.S. Fish and Wildlife Service has also carried out a small collaborative research program.

V. Constraints to Effective R&TD

India currently has inadequate human and institutional capacity as well as financial resources to tackle the forestry and environmental problems discussed above. The complex nature of the land reclamation/soil improvement problem requires an interdisciplinary approach that is lacking at virtually all institutions. As discussed in Section III, various institutions are working on pieces of the problem, yet no effective integrating system appears to exist. The Special Task Force has recommended the creation (or activation) of an Indian Council of Forestry Research and Education as a coordinating body and the strengthening of research and educational capabilities of FRI, ICAR, and CSIR institutions, as well as the state agricultural universities, state forestry departments and some private research. A critical need exists to establish with the Union and possibly the State Public Service Commissions a career specialization in forestry and environmental research. The social and management sciences also need to be integrated more effectively into this research field. This will be a major challenge for the Department of Environment in developing the Himalayan Institute of Environment and Development. Interdisciplinary programs in forestry and environment sciences are also urgently needed at Indian universities and institutes of science and technology.

NBRI seems to have the most developed program of systematic fuelwood species trials, but they face serious limitations in land, equipment and staff, and would benefit from interaction with U.S. institutions in the design, implementation and evaluation of their trials. Bureaucratic constraints have delayed the USAID-supported initiative that would develop an institutional link between NBRI and a U.S. forestry school or consortium of schools.

Tissue culture research is at a fairly advanced stage at both NBRI and NCL. The techniques developed now need to be focused on mass propagation of genetically superior fuelwood species adapted to different soils and conditions. Most species trial work to identify superior material, however, is only in the early stages.

The resources allocated to research and education in forestry and environment will have to be greatly augmented in the Seventh Five-Year Plan if the necessary technical knowledge and personnel are to be developed. Current indications are that a level of about $120 million may be forthcoming for forestry research in the Seventh Plan.

VI. Sectoral Elements of a Ten-Year R&TD Program

AID has a unique opportunity to make a critical input at the formative stage of a national program for forestry and environmental research. In this regard, it may be a similar juncture to the position India was in during the 1950's when AID launched its major program to build the national agricultural universities system. India must mitigate the environmental degradation that is occurring if it is to sustain its development. This problem is, of course, only partly a question of research. It is more fundamentally a question of leadership, financial resource availability, management, and community and village mobilization. Such rural movements have been successful in restoring lands in China and South Korea. Whether it is possible here in India with its diversity remains to be seen.

The team recommends a long-term research and technology development program in this sector emphasizing the role of trees and grasses in the enhancement of land and water resources and the expansion of rural incomes.

The Program would have three major elements:

(1) Research, professional and institutional development related to the nature, determinants and consequences of land, forest and water degradation. This baseline environment research and educational development is central to increasing awareness as to the economic costs of environmental degradation. The Department of Environment and the new National Land Board under Ministry of Agriculture provide possible vehicles through which to pursue this element. A critical mass needs to be developed to tackle this interdisciplinary problem. A National Institute for Environmental Research and Management may be desirable for long-term development.

(2) Results-oriented research on short-rotation and multipurpose trees (e.g., fuelwood, agro-forestry, construction, "minor" forest products and other uses). This work would include the following:

(a) identification of species and provenances trials on trees suited for conditions in degraded and marginal lands in various regions of the country;

(b) determination of the potential of various trees for agroforestry and silvipasture schemes;[17]

(c) analysis of the yields of fuelwood and minor forest products from different types of trees;[18]

(d) calculation of the impacts on overall soil nutrients and stability of various leguminous and non-leguminous species over time;

(e) evaluation of the preferences of the poor for various kinds of trees and the impact of different tree planting approaches on the poor and landless;

(f) development of nursery and management techniques appropriate for selected species;

(g) selection of genetically superior, especially adapted trees and their mass propagation through tissue culture techniques.

NBRI, the Central Grasslands and Fodder Research Institute and other ICAR institutes, FRI, and the agricultural universities would play key roles in this effort. This program area should be developed in close collaboration with the World Bank. The establishment of an effective Indian Council on Forestry Research as endorsed by the World Bank/AID/ODA team would provide a framework for the development of an umbrella research project similar to the current Ag Research project.

(3) A more basic but modest research effort aimed at genetic improvement of trees through the creation of new hybrids for clonal propagation. Genetic engineering techniques such as protoplast fusion, gene transfer and nutrient breeding would be pursued. This work would be centered at the National Chemical Laboratory at Pune. Dr. Donald J. Durzan, Professor of Biochemistry, Institute of Paper Chemistry, who visited NCL during the May 1981 NAS Team mission, believed that NCL could overcome the developmental barriers to generating plants from protoplast cells or cell suspensions with a sustained research effort [19].

These three elements should be linked to the new joint program being developed by the Asia Bureau and the S&T Bureau in Foresty and Bioresources. Their concentration would have both forward linkages to the AID-supported social forestry programs in M.P. and Maharashtra and backward linkages to the global S&T forestry research and development project and its Asia regional component. An FY 85 project is planned that could provide an early start to the ten-year effort. Thus, this proposal is consistent with the R&TD sectoral approach, the "ribbon " approach of Dr. Nyle Brady and the Asia Strategic Plan for 1983-1988.

A reasonable cost estimate for this program would be in the range of $40-60 million over the ten-year period.

Notes

[1] Center for Science and Environment, The State of India's Environment 1982, New Delhi, 1982.

[2] Meeting with Dr. Jain, Director, Indian Agricultural Research Institute, New Delhi, September 17, 1983.

[3] ESCAP, Review and Appraisal of the Environmental Situation in the ESCAP Region, February 1982, p. 14; World Bank, India: Forestry Education, Training, Research, and Extension--Sub-Sector Review, Draft of June 8, 1983, p. 2.

[4] See Sir Charles Pereira, "The Role of Forestry in Himalayan Watershed Development," in AID, Forestry and Development in Asia, forthcoming.

[5] Center for Science and Environment, op.cit, p. 6.

[6] Planning Commission, Government of India, Report of the Fuelwood Study Committee, March 1982.

[7] B. Bowonder, "Deforestation in India," International Journal of Environmental Studies, 1982, Vol. 18, p. 223, Table X.

[8] FAO estimates that during the Fifth Five-Year Plan (1976-80) a total of 919 thousand hectares of plantation were established in India -- 607 thousand for industrial production; 191 for fuelwood production; and 121 for environmental purposes.

[9] Meeting with Dr. T.N. Khoshoo, Secretary, Department of Environment, on September 17, 1983.

[10] World Bank, op. cit., p. 28.

[11] Inaugural Speech by Shrimati Indira Gandhi, Prime Minister of India at the World Energy Conference, New Delhi, September 18, 1983.

[12] See Government of India, Department of Non-Conventional Energy, Annual Report 1982-83., p. 22.

[13] National Botanical Research Institute, Annual Report 1981, p. 53.

[14] National Academy of Sciences, BOSTID, Trip Report of Biomass Research Team to India, May 6-30, 1981, p. 13.

[15] Stephen Alter, "Social Forestry and Voluntary Agencies," unpublished paper, April 13-15, 1983.

[16] Meeting with Dr. Jain, op.cit.

[17] See B. N. Tewari, "Minor Forest Products of India" in AID, op.cit., for a discussion of the importance of minor forest products (i.e., tendu leaves, oilseeds, tannin extract, gums, lac, grasses, bamboos, canes, oils, drugs, silk, fruits, flowers, stems, tubers, honey, juices, mushrooms) for the poor, particularly the 44 million tribals. Minor forest products in 1980-81 contributed revenues of Rs. 1,701 million out of total forest revenues of about Rs. 4,725 million.

[18] See A. K. Banerjee, "Agro Forestry and Its Potential Contribution to Industry in India," Ibid., (Common combination of agricultural and forestry species grown in India includes: Tectana grandis and maize, tapioca, spices and oil seeds hardwoods (quercus) with potato and maize; evergreens with pepper; pines with maize of rice; Acacia auriculformis with cashew nuts).

[19] NAS, op.cit, p. 14.

Figure 2. Land suffering degradation

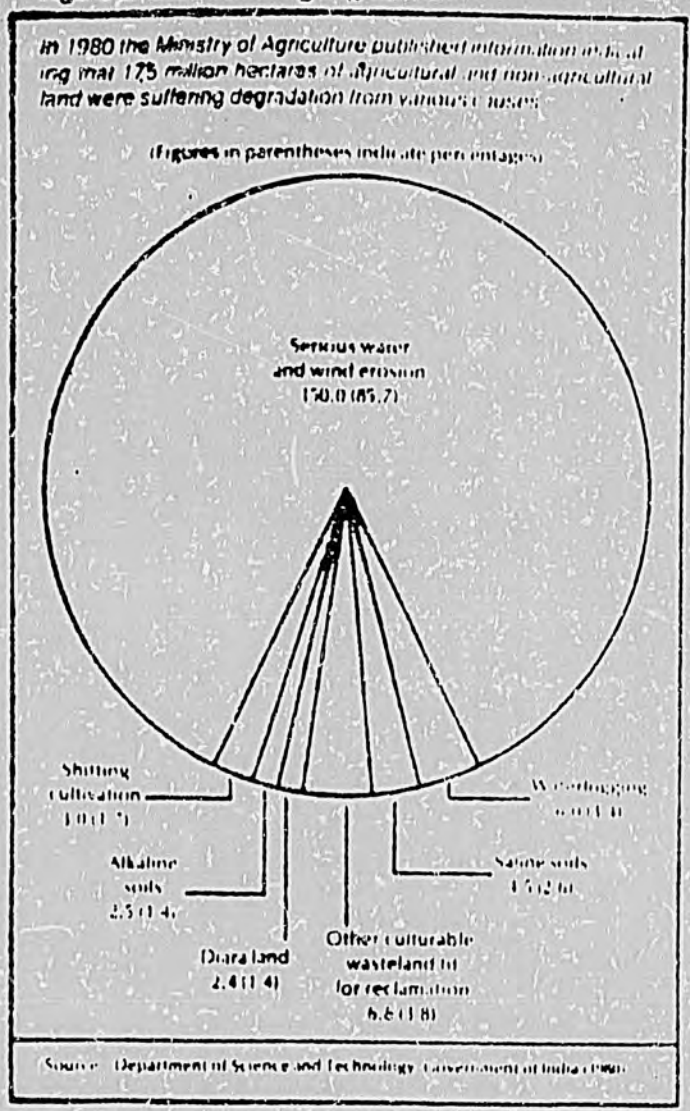
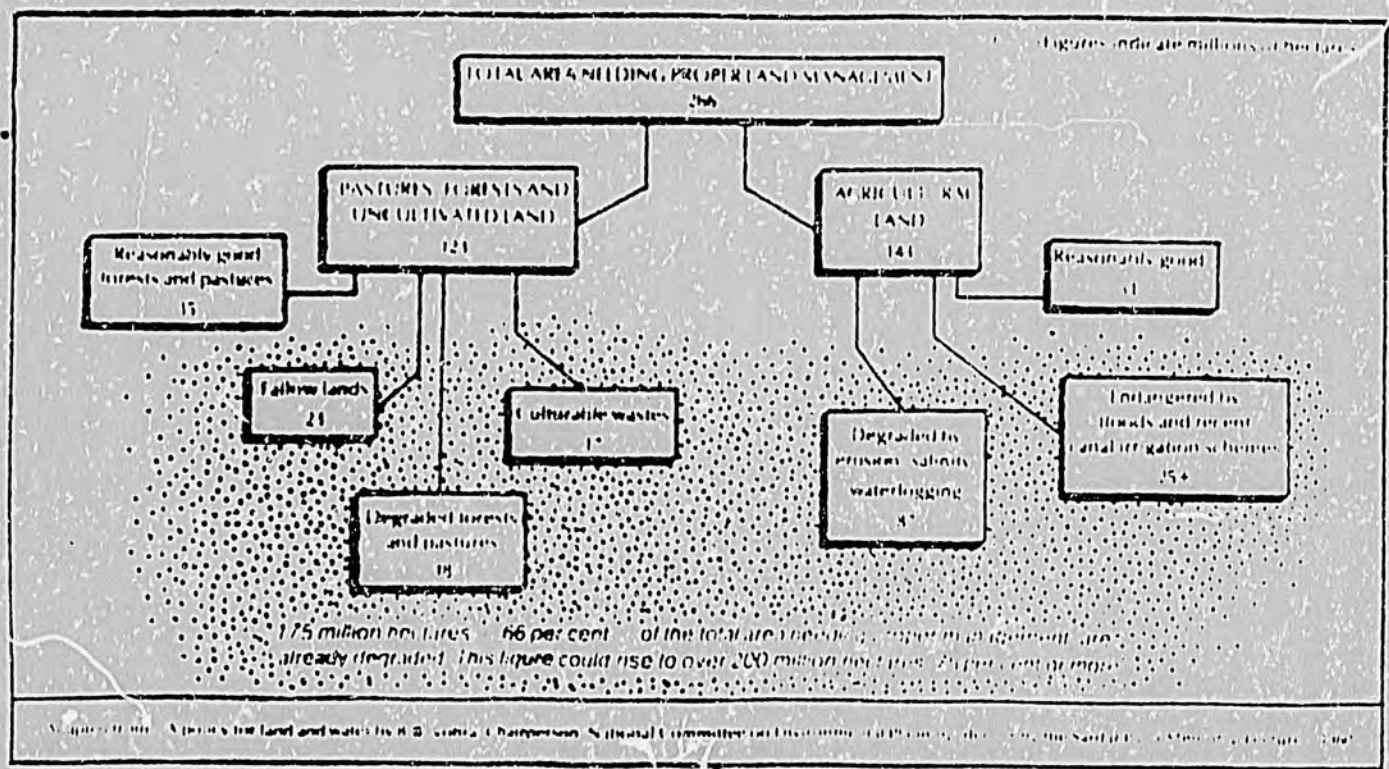


Figure 3. Estimates of land that is wasted, under-utilised and endangered



Appendix B

12 Indian biosphere reserves

By USHA RAI

NEW DELHI, September 27: India is to have 12 biosphere reserves in nine of the 12 biogeographic regions of the country. These regions range from the Himalayan highlands and the Thar desert to the Malabar rain forests and the Deccan thorn forests. A provision of Rs. 7.70 crores has been made for this purpose in the sixth Plan of the department of environment.

These reserves will preserve for posterity the most vital of the 45,000 species of plants in the country. About 150 economically important plants have been identified. Rice, the conservationists point out, originated in India. The best diversities of mango and lentils are also found here. All these were initially wild species. They can still be found in the wild in forests which will be incorporated in the biosphere reserves.

In addition to the plant life, 65,000 species of animals have been identified in India. These include 50,000 species of insects and 1200 species of birds. Many of them are endemic to this region. All of them will now come under the protective umbrella of the biospheres.

Though the idea of biosphere reserves was initiated by UNESCO in 1973-74 under the man and biosphere (MAB) programme and the first draft was prepared by the Tiwari committee on environment, the document was finalised only this year by the department of environment. It has been approved by the committee of secretaries headed by Mr Krishnaswamy Rao Sahib as well as the standing committee of the Indian board for wildlife.

Dr. T. N. Khoshoo, secretary (environment), will present the paper on the Indian approach to the biosphere reserves programme at an international conference on biosphere reserves at Minsk in Russia this week.

Though India has 44 national parks and 207 sanctuaries which play a key role in conservation, it is felt that the conservation of plants and the biotic community as a whole has not received sufficient attention. The focus has so far been on conservation of major species of mammals. The sanctuaries and parks do not cover adequately the ecological diversity of the threatened habitats or study of the conservation of plants and gene pools of economically important plants and animals. In some areas there has been undue emphasis on tourism. Research and scientific management is lacking in most protected areas.

The significant gaps in the existing network of national parks and sanctuaries are to be covered by the biosphere reserves. Each reserve is expected to be large enough to be an effective conservation unit.

The 12 biosphere reserves are to be set up in the Nilgiris — Tamil Nadu, Karnataka and Kerala, Namdapha in (Arunachal Pradesh), Nanda Devi (Uttarkhand valley of flowers) in U.P., north islands of the Andamans, the Gulf of Mannar in Tamil Nadu, Kaziranga in Assam, the Thar Desert in Rajasthan, Manniss in Assam, and Nokrek (Tura range) in Meghalaya.

The first four biosphere reserves, the project reports for which are ready, are to be set up in the next two years. The Nilgiri biosphere has a core area of 2020 sq kms. It supports 100 species of mammals, 550 of birds and 80 of reptiles and amphibians. About 3,500 of the 13,000 species of known flowering plants are from this region.

The Namdapha reserve will have a core area of 3500 sq kms. It has 50 species of mammals, 560 of birds and 90 of reptiles. Though the Nanda Devi reserve will have a smaller core area — just 800 sq kms — it supports 86 species of mammals, 534 of birds and 45 of reptiles. This area is rich in herbs — 552 species. It has 18 varieties of grass and 341 species of trees.

The Uttarkhand biosphere reserve will have a core area of 1800 sq kms. It is rich in flora with over 1300 species.

About 58 countries have so far set up 215 biosphere reserves. The Indian biosphere will become a part of the worldwide network maintaining established standards and facilitating exchange of scientific information.

The department of environment has been recognised as the nodal agency for the biosphere programme. Biogeographic regions and vegetation types have been mapped out, critical areas identified and intensive study done.

The Central government will bear the cost for the establishment and maintenance of the reserves. The cost of acquisition of land will be shared equally by the Centre and the concerned states. Initially, the reserves will come under the legal purview of the Wildlife Protection Act, 1972.

The MAB programme seeks to involve the local population in the research projects as well as maintenance programmes. It is feared that as the population increases and resources become scarce the pressures on nature will increase. Unless the local population has a permanent stake in the reserve, its long-term development cannot be guaranteed.

Paryavarn kendras (environmental centres) will be set up in each reserve to educate students, teachers of botany and biology and the public at large about environment.

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ANNEX C: ENERGY

I. Overall Development Context:

Energy is a vital input to agricultural and industrial development; per capita GNP is closely correlated with per capita commercial energy use (see Appendix A).[1] In 1980, India with a per capita GNP of about $235, consumed about 0.13 tons of oil equivalent per capita. If India is to achieve by the year 2000 the same per capita GNP as Thailand in 1980 ($670), then it will need something like 250 million tons of oil equivalent (TOE), compared with 105 million TOE in 1980/81. This prospect represents a formidable task even if world oil prices remain stable in real terms.

As shown in Appendix B, India's commercial energy needs have increasingly been met by oil. Since 1975 oil consumption has steadily risen from 24 million tons in 1975/76 to an estimated 36 million tons in 1982/83 (see Appendix C).[2] The Chairman of ONGC estimates that demand will reach 54 million tons 1988/89.[3] With increased volumes and prices for oil imports, India in 1980 was paying an equivalent of about 80% of its total export earnings for imported oil, compared with 20% in 1973 (see Appendix D). India, like other developing countries, was forced to borrow heavily to pay for this oil (see Appendix E). With increasing domestic oil production and declining oil prices, oil import costs in 1982/83 of nearly 6 million crores have dropped to an estimated 66% of total export earnings.[4] But this level still represents an unsustainable drain on the economy and a brake on new resource mobilization and investments. Prospects for increased domestic oil and gas production are good, however, and one forecast has India meeting 80% of its oil needs from domestic sources by 1985, against 45% at present.[5]

The higher prices for oil have been passed on to domestic consumers. The fuel price index increased by 700% between 1960 and 1980. These price increases have put the price of oil and other commercial energy out of the reach of the lower income groups and kept them dependent on traditional sources of energy. At the same time, population pressures and shortages of fuelwood pushed up prices for wood in urban markets. Appendix F shows the close correlation between commercial and firewood prices.

India remains over 50% dependent on traditional or "non-commercial" energy. The Asian Development Bank estimated Indian non-commercial energy use at about 120 million tons of oil equivalent in 1978 (see Appendix G). Growth in non-commercial energy use is assumed to have grown about 1.7% per year since 1965, but no reliable statistics are available over time. Most of the traditional energy is used for cooking and heating purposes in the household. As Appendix H reveals, the bulk of the non-commercial, household energy consumption is in rural areas. Wood, including logs, twigs, branches, etc, is the dominant type of household fuel except in U.P, Bihar, Punjab, Haryana and West Bengal where dung and agricultural residues are of equal or greater importance (see Appendix I). According to the NCAER nation-wide survey, logs accounted for 43% of household wood consumption (in coal replacement equivalents). Some positive relationship seems to exist between a state's household energy consumption of logs and its classified forest area (see Appendix J).

GOI policies and financial allocations give high priority to developing India's indigenous oil, gas and coal resources. Prime Minister Gandhi, at the recent World Energy Congress, stated: "Our planning gives priority to energy, next only to agriculture."[6] The Sixth Five-Year Plan allocates 26,535 crores to energy or 27.2% of public sector development expenditures. Of this, power receives 73%, coal 11%, oil 16% and non-conventional energy 0.1%.[7] When the 5 million crores for forestry are added, the energy investment exceeds 30% of the Plan total. If transportation and fertilizer expenditures are included, the overall energy-related expenditure level is closer to 40% of the Plan outlays. These figures do not include R&D expenditures.

Despite the large investments in power, shortages are occurring in virtually every state, with an overall annualized average shortfall of about 9%. Blackouts and brownouts are seriously affecting industries and reducing the efficiency of energy, capital and labor utilization. Industries are purchasing oil-based captive power units to ensure reliable power. Electricity consumption has increased steadily (see Appendix K) with agricultural demand particularly strong as the number of tubewells increases

II. GOI Objectives, Priorities and Policies for R&TD

The Government of India supports a broad-based research and technology development program in the energy sector. The basic thrust of this effort is towards:

- improvement and adaptation of existing technologies with emphasis on conservation;
- development of more efficient technologies for utilizing indigenous conventional sources of energy;
- development of renewable energy technologies.[8]

The cited report describes the needs and R&D priorities in the coal, oil, nuclear, power, conservation and alternative energy sub-sectors (see Appendix L).

The Department of Science and Technology reports that total R&D expenditures (central, state, and private) in 1980/81 on energy production, conservation, and distribution of energy totaled Rs. 8775.44 lakhs or about 12.5% of overall R&D expenditures. The central government provided Rs. 7615.90 lakhs (mainly in nuclear and petroleum areas), the private sector supplied Rs. 1032.87 lakhs, and the state governments a nominal amount. Energy represented 14% of central government R&D expenditures.[9]

Two areas of increasing priority for R&TD are coal and biomass. India has the largest coal resources in the developing world with over 100 billion tons of probable reserves. The coal is, however, of poor quality (unsuited for export) with an average ash content of between 35-40%. This ash content is increasing as a larger percentage of coal comes from open-pit mines. This ash factor complicates boiler operation and adds significantly to the cost of coal transportation. India is therefore keenly interested in technologies for beneficiation (cleaning), transport (i.e., slurries) and utilization of low quality coals (fluidized bed, coal gasification, coal-water mixtures).

With the introduction of fast-growing trees in the State Social Forestry Programs and the improvement in technologies for biomass conversion, the GOI is taking an increased interest in research and development in both biomass production and utilization. Energy is a prime focus of the "Long Term Plan in Biotechnology for India." Five research objectives for biotechnology are laid out for the energy sector:

(1) improved methods of producing gases and liquid fuels from various organic wastes including distillery wash;

(2) conversion of lignocellulosic materials with biofuels, SOP and chemicals;

(3) newer techniques of selection and propagation of woody plants for reforestation, energy plantations and social forestry (biomass production);

(4) development of novel immobilized bio-reactor systems for the production of ethanol and methane;

(5) utilization of bioreactor effluents for the production of biomass, for fuels and for fuel purposes.[10]

Prime Minister Gandhi stressed biotechnology research in her address to the World Energy Conference in New Delhi on September 18, 1983. She called for urgent action in the following research areas:

(a) The application of new biological advances in biomass production (e.g., tissue culture, protoplast fusion, genetic engineering, nitrogen fixation, improved photosynthesis, etc.), particularly on lands not suitable for agriculture;

(b) Photochemical techniques to produce hydrogen to be used as mobile fuel;

(c) Energy storage devices to make transportation less dependent on oil;

(d) Photovoltaic devices to provide electricity directly from sunlight costing 10 to 100 times less than today;

(e) Integrated energy systems to optimally meet a variety of needs.[11]

III. Major Current R&TD Institutions and Programs in the Sector

The emphasis below is on coal and biomass, two areas of significant energy potential where a basis for collaborative Indo-U.S. research has already been established.

Coal R&TD[12]

India has a relatively large coal R&TD program focused in Bharat Heavy Electicals Limited, with labs at Trichy and Hyderabad; and the Central Fuels Research Institute (CFRI) at Dhanbad, and the Regional Research Institute at Hyderabad. BHEL is a first-rate company with programs in atmosphere fluidized-bed; pulverized coal firing; combined cycle (6 mw gas/steam power plant); combustion of coal/oil and coal/water mixtures in small, oil-fuel industrial boilers; pressurized fluidized bed gasification and combustion.

The CFRI is a CSIR laboratory with extensive pilot plant facilities for coal analysis:

- composite coal washing (40 tons/hr.);
- oil agglomeration plant (100 kg/hr.);
- low-pressure briquetting plant (1.5 tons/hr.);
- fluid bed carbonization plant (2 tons/hr.);

- fluid bed combustion plant (2 tons/hr.);
- fixed bed gasification unit (1 ton/hr.);
- Fischer-Tropsch plant (5 liters/day);
- high-pressure vapor-phase hydrogenation plant (0.5 TPD);
- K-T and Winkler plants.

Of particular interest is their work on coal liquid mixtures. CFRI has prepared and tested 20% of coal in coil and has initiated stablization and rheological tests with coal-water slurries.

RRL-H is the largest of the coal laboratories, with over 500 scientists and engineers. It is a center for graduate studies as well as research. Like CFRI, RRL-H has facilities for gasification and coal liquids analysis. RRL-H is collaborating with BHEL in a fluidized bed research program.

Biomass R&D

Major biomass production research programs were discussed in the forestry and environment sector annex. The Department of Non-Conventional Energy (DNCE) is also sponsoring several projects on petroleum yielding plants -- one at the University of Rajasthan on Euphorbia Cathyris and one at NBRI in Lucknow. NBRI has identified 22 promising species out of 380 potential species. Latex from these species has been analyzed by the Indian Institute of Petroleum, Dehra Dun for chemical characteristics. A second phase is planned on the techno-economics of cultivation of promising species and the building up of a germplasm bank of selected species.[13]

DNCE is considering a feasibility report on Biomass Energy for Agricultural Societies, prepared by Hindustan Aeronautics Limited of Bangalore. The report proposes to use non-edible agricultural residues at major processing plants to fuel two externally-fueled gas turbines.

The other major area of research interest is the conversion of biomass to liquid fuels and methane through improved microbial and enzymatic processes. The leading work in India is being performed at the Biochemical Engineering Research Center, Indian Institute of Technology (IIT). They are focusing on (1) pretreatment of ligocellulosics; (2) production of high activity cellulase; (3) ethanol fermentation via novel routes; (4) design of reactors for both microbial and immobilized enzyme processes; (5) conventional as well as microprocessor coupled fermentation and process simulation; (6) biochemical and physiological aspects of microorganisms via molecular and cellular approaches.[14] IIT is receiving funds from DST for this research.

In the private sector, Jyoti Limited in Baroda is conducting research and development on small gasifier systems of 5KW or less that can operate on various kinds of agricultural residues. AID is sponsoring colla' ative research and technology development with Jyoti Solar Energ. Institute and IIT (Delhi) in these systems, which are being coupled to diesel engines for use in water pumping or electricity production. Jyoti is also manufacturing solar panels and small hydro turbines.

Other R&D

Research on solar, wind and small hydro technologies is being conducted at numerous institutes in the country. Leading centers are the Central Electronics Laboratory in Photovoltaics, BHEL and the Indian Institute of Sciences (Bangalore) in solar thermal, and the University of Roorkee in small hydro. The Department of Non-Conventional Energy has recently established a solar thermal center outside of New Delhi for testing and standards development for solar thermal systems.

IV. Current USG-Supported R&TD Efforts

AID has two current projects in the energy sector. A Technologies for the Rural Poor project is financing collaborative research between U.S. and Indian institutions in solar rice drying (CSU and Annamalai U.); solar parabolic collectors for process heat (U. of Houston and IIS Bangalore); solar village field test (JPL and BHEL); and electronic controlling and innovative end uses for mini-hydro (Boston U. and U. of Roorkee). These projects follow a model not dissimilar to the STI approach and emanated out of proposals from the Indian side at meetings of the Subcommission on Science and Technology.

The second project ("Alternative Energy Resources Development") involves four principal activities: (1) institutional and research support for the biomass centers at NBRI and Madurai Kamraj U. (see Forestry and Environment Sector);
(2) collaborative research and professional development in coal and biomass conversion technologies; (3) technical information exchange on energy conservation in specific industries; (4) technical information exchange in new and renewable energy, with initial focus on thin-film solar thermal systems.

Both projects involve cooperation with the U.S. Department of Energy. For the JPL-BHEL project, DOE is providing SFC for the rupee costs. Under the second project, DOE's Pittsburgh Energy Technology Center is providing technical program management for the coal and biomass conversion components.

V. Constraints to More Effective R&TD in the Sector

Three basic observations can be made about the Indian energy R&TD program as it relates to coal and renewables: (1) little overall technology and economic planning exists that systematically examines policy and research options. As a result, few decisions are made which focus research on economically viable, high pay-off areas; (2) much unnecessary duplication exists within government labs that for the most part reinvents the technologies developed in the industrial countries; (3) very little interaction takes place between the government research laboratories and private industry in the planning of tests and field demonstrations, thus helping to ensure that the technology in question will be looked at sceptically by private industry.

VI. Sector Elements of a Ten-Year R&TD Program

Numerous areas exist where a useful long-term collaborative program in alternative energy technologies might be pursued, i.e., coal, biomass, solar. These technologies are all keyed to India's future energy development and the U.S. has a strong research base. Yet a basic problem exists in structuring such a program. The technological expertise on the U.S. side rests principally in our private companies, not in the universities or national laboratories. The DOE laboratories offer a mechanism acceptable to the Indians for interacting with U.S. private companies. But it is probably a second best approach to direct licensing or joint venture arrangements. It is also not clear what the balance should be in AID's thinking between promoting Indian access to the best U.S. technology at the lowest cost as a spur to development and our support for U.S. commercial interests in selling and licensing the technology.

The Alternative Energy Resources Development project has been structured so that a mix of U.S. private and public sector institutions are involved. The Indians receive exposure to U.S. private industry and U.S. experience in coal, biomass, and solar area plus an opportunity to discuss possible commercial deals. The project is just beginning and the specific work plans for collaboration are not yet finalized. At this juncture a continuation of the current technical exchange and professional development activity in new coal and biomass conversion technologies, i.e., fluidized bed, beneficiation of lignites, coal water mixtures, coal and biomass gasification/combined cycle, and coal and biomass liquefication, offers the best prospects for making a substantial impact on Indian energy R&D policy and planning for major energy investments in both the centralized and decentralized sectors. A coal and biomass workshop is planned for this fall that will provide a basis for evaluating the feasibility of a long-term program. Several U.S. private companies will be attending this meeting and will provide a gauge as to whether AID can serve as a catalyst for

promoting cooperative R&D, licensing or joint venture arrangements. If this activity proves effective, then plans for a larger and longer-term (i.e., seven-year) follow-on project in FY 86 should be pursued. A reasonable cost estimate for a ten-year program of collaborative research and professional exchange is $15-25 million including about half for research. An illustrative budget is contained in Appendix M. A major coal or biomass demonstration plant, e.g., for fluidized bed, could cost this much itself, and it might be cheaper to undertake such an effort in India than in the U.S. The Indian side would like such a visible demonstration project and would probably be willing to put up at least 80 percent of the costs. This option should be explored in the future.

Notes

[1] For India, the correlation coefficient (R^2) for GDP/Commercial energy use for 1960 to 1981 (selected years) is .99. The coefficient of multiple correlation between GDP, population and urbanization and commercial energy use over the same period is .997.

[2] World Bank, Staff Appraisal Report for Krishna-Godavari Petroleum Exploration Project, Sept. 10, 1982, p. 470.

[3] Times of India, Sept. 20, 1983, p. 11.

[4] Center for Monitoring Indian Economy(CMIE), Current Energy Scene in India, May 1983, p. ii.

[5] Times of India. op.cit., p. 130.

[6] Prime Minister Indira Gandhi, Inaugural Speech to the World Energy Conference, New Delhi, September 18, 1983.

[7] CMIE, op.cit., p. 2.

[8] GOI, Planning Commission, Report of the Working Group on Energy Policy, New Delhi, 1979, p. 100.

[9] GOI, Department of Science and Technology, Research and Dev. Statistics 1980/81, pp. 64-5.

[10] National Biotechnology Board, Department of Science and Technology, Long-Term Plan for Bio Technology in India, April 1983, p. 8.

[11] P.M. Indira Gandhi, op.cit.

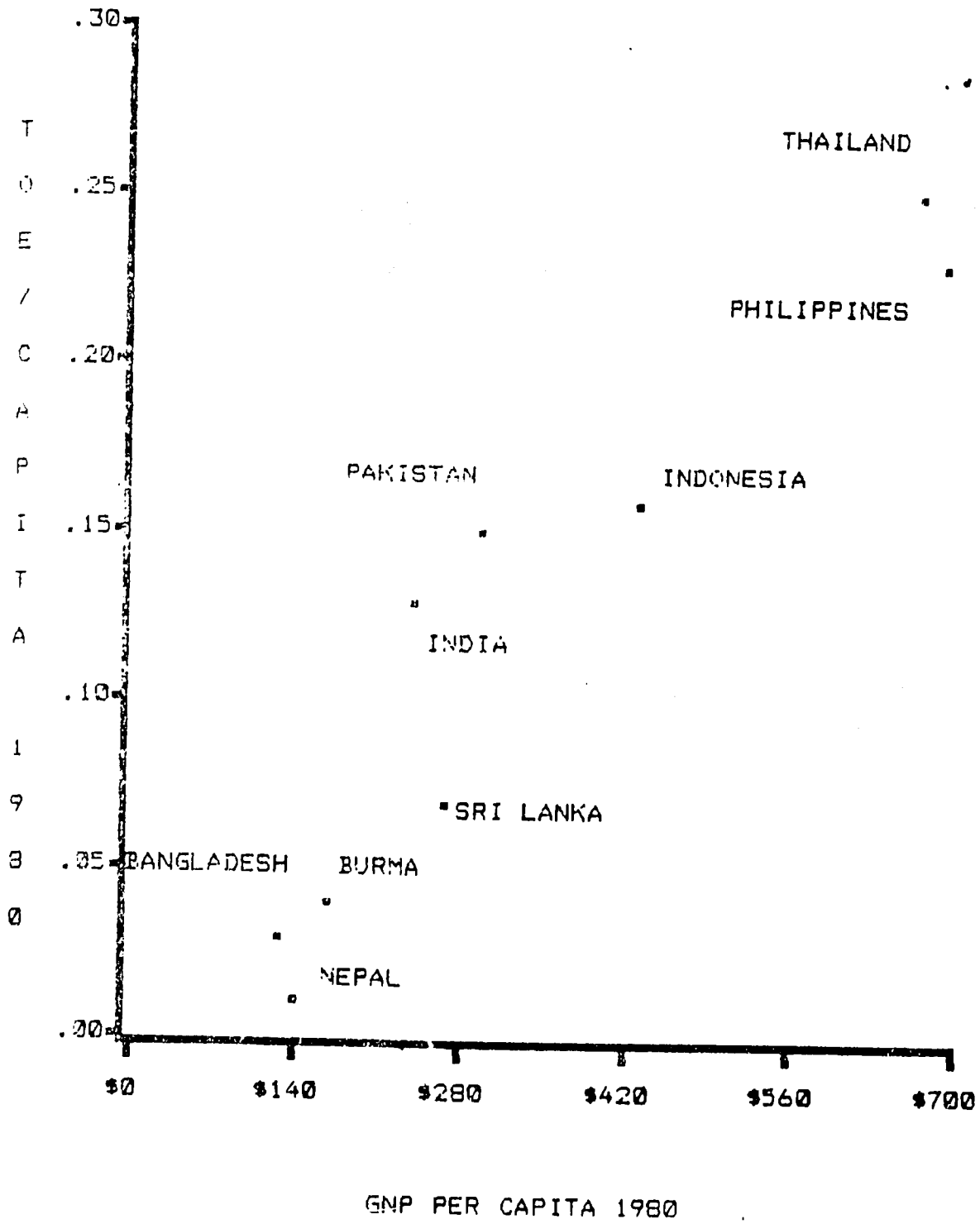
[12] This section is drawn from the Trip Report of the PETC Team to these institutions in May 1983.

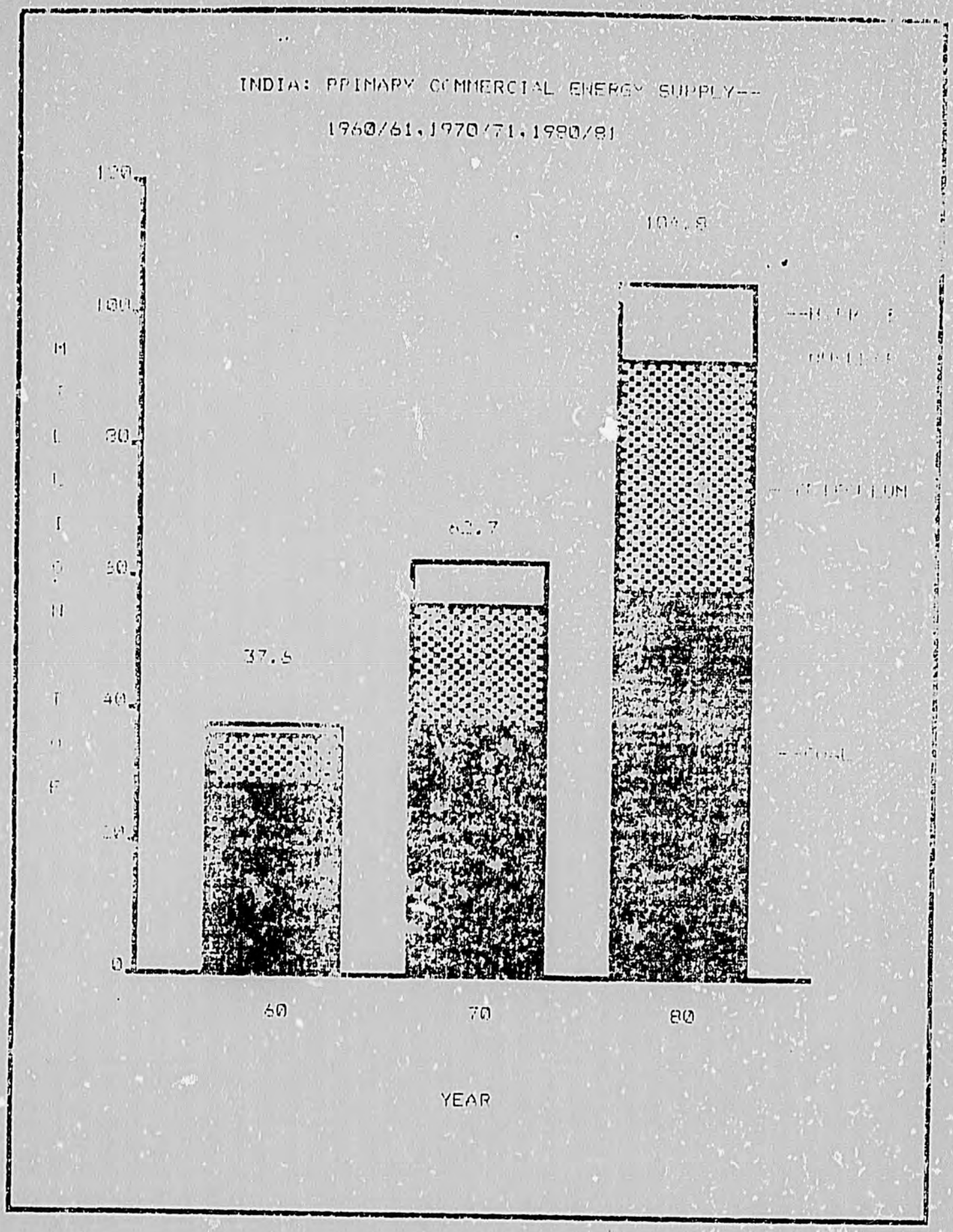
[13] GOI, Department of Non-Conventional Energy, Annual Report 1982/83, p. 25.

[14] Indian Institute of Technology. "Academic Training, Research and Development in Biochemical Engineering and Biotechnology," pp. 3-4.

CHART VI

PER CAPITA COMMERCIAL ENERGY USE VS. GNP/CAPITA




INDIA: PRIMARY COMMERCIAL ENERGY SUPPLY--
1960/61,1970/71,1980/81
120
100
80
60
40
20
0
37.5
60
70
80
YEAR

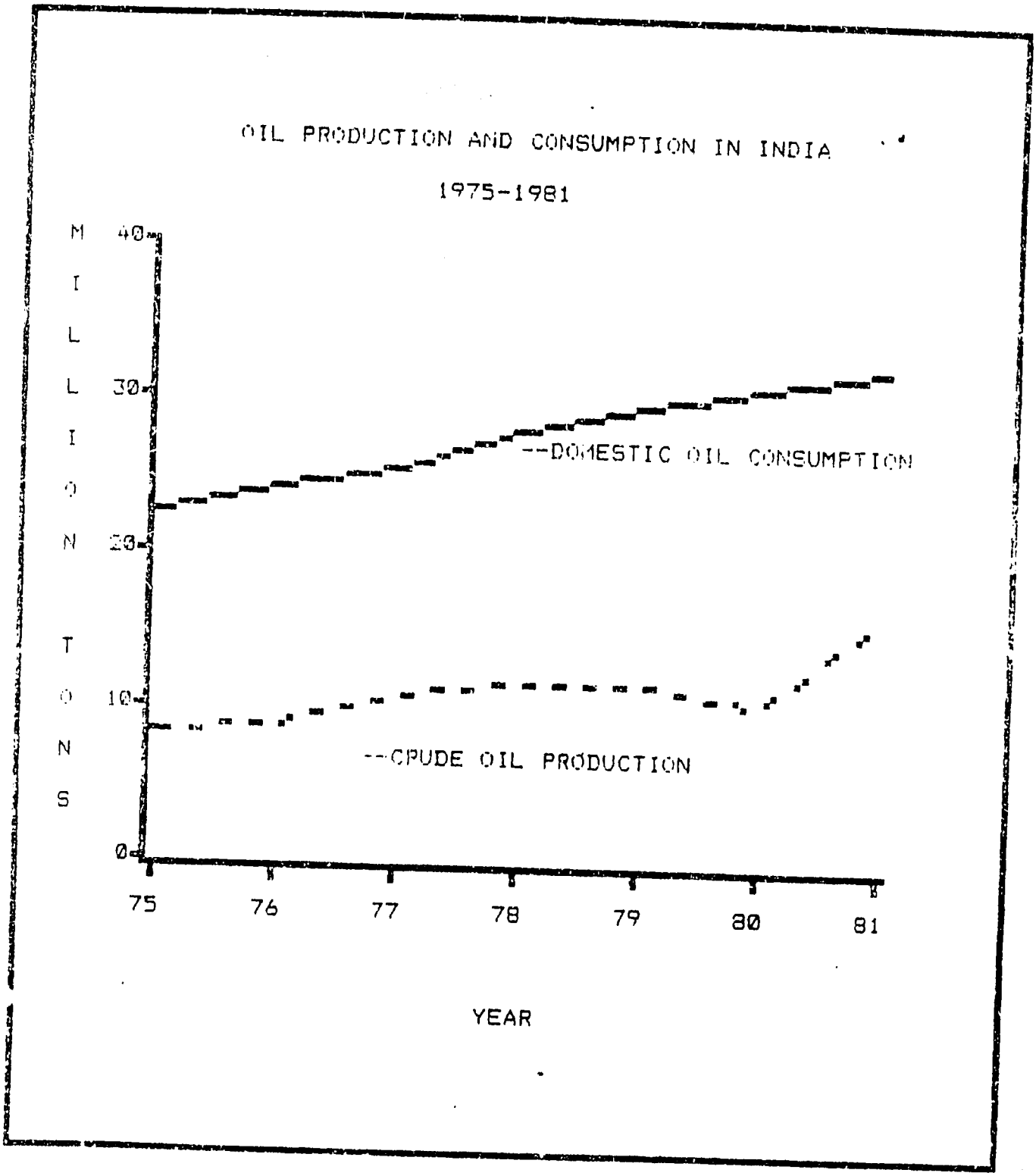
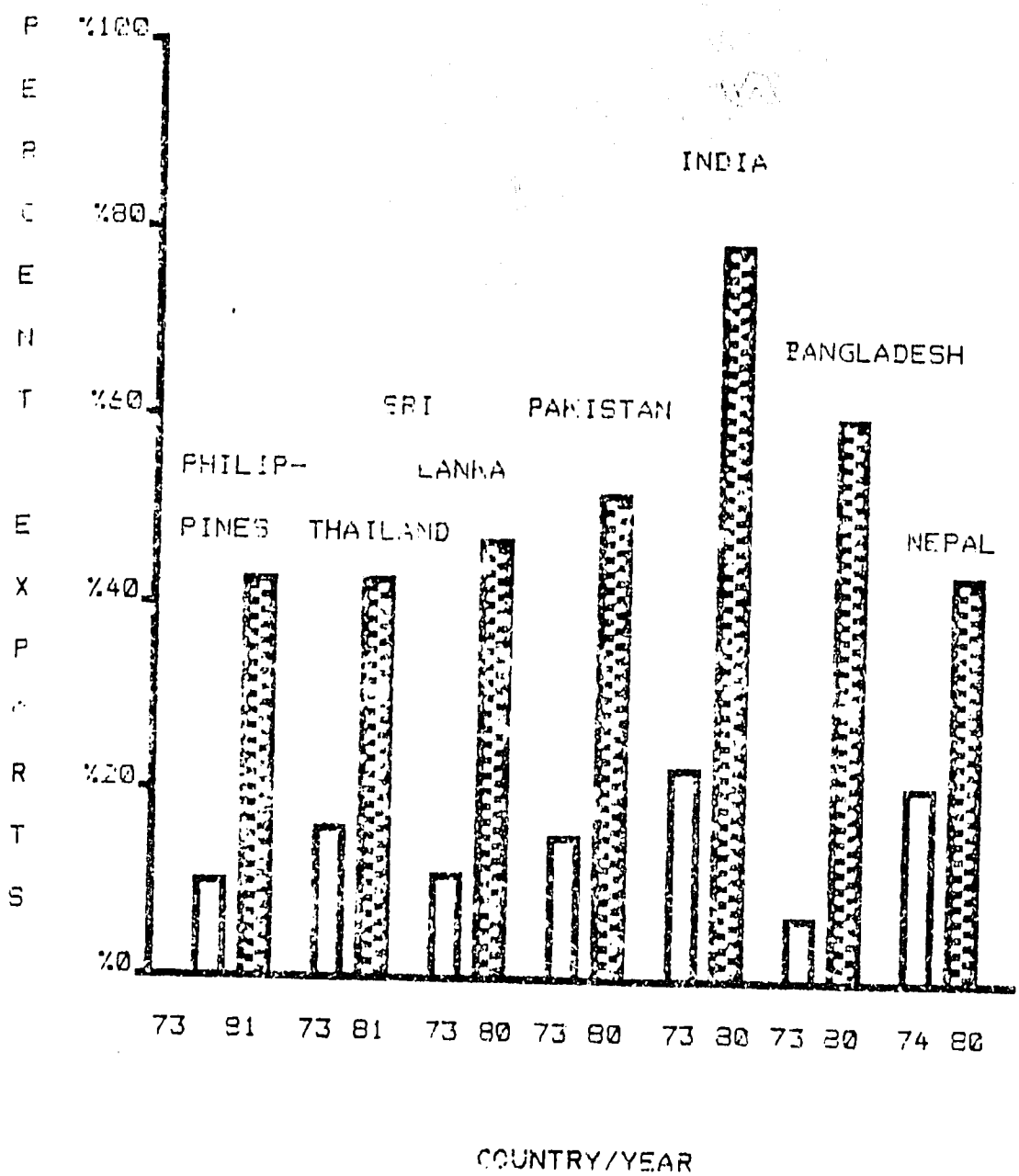

OIL PRODUCTION AND CONSUMPTION IN INDIA
1975-1981
MILLION TONS
40
30
20
10
0
--DOMESTIC OIL CONSUMPTION
--CRUDE OIL PRODUCTION
75
76
77
78
79
80
81
YEAR

CHART V

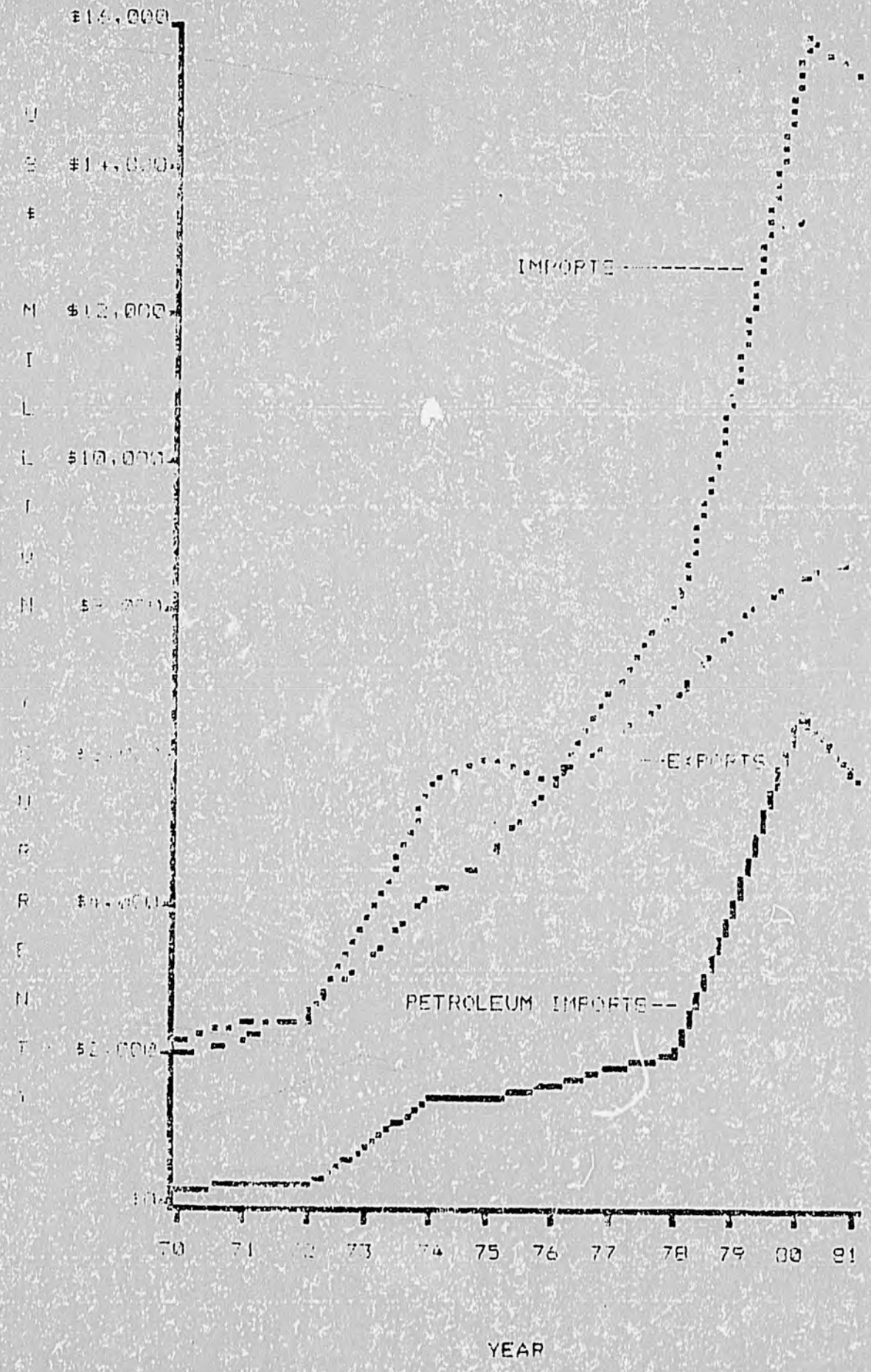
PETROLEUM IMPORTS AS % OF EXPORT EARNINGS

IN AID ASIA COUNTRIES: 1973/74 & 1980/81



INDIA: PETROLEUM IMPORTS VS. IMPORTS/EXPORTS

(1970/71 -- 1981/82)

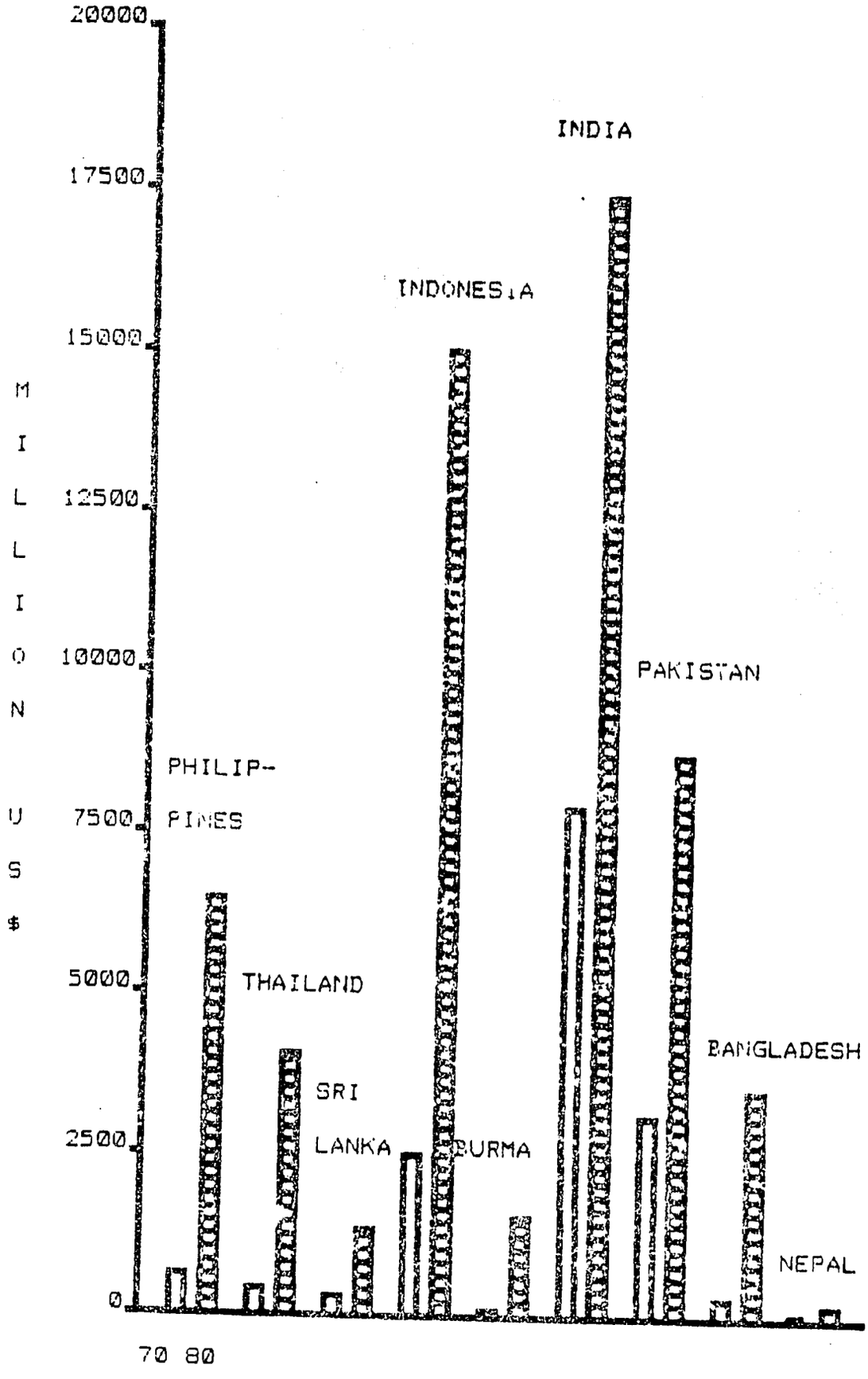


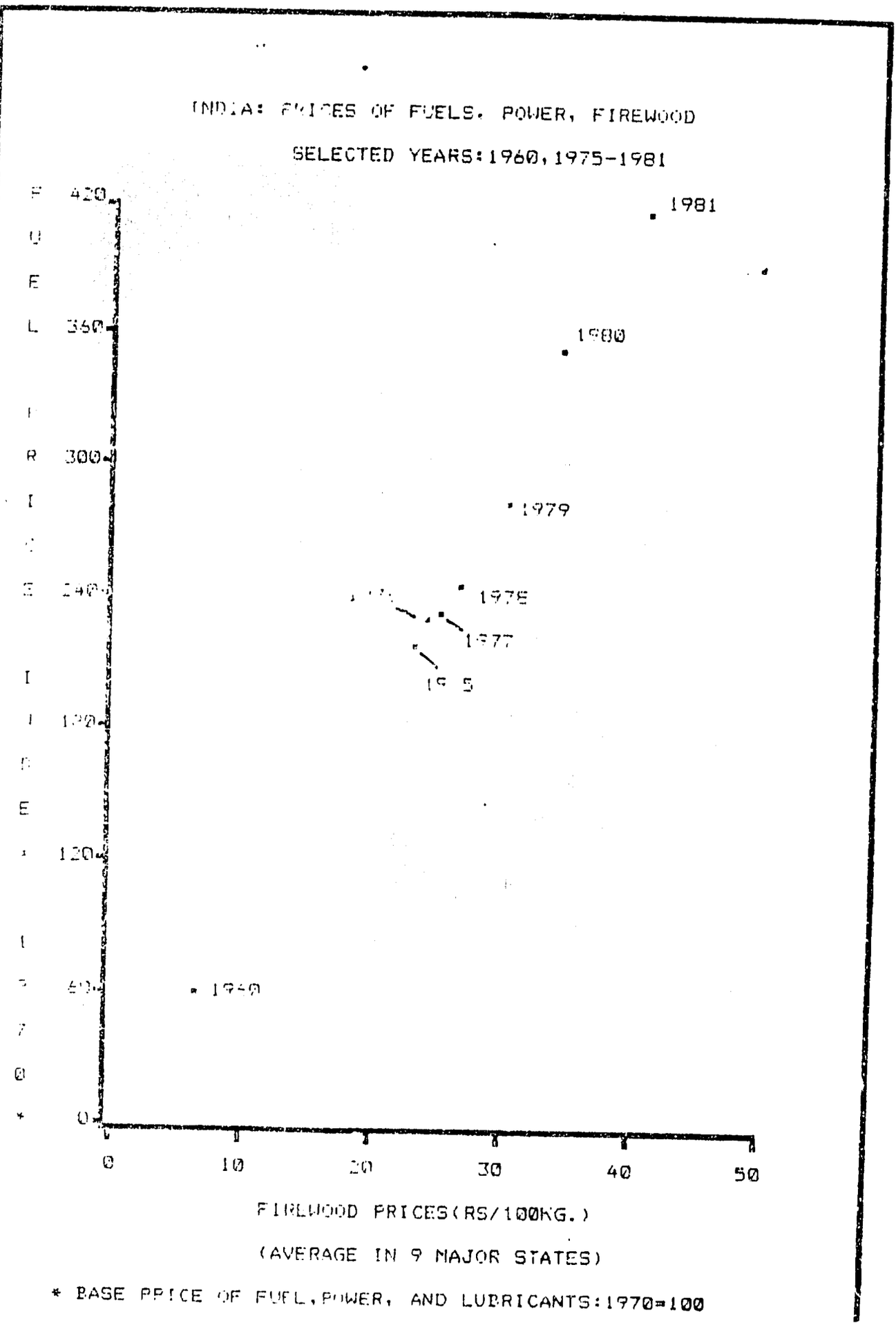
APPENDIX E

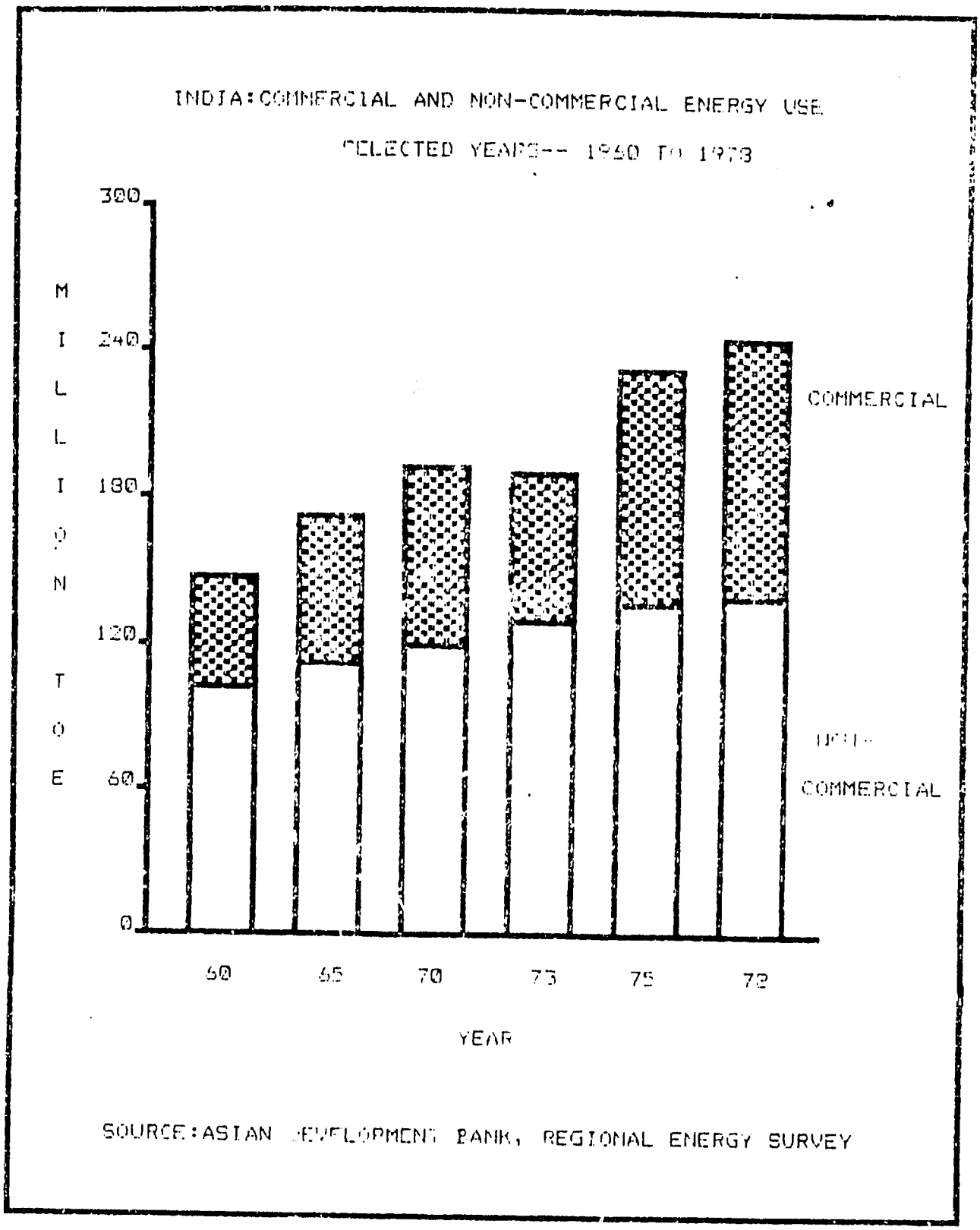
~~CHART IV~~

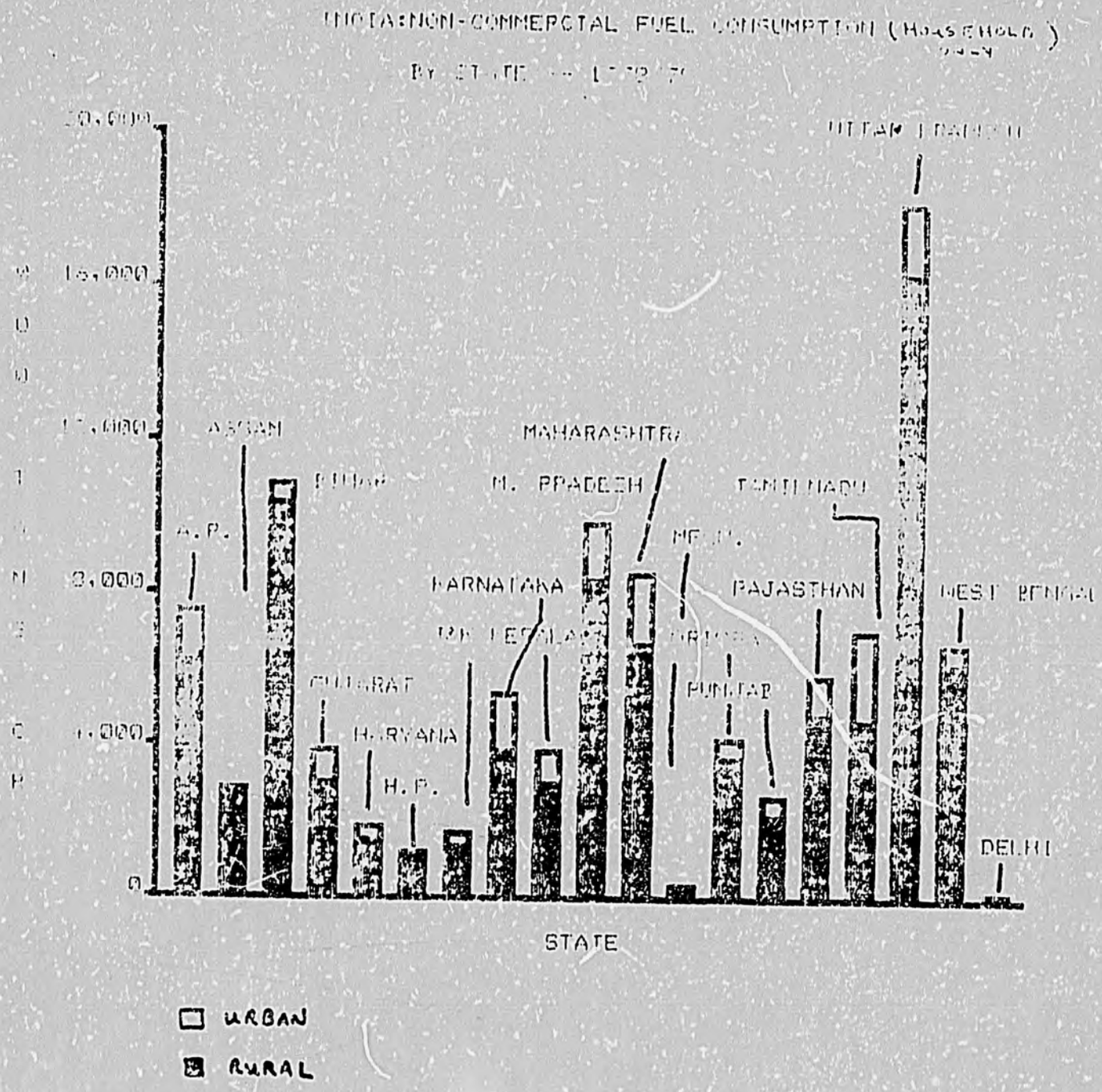
DISBURSED EXTERNAL PUBLIC DEBT

IN AID ASIA COUNTRIES: 1970 AND 1980



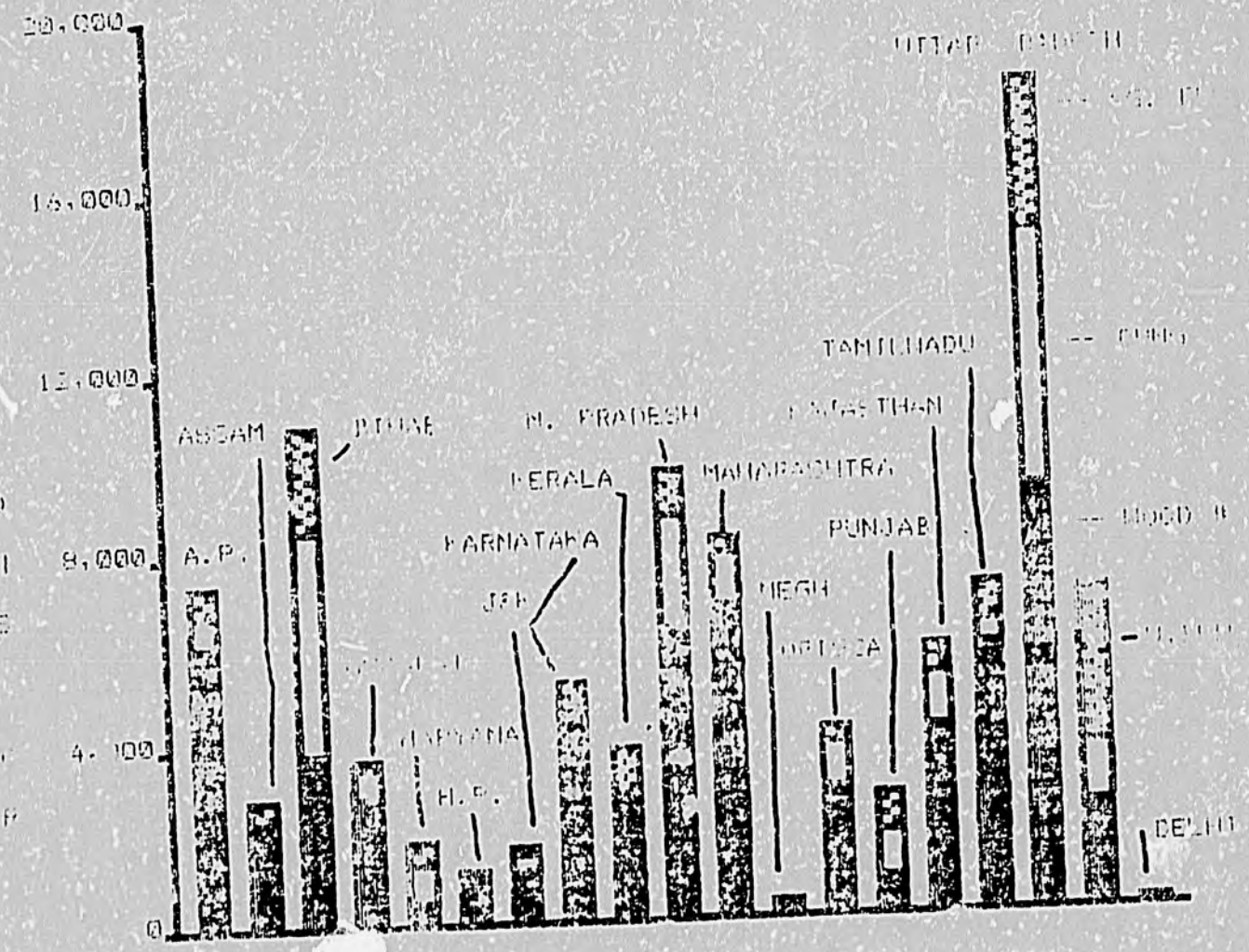

INDIA: PRICES OF FUELS, POWER, FIREWOOD
SELECTED YEARS:1960,1975-1981
FUEL PRICE INDEX 1970 *
420
360
300
240
180
120
60
0
1981
1980
1979
1978
1977
1960
0
10
20
30
40
50
FIREWOOD PRICES(RS/100KG.)
(AVERAGE IN 9 MAJOR STATES)
* BASE PRICE OF FUEL,POWER, AND LUBRICANTS:1970=100


INDIA: COMMERCIAL AND NON-COMMERCIAL ENERGY USE
SELECTED YEARS-- 1960 TO 1978
MILLION TOE
300
240
180
120
60
0
COMMERCIAL
NON-COMMERCIAL
60
65
70
73
75
78
YEAR
SOURCE: ASIAN DEVELOPMENT BANK, REGIONAL ENERGY SURVEY


INDIA: NON-COMMERCIAL FUEL CONSUMPTION (HOUSEHOLD)
BY STATE
UTTAR PRADESH
MAHARASHTRA
M. PRADESH
TAMIL NADU
A.P.
KARNATAKA
RAJASTHAN
WEST BENGAL
GUJARAT
HARYANA
H.P.
DELHI
STATE
URBAN
RURAL

INDIA: NON-COMMERCIAL ENERGY CONSUMPTION 1[illegible]

BY STATE AND FUEL SOURCE (WOOD, DUNG, AG. RESI[illegible]



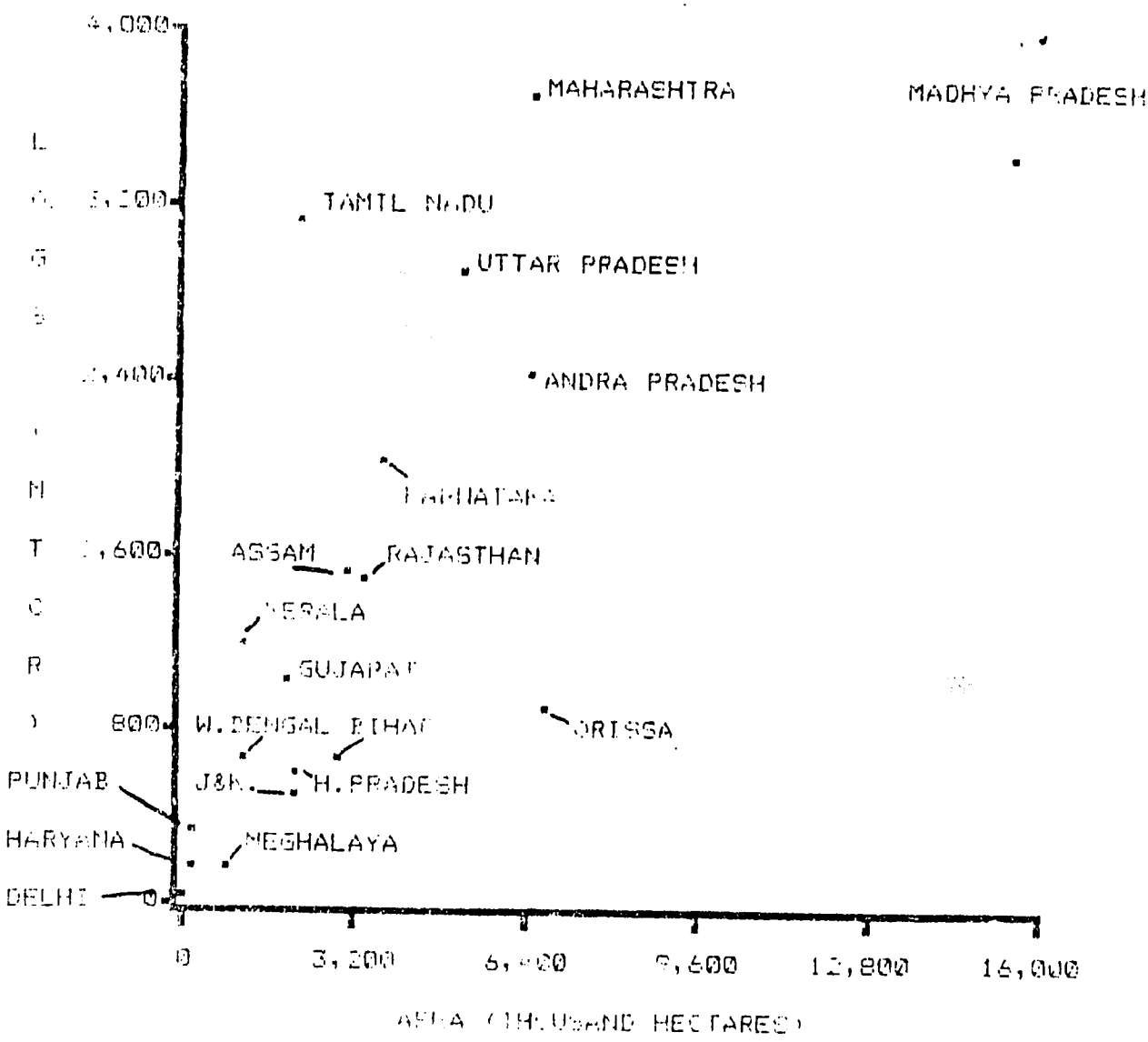
SOURCE: NATION[illegible] COUNCIL OF APPLIED ECONOMIC RESEARCH

WOOD = LOGS, TWIG, BRANCHES, SAWDUST, WOODSHAVINGS, CHARCOAL

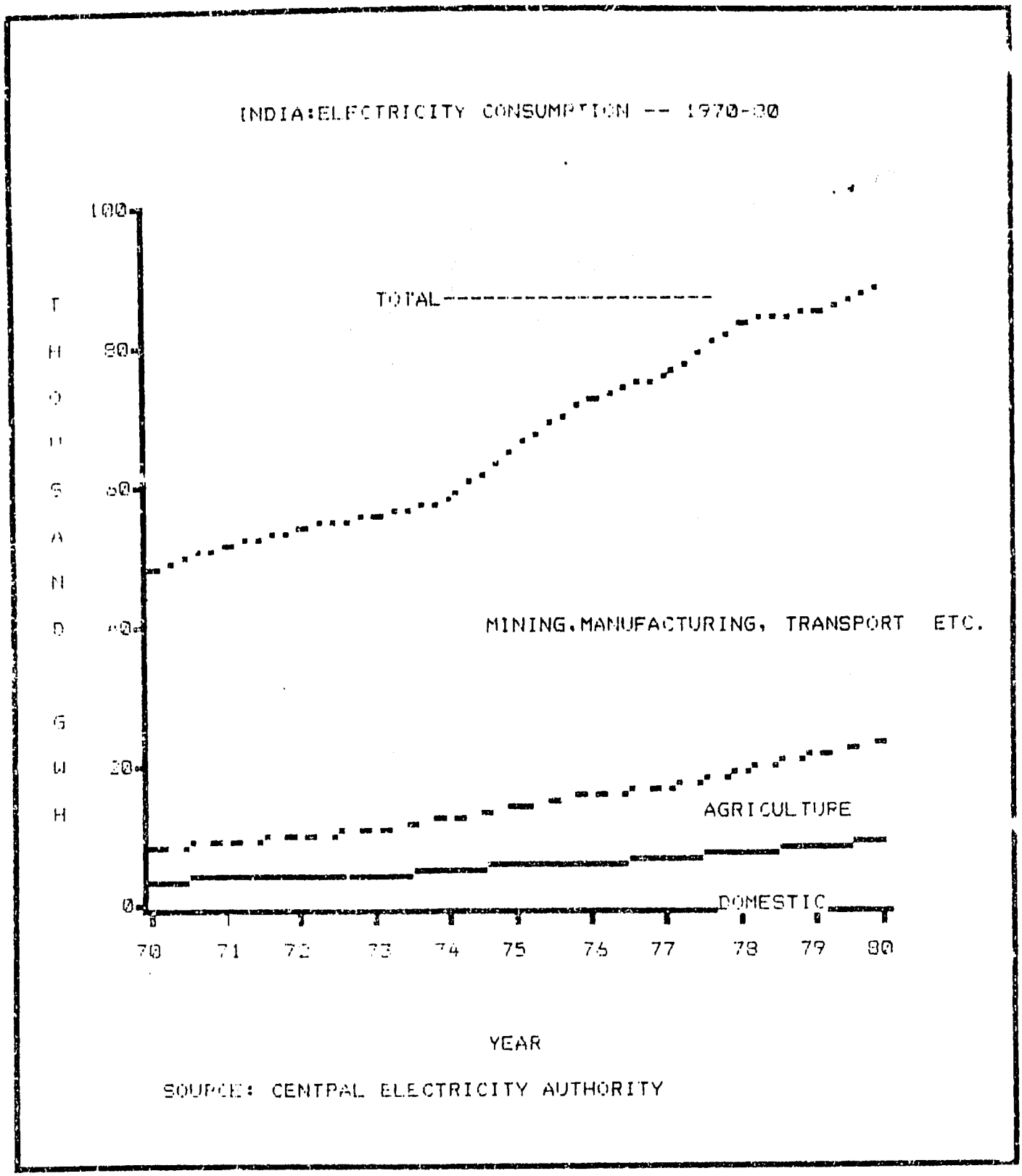
INDIA:

HOUSEHOLD LOG CONSUMPTION VS. FOREST AREA

1979/80

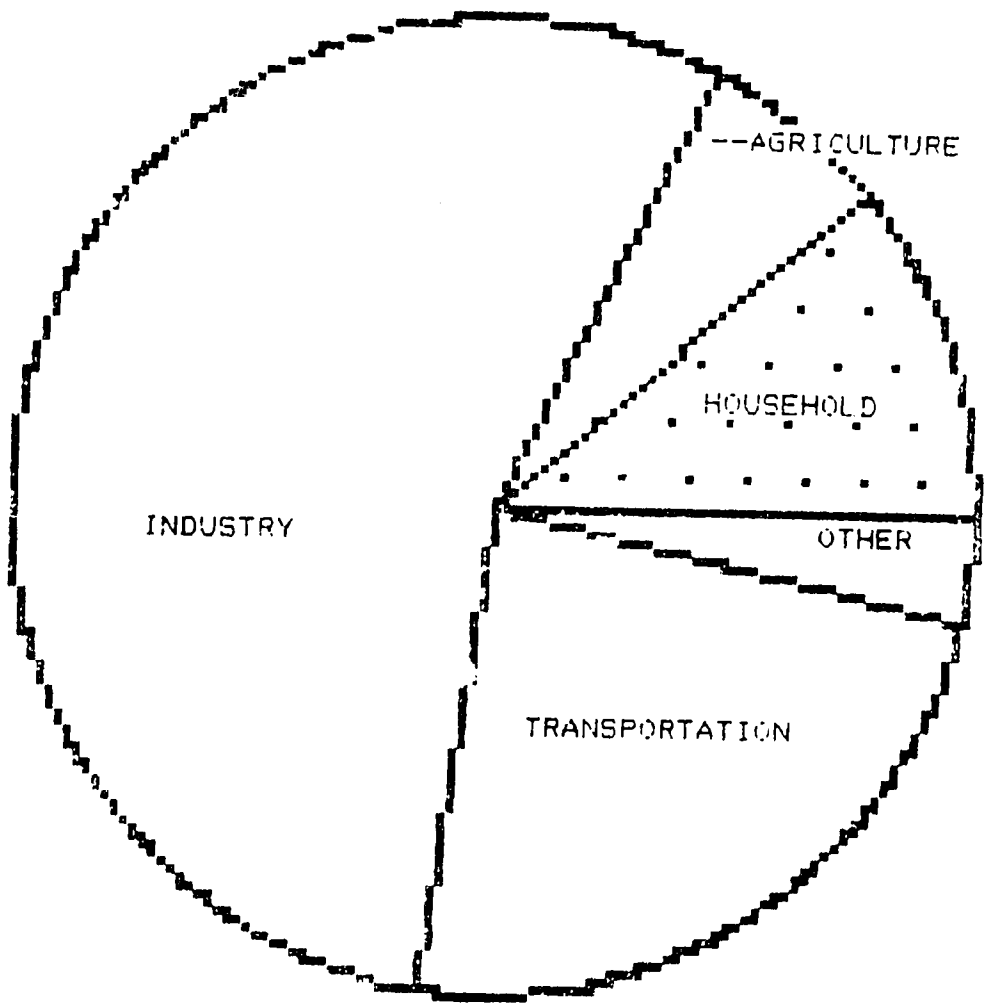


SOURCE: CENTER FOR SCIENCE AND ENVIRONMENT AND NATIONAL COUNCIL OF APPLIED ECONOMIC RESEARCH


INDIA:ELECTRICITY CONSUMPTION -- 1970-80
THOUSAND GWH
100
80
60
40
20
0
TOTAL
MINING,MANUFACTURING, TRANSPORT ETC.
AGRICULTURE
DOMESTIC
70
71
72
73
74
75
76
77
78
79
80
YEAR
SOURCE: CENTRAL ELECTRICITY AUTHORITY

COMMERCIAL ENERGY CONSUMPTION IN INDIA BY SECTOR

1980/1981



TOTAL CONSUMPTION= 81.6 MILLION TOE

CHAPTER XIV

RESEARCH AND DEVELOPMENT IN THE ENERGY SECTOR

14.1 Research and Development (R&D) in the energy sector would necessarily be related to and linked with the various policy prescriptions outlined in the earlier Chapters. It is not intended to catalogue all R&D programmes necessary to develop the energy sector; instead, R&D priorities and specific areas of thrust will be dealt with keeping in view the overall policy objectives. The Group is of the view that in order to tackle the complex technological problems of the energy sector, R&D efforts on a substantially increased scale would be essential. In the time frame considered in this report, it is clear that conventional sources of energy, together with non-commercial sources will be the mainstay of all major energy consuming sectors. The Group is cognizant of the imperative need for development of renewable sources of energy and their potential role in the future. The basic thrust of the R&D effort should be oriented towards:

— improvements and adaptation of existing technologies with emphasis on conservation;

— development of more efficient technologies for utilising our indigenous conventional sources of energy; and

— development or renewable energy technologies.

14.2 Coal will continue to be a major source of commercial energy in the foreseeable future and as such, programmes that enhance its production and promote its efficient utilisation in all the consuming sectors, should receive high priority. In the oil sector, R & D priorities should be oriented towards maximising recovery from the oil reservoirs and efficient utilisation in major sectors like transport, industry and household as well as towards interfuel substitution wherever feasible. R & D programmes in the electricity sector will have to have a high priority inconsonance with the power programme. In the area of alternative energy sources, R&D efforts in the fields of solar energy and biomass should be accorded high priority in view of their vast potential and their relevance to rural energy programmes.

14.3 Over the years, attempts have been made in the country to build up an R&D base in the energy sector. However, the Group feels that this is not commensurate with the total needs of the energy sector, both current and the future.

14.4 The responsibility for R&D is distributed among several Ministries/Departments and agencies. In some of the sectors like coal and oil R&D programmes are fairly well institutionalised. For example, in respect of coal, R&D efforts in the areas of coal surveys, mining, coal preparation, etc., are dealt with mainly by CFRI, CMRS and CMPDI. In respect of oil, Institute for Petroleum Exploration, Indian Institute of Petroleum, IOC R&D Centre, etc. deal with major programmes in this sector. In the case of nuclear power, R&D programmes are well institutionalised and are being carried out by the Department of Atomic Energy. In other sectors such arrangements do not exist in an adequate measure and as a consequence, the R&D activities have not received the needed attention. For example, R&D programmes in the power sector are inadequate and do not reflect the priorities needed to ensure optimal production and efficient use of electricity. In the area of alternative sources of energy also, there is no institutional set-up. It is, therefore, necessary to develop proper institutional arrangements to promote R&D in a coordinated manner keeping in view the priorities of the energy sector.

R&D in the Coal Sector

14.5 R&D requirements in the coal sector range from improving methods of production and introduction of new technologies of coal-mining to better and more efficient methods of utilisation.

14.6 R&D activities in the field of coal-mining technology are presently related mainly to conservation of coal. The schemes presently in progress mainly relate to improved mining practices designed to increase recovery of coal and protect resources from fire hazards and collapse of mines. The coal mining programme envisaged for the future is so large that it is necessary to develop large mines with requisite capabilities. This would require development of some mining technology and use of larger and more sophisticated equipment. It is necessary to have

tailed review of the present status carried out to entify what further inputs will be required in this a.

14.7 Considerable R&D work has been done in field of coal beneficiation by CFRI and Regional search Laboratory at Hyderabad. A few R&D emes covering areas of spherical agglomeration of l, better recovery of coal from washeries, utilisa- of rejects from beneficiation plants are presently progress. However, the efforts are diffuse and uire more emphasis. The Group feels that a rdinated approach would be required with close olvement of the user industries not only to upscale ain technologies which have been developed at the ry level but also to explore other promising niques such as froth flotation, oil agglomeration chemical demineralization.

14.8 For production and supply of relatively nex- coal based smokeless domestic fuels, the low perature Carbonization technique is considered a option. The CFRI and RRL, Hyderabad have iderable R&D experience in this field. Further is required to develop less expensive techno-

14.9 R&D efforts in the field of coal combustion, cularly in respect of technologies for efficient g of low grade coals are extremely important relevant for the energy economy. In this regard, ized bed combustion offers considerable promise. ady, work is underway at CFRI, CMERI, RRL, and BHEL and there has been significant pro- A 10-ton per hour experimental fluidized bed has been developed and tested by BHEL and are being made to upscale this type of unit. Group feels that the R&D efforts in this field be reviewed and intensified so that the techno- ad justly developed for use in both the and the power sector.

14.10 Technologies for gasification and liquefac- of coal are being considered in countries with ial coal reserves in the context of finding a ute for oil or gas and environmental considera- ith. Group feels that the relevance of these ologies to India needs careful assessment. R&D relating to coal gassification on a modest scale ing pursued by CFRI, RRL Hyderabad and On the question of liquefaction, recently a d study of the processes available for conver- coal to oil and their economics under Indian ns has been made. The Working Group feels he need for pursuing R&D activities in these under our conditions should first be clearly ched after which a comprehensive programme should be drawn up keeping in view the extent of and the time frame in which the gas and oil produced from coal would be required to play a role in our energy economy.

R&D in Oil Sector

14.11 The main thrust of the R&D efforts in the oil sector will have to be on enhancing our exploration capability, maximization of yield from oil reservoirs and efficient utilisation in all the consuming sectors. In the area of exploration, the Institute of Petroleum Exploration has been set up at Dehradun to carry out basic and applied research to support the exploration programme and in understanding the environment of the reservoirs. The Institute has been carrying out studies relating to sedimentary processes and delta formation, oil generation, migration and accumulation, production and reservoir problems. It has also been working on indigenous development of equipment required for oil exploration and development of sophisticated techniques for resolving geological, geophysical and reservoir problems. The adequacy of the present efforts need to be reviewed and they have to be reinforced and strengthened where necessary so that the expanding exploration activities required to locate potential oil and gas reservoirs in the country are adequately supported.

14.12 Development of secondary and tertiary recovery technologies is vitally needed to maximise the yield from oil reservoirs. An Institute for Reservoir Studies has been set up in Ahmedabad mainly to provide the R&D inputs necessary to develop such methods.

14.13 In view of the fact that the demand for middle distillates is large in our country, process technologies to upgrade heavier fractions such as LSHS to distillate products is of considerable importance. A scheme of establishing secondary processing facilities is already in progress in a number of Refineries. The Group would like to emphasise the need for R&D which is directed towards optimising such process technologies.

14.14 The Group is of the view that R&D efforts in the sphere of efficient utilisation of petroleum have been very inadequate with the result that significant technology gaps have developed. The transport sector which is a major consumer of liquid fuels should aim at a much higher efficiency of utilisation. Automobile engine and vehicle designs need to be considerably improved. In advanced countries, the performance of internal combustion engines has shown marked improvement while in India very little progress seems to have been made in this direction. It is also possible

158

to develop transportation systems which would be optimal from the point of view of energy consumption. Considerable R&D would be required in these areas. Institutional inadequacies would also need to be rectified.

14.15 Inter-fuel substitution in the transport sector is important from the point of view of reducing the reliance on oil products. The areas which should receive attention are the development of battery powered vehicles and the possibilities of using fuels like alcohol and producer-gas for transport vehicles. R&D work has been initiated in a small way for the development of battery powered vehicles. The adequacy of such efforts need to be examined with a view to identify the suitable technological option. A battery powered two wheeler is under development in an industrial undertaking in the State of Karnataka. Battery powered buses for city use and commercial vehicles for short range applications show economic potential with further development.

14.16 The use of alcohol-run internal combustion engines has been pursued in the past and the technical feasibility of running automobile engines with blended petrol is reasonably well established. An interministerial committee in the Ministry of Petroleum & Chemicals is currently examining the various issues connected with the use of alcohol in the transportation sector. The Working Group feels that despite the fact that there are many complex issues involved requiring detailed examination from the long-term point of view, extensive R&D efforts covering optimum blends for use in existing engines, design of new engines to run entirely on alcohol, use of ethanol and methanol in diesel engines should be undertaken. There are sufficient indications that many new bio-conversion technologies being researched all over the world may render production and utilization of alcohol much more attractive than is apparent now.

14.17 The potential of hydrogen as a source of liquid fuel for the transportation sector should be kept in view, although it is very unlikely that its potentialities can be realised within the next two decades. R&D programmes should be supported at an appropriate level so that the necessary capabilities could be gradually built up to be utilised whenever the use of hydrogen becomes technically and economically viable.

R&D for Nuclear Power

14.18 The Research & Development activities for nuclear power are primarily carried out at the Bhabha Atomic Research Centre at Trombay and in respect of fast breeders at the Reactor Research Centre at Kalpakkam. A number of test facilities have been set up. A 100 MWe thermal research reactor is under construction at BARC. The Fast Breeder Test Reactor (FBTR), under construction at Kalpakkam will serve as a facility for developing improved fuels having high specific power and better breeding ratios and material development for fast breeders. Studies are in progress regarding the feasibility of using thorium of which large deposits exist in India in the existing heavy water reactors. This will also provide an alternative to the fast breeder reactor route in case the breeder development gets delayed for any reasons. Work related to U_{233} separation is also on hand. While the technology for fabrication of uranium fuel elements has been well established, developmental work for fabrication of thorium plus U_{233} fuel and plutonium fuel is also being carried out. If the technological feasibility of the fast breeder reactor system, particularly based on the thorium fuel cycle, is established and indigenous capabilities adequately developed, a much larger nuclear programme becomes possible, particularly for the period beyond the year 2000 AD.

R&D in Power Sector

14.19 The large programme for expansion of the power sector envisaged for the future requires the development of technological capabilities and R&D support on a very big scale.

R&D in the power sector falls into the following categories :

(i) R&D concerning equipment manufacturing industry and system engineering including development of new designs for equipment, development of new materials and technological practices and systems to ensure better performance and higher reliability.

(ii) R&D oriented towards solving various operational and maintenance problems faced by various State Electricity Boards and Corporations.

(iii) R&D related to power system planning and operation.

14.20 With the growth of capacity and the interconnection of systems first on a regional basis and later on an all India basis, new problems have to be faced which require considerable R&D in many aspects of power system engineering. Concomitant with these efforts, there is also need for the development of facilities for manpower training in the sophisticated areas of automation, load despatching,

n-line computer control, system simulation, and optimisation, system dynamics and system protection.

14.21 The investment on R&D in the power sector mounting to roughly 20 crores per year has hardly y bearing on the size of the investment in the wer sector or on the burgeoning problems. What more, much of the annual R&D outlay is actually ent on routine operations such as quality control d testing and with a few exceptions, not enough novative projects have been attempted. The Group, erefore, recommends that necessary resources should allocated for substantially enhanced R&D efforts this important sector. A concerted effort is needed build a proper infrastructure and institutional mework for R&D activities in this area.

14.22 The Group is of the view at significant R&D inputs are required in the following areas :

(a) improvement in the methodology of load estimation and forecasting, power system planning including site identification, construction and project management techniques ;

(b) improvement of the reliability of power systems ;

(c) improvements in power system protection techniques ;

(d) optimisation of system economics, measures for power transmission and distribution in the low load areas, particularly the villages ;

(e) software development for problems in power system operation, load flow, short circuits, overvoltages stability, etc.

(f) research in the problems of integrated operation of power systems ;

(g) research and training in on-line computer control of power systems , and

(h) research on EHV transmission and HVDC techniques.

ordinated research plan on power systems should volved involving the Central Power Research ute, the Central Board of Irrigation and Power, L, CEA and State Electricity Boards.

gy Conservation

23 The scope for energy conservation in the trial, agricultural and transport sectors is indeed vast. R&D activities relating to energy conservation in industries would involve improving existing ses to make them less energy intensive or developing new less energy intensive processes. The approach to be adopted would depend on the specific industry. It is necessary to review each major industrial process and identify the R&D efforts required to reduce energy consumption. As part of this exercise, the possibilities of substitution of coal for oil in various industries and the R&D required for such substitution should also be identified.

14.24 In the agricultural sector, the efficiencies of agricultural pumps commonly being used are poor due to both design and manufacturing deficiencies and improper motor-pump combinations. There is scope for significant improvements and therefore attempts should be made to identify R&D inputs required to improve energy use in agriculture.

Alternative Sources of Energy

14.25 The Group took note of various alternative sources and their potential applications. Amongst the alternatives, solar energy (direct), wind energy and bio-mass appear to be areas of high priority and therefore the Group feels that the basic thrust of the R&D effort should be directed towards development of technologies that appropriately harness these sources of energy.

Solar Energy

14.26 R&D in the field of solar energy is being pursued by a number of acadamic institutions, National Laboratories and a few industries such as BHEL, CEL, Jyoti, etc. They cover a number of application areas such as water heating, grain drying, refrigeration, cooking, space heating, pumping, power generation, etc. Research efforts in most areas have been mainly at the laboratory level although some devices and systems have reached the stage of demonstration and field testing. Commercial activity is yet to develop on any significant scale.

14.27 Although a coordinated programme at the national level has emerged, certain inadequacies exist in respect of engineering and fabrication support to R&D projects, institutional arrangements and extension activity. With the groundwork already laid, it is now necessary to determine how best the existing capabilities could be mobilized and further strengthened. The Group recommends that extensive field testing and demonstration of technologies which are ready should be undertaken on a country-wide basis with a view to promote their use. Solar energy devices for post-harvest operations and photovaltaic systems are areas in which considerable R&D work has been done but further efforts are needed to make them cost-effective. Photovoltaics is an area where

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a break through might occur in the foreseeable future.

14.28 One of the major drawback of some of the renewable sources of energy is their cyclic availability. Development of energy storage systems is essential to use sources such as solar energy and wind energy according to needs. There is strong need to strengthen the R&D efforts in this area.

Wind Energy

14.29 The potential of wind energy on a country-wide basis is yet to be assessed accurately. The available data indicates that the promising regions with good wind energy potential are the coastal areas of Karnataka, Gujarat, Maharashtra, Rajasthan and some hilly areas. In the interior of the country the average wind velocity is generally low but there appear to be certain periods during the day or month and this would vary depending on the season, when the wind velocities are sufficiently high to make wind mill installation feasible. It is felt that more detailed wind data especially regarding daily wind frequency distribution, seasonal variations, etc should be collected and the wind energy potential should be reassessed.

14.30 In the past few years, considerable progress has been made in the technology of wind mills in many western countries. However, these design may not be suitable for Indian conditions without modification and adaptation. Some wind mill designs have been evolved for low wind speeds also, but the cost-effectiveness and reliability are not yet proven.

14.31 The National Aeronautical Laboratory which had developed the horizontal axis wind mill and field tested many units has been continuing its efforts to evolve a cost-effective design suitable for Indian conditions particularly for pumping applications. Sail-type wind mills that could be made locally in rural areas are being investigated. Work is also in progress on vertical axis wind mills for electricity generation as well as for pumping application. A field Testing Programme of wind mills at Ghazipur in U.P. has given encouraging results. All these indicate that with further R&D, wind energy could become cost effective in many parts of the country particularly if the pattern of agriculture could be adapted to suit the wind conditions.

Fuels from Bio-Mass

14.32 The studies of the Group underline the importance of continuance of fuel wood as a source of fuel and the need for reliance on bio-mass for meeting the energy need in the foreseeable future. Research efforts directed towards identification of fast growing species, methods of increasing photo-synthetic efficiency and development of cost-effective processes utilising bio-degradable materials for producing fuels—gaseous as well as liquid deserve high priority.

14.33 Many bio-conversion routes are being researched. The choice of bio-conversion route is dictated by the physical nature of the material, its techno-economic viability and environmental benefits. The biological conversion of organic wastes by anaerobic digestion process is an area where considerable R&D is already in progress. Although the bio-gas programme based mainly on cow dung is being pursued with considerable emphasis, new techniques are required to utilise other types of solid materials like vegetable wastes and agricultural residues.

14.34 The technology of bio-gas production from animal dung is fairly well developed and a programme to popularise bio-gas plants based on the known technology is in progress. The present strategy is to encourage mainly individual effort with the result that the programme has benefitted individual families of a certain category in rural areas. While the present programme has served the need of bringing the technology to the rural areas, it is not adequate to harness the sizeable bio-gas potential and achieve the objective of the benefits reaching a larger section of the rural community. There are a number of scientific, technical and socio administrative problems to be resolved to harness the bio-gas potential and make it an effective component in the rural energy economy. A national level co-ordinated R&D programme is presently in progress to find solutions to some of the basic problems. The main objectives of the programme are : improve the gas yield, reduce costs, increase reliability, develop larger plants for community level application, develop cheaper bio-gas stoves and other appliances, study the socio-economic impact and administrative arrangements for community level plants, etc. The pace of this programme has to be accelerated and has also to be given a thrust so that the efforts can be concentrated in some of the more important areas.

14.35 The conversion of bio-mass into fuels by pyrolysis is a process of destructive distillation carried out in a closed vessel in an atmosphere devoid of oxygen. The gases produced are usually a mixture of hydrogen, methane, carbon monoxide, carbon-dioxide and lower hydrocarbons. The liquids are oil-like and the solids are similar to charcoal. Several versatile processes have been developed capable of using diverse feed-stocks such as coal, tree bark, waste timber, rice husk, urban waste with yields of as much as a barrel

Best Available Document

of oil for each ton of wet bio-mass. There are also ther possibilities of using urban waste to generate ectricity by direct combustion. In fact some western untries are already using such techniques on a comercial scale. Producer gas units based on wood/charal needs to be revived; R&D inputs necessary to evelop cost effective units for rural application should identified. Liquid and gaseous fuels can also be proced from bio-mass through the fermentation process. l these areas need intensive study to establish their ole in the Indian energy scene.

ecentralised Integrated Energy Systems

14.36 The possibility of decentralised energy producn and distribution as against the centralised method erves serious consideration particularly for meeting rgy needs of the dispersed rural population. Such rgy systems would be based on a system approach energy problems taking into account all available rgy resources in a given location with particular phasis on new and renewable energy technologies. st research on alternative energy sources has conntrated on single sources like solar or bio-gas or wind geo-thermal and often a single application of that ree. The intermittent nature of some of the sources solar, wind etc. is one of the major problems in ir effective utilisation. However, combining several ices might help to alleviate this problem and imve system reliability R&D to establish the feasity of integrated systems based on solar, wind, bio- and mini-hydro wherever available, will have to be dertaken expeditiously. The scope for such integrated tems seems to be most high in village situations, but it st be recognised that such technologies should as far ossible be simple and maintenance requirements low.

It is necessary to take up a few pilot scale studies on integrated autonomous energy systems in village situations, including studies on socio-administrative problems and institutional requirements.

Application of R&D Results

14.37 The success of the R&D programme would ultimately be dependent on the application of their results for regular use in the energy economy. While the application of the results of the R&D programmes would provide considerable socio-economic benefits to the economy, only a few programmes will lead to direct monetary savings and profits in the near term. In the absence of sufficient direct motivation, difficulties would be faced in popularising the application of the results from R&D programmes for actual use. In this context, it would be necessary to consider monetary incentives and other motivating and regulatory measures to extent the results of the R&D activities to the field.

14.38 The measures to be taken to solve some of the problems being faced in providing assured energy supplies in rural areas have been dealt with in the earlier chapters. Considerable R&D inputs are required to make the present pattern of utilisation more effective and evolve new systems for application in the longer term. What is crucial in developing rural energy systems is the follow up action required to propagate and popularise them for application. Such follow up action through appropriate extension programmes should form part of the overall R&D programme to ensure that the benefits of R&D activities ultimately reach the sections of population for which they are intended.

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Appendix M

Energy

Illustrative Breakout

		Research	Technology Dev.	Total
1.	Combustion	9	6	15
	--Fluidized Bed	5	5	10
	--Coal Mixtures	3	1	4
	--Sterling	0	1	1
2.	Gasification	5	5	10
	--Combined Cycle-hotgas	4	2	6
	--Residue Gasifiers	-	2	2
	--Advanced Pyrolytic Approaches	1	1	2
3.	Liquefaction of Biomass	1	1	2
	--Enzmatic Processes for Cellulose	1		
	--Reactor Designs		1	
4.	Beneficiation and Carbonization	2	1	3
	--Any Methods	1	-	-
	--High Ash Coals-Oil Agglommeration	1	-	1
	Carbonization of Residues	-	1	1
TOTAL		17	13	30

ANNEX D: BIOMEDICAL RESEARCH

I. Overall Development Context

A. Background

The interests of both India and the United States in research lie in eventual application of new technology to development. This rather restricted objective must be kept in mind as a new Research and Technology Development (R&TD) program is considered because the engine which drives R&TD in general is energized by challenges and rewards intrinsic to the technical field itself. While it is wholly appropriate to maintain a development-oriented focus of S&T in the health sector in India, care must be taken to harness the energy of the research community and direct it toward development goals without stifling individual interest and ideas. A successful R&TD program requires the active participation of the truly talented scientists in the field, many of whom may be skittish about participating in a program which does not acknowledge the primacy of technology.

In the health sector, one point where development and technical considerations may balance would be at the highest Indo-U.S. joint group where senior development and technical personnel could jointly list the goals of the program in development terms, describe the broad parameters of the program, and determine the general rules of play. Once that process is complete, it is important to let a technical group oversee the technical activities. This once removed posture is essential, for most development experts are not qualified to judge highly technical work. Similarly, most technical experts cannot broaden their technical perspective sufficiently to see the development picture. Success will not depend necessarily on educating either group to the other point of view.

One reasonable set of development criteria which might be proposed as a starting point are the various AID sector and Asia Regional Strategies in health. For instance, R&TD directed toward causes of infant and young child mortality and the burden of illness in the workforce (including mothers) would invite discussions about which

disease areas would warrant attention. Among the prominent causes of infant mortality in which R&TD may contribute are respiratory disease and low birth weight; of young child mortality, respiratory disease and diarrheal disease; of labor force morbidity, malaria, tuberculosis and perhaps blindness. It is important to consider both the magnitude of the problem (for a developmental justification) and the potential for research to contribute to a solution (tetanus, for instance, is a major disease, but an immunization program, not more research, is required for solution).

The potential exists for a mock conflict to arise out of the prior documents which identify research priorities. The AID-sponsored meeting at the NIH in December 1982 to list biomedical research priorities produced a document which is heavily biased toward technical issues and neglects the development imperative. The list of priority areas is the technical half of the picture. The same criticisms could be directed toward the excellent reports of the Indo-U.S. Subcommission and to some extent toward the recent Indo-U.S. Science and technology Initiative (STI).

Biomedical research in India is a fairly vigorous field. Of the four Indian scientific publications which were cited in the international technical literature fifty or more times (the arbitrary criterion in judging "significant impact"), all were in the biomedical (or biological) field, although only a minor component of the government R&D budget is spent on biomedical research.* Thus, the argument could be made that the biomedical research field is relatively small but relatively high quality, and biomedical research may present a special case in planning an R&TD program in India.

Because research in the health sector was already fairly well established when the new Government of India Department of Science and Technology (DST)-sponsored initiatives (including STI) were started, it is difficult to describe the overall picture. In general, the introduction of the DST programs provided additional resources to the more basic levels of research which sustain several disease-specific research efforts. Good coordination exists between the established medical research programs undertaken through the Indian Council of Medical Research (ICMR) and the newer S&T research programs.

*As reported in an article by Praful Badwai, "Myths About Indian Science: Some Unpalatable Home Truths," Times of India, September 20, 1983.

B. Major Constraints

1. Capital - The general impression from several sources suggests that capital, including a reasonable amount of foreign exchange, is not a particularly limiting factor, although one successful investigator hoped we would not leave with the impression that Indian investigators were flush. The amounts of rupees available to individual investigators through the ICMR are relatively small compared to the amounts expected from the DST research awards. Laboratories were largely equipped with equipment of Indian origin, which was adequate in nearly all instances. Foreign exhcange is available apparently for essential items which are not available in India although many said the hassles in customs clearance and other bureaucratic issues were difficult to overcome.

2. Human Resources - It was difficult to assess the availability of human resources to man a research program. Most laboratories rely on graduate students (especially M.D. candidates) for manpower in the laboratory. There appeared to be fewer senior-level technicians per investigator than one sees in productive biomedical labs in developed countries. There is a limited number of truly talented and well-qualified investigators, although those who profess to be medical research professionals apparently do not devote any time to the practice of medicine or to demanding administrative jobs.

3. Policies - In general the policy climate favors an advance in R&TD in India. The existence of a National Biotechnology Board should greatly facilitate coordination among the several sectors which are interested in technology development. Also, it should increase the efficiency of allocating resources among competing sectors.

Several specific policy areas were mentioned frequently by research scientists as being in need of revision. Onerous GOI accounting procedures make it the donor of last resort for investigators who can compete in the international market, and this is an indirect loss to the Indian R&TD effort although none of the scientists indicated they preferred to be classified as being outside of the system. There are constraints to travel, and there are no funds to pay for the foreign part of collaborative efforts which were mentioned as very important by virtually every investigator. The patent policy appears to be adequate although the private pharmaceutical firms objected to lack of enforcement which undermines patent protection and allows unfair competition from other firms. Pharmaceutical firms with majority foreign ownership are encountering unacceptable delays in approval of new products resulting from reseach. This is an example of pressure to shift to Indian control of private firms. This is a matter of national importance which goes beyond the pharmaceutical industry.

4. Technology Development - as practiced now, there is very little which could be termed technology development. Several laboratories have adapted new technology to the Indian situation quickly and easily to solve a particular problem. The exception may be in the private pharmaceutical arena where efforts are being made to develop new (and patentable) processes for manufacture of pharmaceuticals which fit readily (and without royalty paid) to the Indian situation. This is partly due to Indian policies requiring that all ingredients of pharmaceuticals be produced locally. This policy is an effort to curb the practice of importing expensive bulk pharmaceuticals as "ingredients" from parent multinational plants thereby underwriting indirectly the flight of profits abroad. But regardless of the reason, the result reflects poorly on the capacity of the Indian pharmaceutical industry to stay abreast of the world market over the short run.

II. GOI Objectives, Priorities and Policies for Research and Technology Development in the Sector

A. Objectives

The basic objectives of the overall Technology Policy ("Technology Policy Statement" pp. 3-4, Department of Science and Technology, New Delhi, January 1983) are development of indigenous technology .and efficient absorption and adaptation of imported technology appropriate to national priorities and policies. Special emphasis will be given to food, health, housing, energy and industry.

As listed by the National Biotechnology Board, located in DST, the priorities in health are:

1. Development/production of vaccines against major viral, bacterial and protozoal diseases using modern methods of animal cell/tissue culture and genetic engineering.

2. Development of effective and safe vaccine for fertility regulation for mass use.

3. Development of diagnostic kits based on enzymes-immuno-assay which would facilitate accurate diagnosis of various disease of man and animals even under field conditions.

4. Development of new methods of drug delivery based on immunochemical approach and tissue targeting.

5. Production of hormones and other chemotherapeutic agents using techniques of genetic engineering and hybridomas.

III. Major Current R&TD Institutions and Programs in the Health Sector

A. Public

The DST biotechnology program appears to be a focal point for funds and policy guidance for R&TD in the public sector. In health, the DST does not have any laboratories, but they sponsor research in existing research units.

The DST program will have three tiers when it is fully operational. The first tier is project-specific and targeted in biomedical R&TD. This is, in fact, a continuation of the more basic biomedical research sponsored for many years by the ICMR, chiefly. The DST program provides an additional source of funds for this research which is conducted primarily in non-ICMR laboratories. Many research awards go to university-based investigators.

A second tier is a new program for thrust areas which is more comprehensive and which involves scientists from several different laboratories working on a single problem.

A third tier will support national resource centers. These units will develop basic technical resources for the entire biotechnology field in India. Although none are operational, examples of units which are needed include a national genetic engineering center where high-quality reagents, monoclonal antibodies and hybridoma cell lines will be developed for use in other research centers in India.

The Indian Council for Medical Research (ICMR) is a well-established national resource for medical research. The ICMR operates national laboratories which focus research on specific health problems, for example, the National Institute of Cholera and Enteric Diseases. A smaller portion of their funds support biomedical research in non-ICMR labs.

The Council for Scientific and Industrial Research (CSIR) network supports biomedical research at a few of these labs. The primary laboratory for biomedical sciences in this extensive network is the Central Drug Research Institute (CDRI) in Lucknow where a large staff is engaged in biomedical research using the latest biotechnical techniques. The CSIR mandate is to produce technology applicable to the commercial and industrial sector, and within this context the CDRI research is aimed primarily at new drug development with a considerable effort also going toward development of rapid diagnostic tests and basic microbiological research.

The University Grants Commission (UGC) sponsors university-based research. The report "Status of Biotechnology in India" reprinted in 1983 by the National Biotechnology Board of DST lists UGC support for five universities in the health-related biotechnology research field. Several scientists stated, however, that the UGC is a minor source of support for the total biomedical research effort in India. It may, nevertheless, constitute a major source of funds for university-based investigators.

External resources (foreign agencies, foundations, international organizations such as the WHO) are not insignificant sources of support although the total amount of funding may be small. Research support from these sources provides some additional flexibility, opportunities to participate in international networks of scientists and training opportunities -- all of which are coveted by Indian researchers.

The Ministry of Health & Family Welfare (MOHFW) has a few units which engage in biomedical research at the "applied" end of the spectrum. The National Institute of Communicable Diseases (NICD) is the principal unit. The health delivery systems are not major players in basic research although they are critical components of some collaborative efforts at the operations research stage, such as collaboration with the National Tuberculosis Research Center on an intensive short-term course of antituberculosis therapy in Chingleput Districh in Tamil Nadu.

It appears as though communications between DST & ICMR are sufficiently good to allow research proposals to be brokered efficiently. One general principle is for DST to support more basic biotechnology activities and for ICMR to support research which is more specifically targeted on medical research.

B. Private

In the private sector, the non-profit foundations such as the Tata Institute for Fundamental Research, represent a considerable resource for biotechnology research. Interestingly, the bulk of support for the conduct of research at this institute and probably at other foundations comes from public sources for which institute scientists compete successfully. The quality of research is adequate for some of the Institute staff to compete successfully for research funds from the U.S. Any R&TD program which supports investigator-initiated proposals must allow scientists from this small but potent sector to compete.

In the industrial or commercial part of the private sector there is evidence of sporadic, "as needed" biotechnical research. As

expected, the research we heard about was very directed. In the case of developing monoclonal antibodies, for use in a highly specific, rapid diagnostic test for filariasis, this was done with ease. There does not appear to be any interest in the few private commercial research units of pharmaceutical companies we visited to participate actively in any R&TD program operated through the GOI. They were interested, however, in any efforts to introduce flexibility into the regulatory environment, and it was apparent that the commercial laboratories constitute a potential market for any high quality research reagents which might be produced locally with the sponsorship of an R&TD program.

The small entrepreneur does not exist in the biotechnology field in India. Several firms have been approached to solicit interest in developing a commercially viable biotechnology industry, but, according to several scientists we spoke with, none are interested in taking the risk. Dr. G. P. Talwar of the National Institute of Immunology has patented a monoclonal antibody for beta-human gonadotrophin (beta-HCG) and has established a trust from the proceeds of marketing this reagent. Such entrepreneurial spirit was lacking elsewhere.

IV. Current USG-supported Biomedical R&TD efforts:

A. The following biomedical research projects are currently supported by the Special Foreign Currency Program:

- Malaria: drug evaluation and seroepidemiology
- Filariasis: long-standing project with the NIH
- Tuberculosis: development of a rapid diagnostic test
- Leprosy: two projects on immunology
- Cancer: one project on oral cancer, another screening Indian plants for anti-cancer activity
- Blindness prevention: with the NIH
- Amoebiasis: collaboration between NIH and a private medical research foundation in Calcutta
- Iron deficiency anemia: epidemiological project with the National Institute of Nutrition in Hyderabad
- Diarrheal diseases (proposed): a study of rotavirus

- Biofeedback: project with National Institute of Mental Health

- Longitudinal study of a cohort: very valuable study continuing since 1966, now in 3rd phase

- Respiratory diseases (proposed, all GOI clearances obtained): Christian Medical College, Vellore

- Hepatitis (proposed, all clearances obtained)

- Cancer of the breast, stages I and II

- Reagent bank in reproductive physiology

- Laboratory animal treaty - proposed, not negotiated

For details, Mr. Bilis Saxena, Office of the Science Attache, is an invaluable source.

It is apparent from this list of projects that technical issues predominated in shaping the program. Each project is characterized by excellent collaboration between U.S. and Indian scientists. (An outstanding example is Dr. Shanti Ghose's longitudinal cohort study which has outlasted collaborators and the vagaries of the Indo-U.S. relationship.) The principals may be interested in extending their areas of collaboration to include topics more germane to development. At least, the SFC program is an acceptable forum for research specialists to get together to discuss areas of future scientific collaboration.

B. The following areas are under study through the <u>Science and Technology Initiative</u> (STI) (nee: Blue Ribbon Panel):

- Tuberculosis (immunological focus)

- Filariasis (immunological focus)

- Blindness (basic research)

- Reproductive physiology (immunological focus)

- Malaria (vaccine development)

In all areas except malaria, programs were chosen from among existing collaborative efforts with both the Indian and U.S. rosters expanded to include additional well-recognized scientists. Interestingly, some Indian investigators we visited in this trip suggested collaborative links were more productive if the scientists chose their own partners rather than forcing collaboration with people not known to each other, as was done in the case of the STI panels.

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C. Components of USAID projects which bear on the issue of R&TD in health and population include:

- The Maternal Nutrition and Infection and Infant Survival Project devotes a significant portion of resources (approximately 1 million over six years) to biomedical research. The research will be directed toward understanding the cause of low birth weight, a major cause of infant mortality. The science proposed is state-of-the-art featuring leading experts from Harvard U., the CDC and the NIH and investigation from premier Indian medical institutions. This project has all of the features required to be an excellent example of biomedical research.

- The proposed Biomedical Research Project will invest considerable resources in the development of rapid diagnostic technologies, one of the priority areas for biotechnology identified by the National Biotechnology Board. This project will also bridge the gap between R&TD and utilization in the health system by actually programming for the intermediate steps leading to application of the technologies. During project design the disease areas to be addressed by the research will be chosen from among the list of known leading causes of infant and young child mortality or workforce morbidity, those areas in which an investment in research is likely to pay dividends and which are of interest to the GOI health services and the biomedical research establishment.

V. Constraints to More Effective Biomedical R&TD

A. Policies and Procedures

1. Budget Allocations: the overall amount of GOI support available for R&TD is said to be adequate, although one gets the impression the availability of funds may well limit the acceleration of development-oriented biomedical research. The ICMR budget is apparently better funded than the DST budget because it is an older, more well-known program.

2. Salary Structure: According to one scientist in a private pharmaceutical firm, the public sector salaries are inferior to the private sector salaries. Within the public sector in health, the rewards in research positions apparently are competitive.

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3. Priority-setting Process: In the National Biotechnology Board of DST, the initial priority-setting process was a lengthy (five-year) exercise which effectively reached a consensus and involved a large number of groups. There appears to be widespread support in the biomedical research community for the DST list of priorities for biotechnology.

4. Relevance to Development and Application: The DST list of priorities is so basic that the question is difficult to address. This list could relate well to development goals, but the degree to which the work actually applies to development will depend on the nature of the undertaking. The jury is still out. With regard to the research programs of the ICMR, many of the research topics are of interest to special interests and to aca- demics. Epidemics of Japanese B-encephalitis cause a major stir in the population and politicians are eager for the scientific community to respond. Foreign scientific collaborators are enthusiastic to adapt their new tools to the study of "exotic" diseases. However, many of the diseases are not major killers of children. Neverthe- less, identifying specific disease targets must be a fully coopera- tive Indo-U.S. process. Ultimately, AID must be willing to consider the judgments of Indian scientists and decision-makers as to whether a disease is significant or not. The best insurance for agreement on the areas for health research is a careful, iterative process involving development and technical experts.

5. Project Approval and Monitoring Process: The only criticism we heard about the project approval process was the delay which frequently occurs with ICMR awards. In one instance the investigators at All India Institute of Medical Sciences were told their proposal was approved, but the actual award was delayed so long that many of the technical staff were forced to go elsewhere to seek employment. Apparently the delays are due to the vagaries of the ICMR getting rupees released. The project monitoring process seems to be lax in terms of technical content. As for financial audits, several complained about the time required to satisfy GOI auditors. Some feel the new DST program would streamline the reward and monitoring process.

6. Policies Regarding Access to Foreign Technology: Policy appears to encourage broad acquisition of foreign technology in the biomedical research area as in other areas. Foreign exchange will reportedly be made available to acquire the technology.

However, there is a lack of coordination between the relevant GOI administrative units and actual operations. For instance, customs is seldom persuaded to facilitate import of even short-lived reagants. Dr. Ramachandrau, Secretary of the National Biotechnology Board, personally went to the U.S. with $300,000 to buy critical reagents and supplies for recombinant DNA research. He

personally cleared them through customs in his baggage so they would not sit in customs and deteriorate. The total supply of reagents and supplies which are available today to the biotechnology network in India are those reagents Dr. Ramachandran brought back from the U.S. While this is a nice testimony to the vigor of the Secretary of the Board, it indicates that ancillary "policies" and procedures need to be streamlined.

An active private sector in research reagents and supplies would greatly enhance development of useful technologies. For instance, locally manufactured plastic ELISA trays will be required if this type of rapid diagnostic test is to be applied in the health delivery system. Until such a basic item is available locally, no one will seriously consider developing and applying widely this simple but elegant test system. Developing a technically useful plastic for local private sector production might be an appropriate topic for one of the CSIR laboratories.

B. Institutional Capacity

Staff quality: There are several excellent biomedical research professionals in India. Most work alone; there are few relatively large concentrations of professionals although there appears to be fairly good communication between investigators. With the apparent exception of the Central Drug Research Institute in Lucknow, Post Graduate Institute at Chandigarh and the Christian Medical College, Vellore, there is seldom more than one talented investigator per centre. Post-doctoral or graduate students serve as junior researchers (and/or senior technicians). There are few technicians, but the productive laboratories have a few who were specially trained in their labs to a high level of skill. The requirement for opportunities to be a visiting scientist in other labs abroad and the need for post-doctoral training are not addressed adequately in current programs.

Facilities are adequate but certainly not lavish. For example, the laboratories with hybridoma cell lines have been able to develop the elaborate and functional "clean" rooms required to propagate tissue cultures without the risk of contamination. Nevertheless, one is impressed that the quality of research appears to outstrip the physical facilities.

Equipment appears to be adequate at best. There is every indication that productivity cannot increase dramatically in most productive laboratories without additional, improved equipment. Equipment is not the only limiting factor, however; trained manpower, research reagents and other critical elements of the research laboratory also limit potential increases in productivity.

Training is one area in which there was virtual consensus. All of the Indian investigators mentioned the need for greater access to short to mid-term training or visiting scientist opportunities for themselves and their younger colleagues. Most mentioned post-doctoral, non-degree training as a need.

In a broader perspective, fifteen years ago there were substantial numbers of Indians studying in the U.S. in all fields, including biomedical sciences (and through exchange programs, U.S. students in India). That period produced today's talented group of productive Indian investigators and many were trained in the U.S. Since then, there has been a hiatus during which only limited opportunities for clinical training in the U.S. have been available, and most of these available only on an individual basis.

C. Donor Involvement

A partial list would reveal the projects of the USG special foreign currency programs and a likely National Academy of Science (BOSTID) project through AID's Science Advisor's Office in respiratory diseases. The International Development Research Centre (IDRC - Canada) has indicated an interest in working in acute respiratory diseases at the King George Medical College in Lucknow. The WHO has several research activities in India including one from the Tropical Disease Research and Training Program (TDR) with the Ciba-Geigy research laboratory in Bombay.

VI. Elements of a Ten-year Program Under Various Approaches

Key features of the Indian biomedical research field are:

- Success is associated with a few bright and productive individuals who are located in a variety of laboratories.
- There are few concentrations of productive investigators; groups are rare.
- A few are acknowledged researchers in the U.S. and elsewhere; they are part of a network.
- By and large, the acknowledged leaders are not active in areas to be considered of top priority from a development perspective.
- Historically, support has come from the ICMR programs; indeed, many of the leaders in biomedical research work in the ICMR network of laboratories.

- With the exception of the All India Institute of Medical Sciences, the Christian Medical College at Vellore, the Post-Graduate Institute and a few others, productive biomedical researchers are not associated with medical colleges.

- Funding is only one of several potential constraints, and it is probably not the most serious one.

- Indian biomedical researchers cherish the thought of true collaboration with U.S. investigators with whom they are familiar.

- There is a felt need for younger members of the research staff to train at the post-doctoral level in the laboratories of U.S. scientific collaborators.

AID support to biomedical research in India should be disease-oriented and based on the priorities of the Government of India with which AID priorities are congruent. Shared overall objectives to be achieved are: reductions in infant, child and maternal mortality; in fertility and in morbidity of the labor force. Major biomedical research subjects that constrain achievement of these objectives are, in order of priority: respiratory diseases including tuberculosis; diarrheal and enteric diseases including typhoid; reproductive immunology and the immunizable diseases; and nutritional anemia.

The support of priority disease-based research will encompass research on diagnostic techniques, treatment modalities and the development of improved or new vaccines. Thus biotechnical research with particular emphasis on biochemistry and genetic engineering in the expanding hybridoma technology for identification of antigens and antibodies is basic. The use of these newly derived antigens and antibodies for rapid diagnostic techniques will lead to the next level of research to be supported, the field trials. Field trials of diagnostic techniques discovering morbidity patterns should lead to additional research into treatment modalities. This applied research activity needs constant support of bench laboratory research to disclose new drugs and new vaccines. The field trials research should enable bench research to modify advanced diagnostic techniques to the point of making available simple rapid diagnostic techniques which do not depend upon microscopes and expensive equipment for use in primary health centers. The support of biomedical research must be comprehensive, from the bench to health services.

The tools for biomedical research must be strengthened. First in priority is the professional development and training of junior and mid-level researchers and of laboratory technicians through the collaboration of the American and Indian scientific communities. The Indian community should be enabled to take full advantage of the numerous American laboratories (university, NIH, private institutions) that are vigorous in the hybridoma/recombinant DNA -- genetic engineering -- antigen -- antibody -- complex. The return visits of American investigators and lab technicians to Indian laboratories for planning conferences and for scientific councils and seminars should be facilitated.

Beyond training, the essential tools of equipment and reagents must be made available initially by access through foreign exchange but ultimately by the support of local production. Doubtless, local production will spontaneously surface with the increase in demand that should result from strengthening of research capabilities.

The final tool to be emphasized is that of data processing and management information systems; data processing, so essential to extensive bench laboratory work, and management information systems, so essential in field trials and applied research for health services. Management information systems are a main ingredient in translating biomedical research into effective application through health services.

It is said that the Seventh Five-Year Plan will include an emphasis, within the Ministry of Health and Family Welfare, on enhanced cooperation between the Research Division of ICMR and Health Services of the Director General's office. Thus, supporting the spectrum of biomedical research (from the bench to the field) is essentially to be generated through the MOHFW. Close cooperation between the DS&T and MOHFW is to be encouraged, if possible, through a shared Grants Committee which would select, award, and monitor research grants.

With regard to funding requirements, the approaches outlined above will not require a great deal of money initially: $1.5-2.0 million per year would fund 15-20 investigators. Additional funds would be needed if training expenses, workshops of collaborators, and selected equipment and specialized supplies are included.

ANNEX E: INDUSTRY/PRIVATE SECTOR

I. Overall Development Context

Sustained industrial growth is vital for India if the standard of living of its massive population is to rise in the coming decades. Yet the average annual rate of increase in the index of value added from the industrial sector has declined from 6.4% in the 1950's to 5.8% in the 1960's to 4.9% in the 1970's.[1] The pattern of industrial growth between 1970 and 1982 is shown in Appendix A with the most rapid growth being in the beverage, non-electrical machinery, and electricity sub-sectors. Industrial capacity utilization was only 76% in 1982 and the sector provided about 25% of Net Domestic Product.[2]

The Sixth Five-Year Plan calls for an 8% increase annually in industrial production. Growth rates at the mid-term review were well below this target. World recession and the lack of a competitive environment in India are key factors in the slow growth of industry. Although the public sector has 44% of the fixed capital, it contributed only 19% of total value added in 1978/79.[3]

The Sixth Plan gives special priority to basic industries: steel, non-ferrous metals, capital goods, fertilizers, and petrochemicals. The private sector is seen as contributing significantly to growth in fertilizers, cement, paper, textiles, chemicals, pesticides, drugs and pharmaceuticals.

II. GOI Objectives, Priorities and Policies for Research and Technology Development

The Sixth Five-Year Plan recognizes the importance of technology to industrial development: "Industrial progress will necessarily depend upon continued technological excellence; this would call for a judicious blend of permitting import of contemporary technology, and promoting the development of indigenous know-how through domestic research and development."[4] In January 1983, the GOI issued a "Technology Policy Statement." The document presents a view that places heavy

emphasis on self-reliance in science and technology. On the issue of acquisition of technology, it states the following basic principles:

"(a) import of technology, and foreign investment in this regard, will continue to be promoted only on a selective basis where need has been established; technology does not exist within the country; the time taken to generate the technology indigenously would delay the achievement of development targets.

(b) Government may, from time to time, identify and notify such areas of high national priority, in respect of which procedures would be simplified further to ensure timely acquisition of the required technology.

(c) There shall be a firm commitment for absorption, adaptation and subsequent development of imported know-how through adequate investment in research and development to which importers of technology will be expected to contribute."[5]

At the center of regulatory decision-making on technology imports and related foreign investment is the Director-General for Technology Development (DGTD) in the Ministry of Commerce. This office, which has over 700 technical officers, reviews proposed projects involving any investment over $5 million, technology licensing and R&D, and capital goods, spare parts and raw material imports from the standpoint of (1) the economic impact of the investment; (2) the foreign exchange requirements; (3) the availability and comparative quality of domestic technology.[6]

Foreign exchange considerations are divided into two basic areas: (1) capital goods and (2) maintenance and raw materials. In general, no restrictions are placed on importation of raw materials once plant capacity is in place. Capital goods imports are cleared on a case-by-case basis, the principal consideration being whether the item requested is available in the domestic market. Usually, local advertisement for 45 days of intentions to purchase are required prior to approval. An inter-ministerial group on licensing may review decisions on issuing of import licenses.

The technology import issues are reviewed by DGTD staff as to availability of domestic technology; the need for the foreign technology; and the energy, productivity, employment and other characteristics of the technology. Major cases or disputes may be reviewed by the Technology Evaluation Committee, composed of DGTD, DST, CSIR, the National Research and Development Corporation and sometimes outsiders from the IIS's or IIT's. Neither private nor public industry is formally represented on the TEC.

III. Major Current R&TD Institutions and Programs

Total expenditures on industrial R&D by public and private groups totaled 19,376 lakhs in 1980/81 (see Appendix B).[7] The private sector accounted for 55% of the total and their expenditures were concentrated in chemicals, electrical equipment, drugs and pharmaceuticals. Two-thirds of the public sector industrial R&D expenditures in 1980/81 were in electrical equipment, telecommunications and defense industries. Industrial R&D expenditures as a whole constituted approximately 26% of total Indian R&D expeditures in 1980/81.[8]

The Council of Scientific and Industrial Research, the Department of Science and Technology, the Department of Space, and the Department of Electronics are principal agencies under the Central Government conducting R&D in the "industrial" sector. The R&D budgets of all these agencies have increased substantially (at least doubling) over the past decade (see Appendix C).

The CSIR plays a key role in decisions on technology R&TD and, through its position on the TEC, on technology import policy. CSIR controlled about 18% of Central Government R&D resources in 1980/81.[9] With its 38 laboratories, 100 extension centers and regional stations and its 4,300 scientists and 10,000 support technicians, it is a powerful force in the science establishment.[10] Major CSIR institutions are shown in Appendix D.

Industry's view of CSIR is cool at best; they are wary about adopting CSIR technologies without proven demonstrations of their viability or without specific warranties. CSIR is often viewed as an obstacle to obtaining superior foreign technology since it may take the position that its technology is competitive with that being proposed for import from foreign companies. Several component CSIR institutions, such as the National Chemical Laboratory and the Central Fuels Research Institute, have good reputations in industry, however.

There are several large, modern corporations in both the public and private sectors in India that carry out considerable R&D. One public company is Bharat Heavy Electricals (BHEL), which invested about Rs. 2,000 lakhs in 1980/81 on R&D or roughly 3% of its total sales.[11] BHEL has modern research centers at Trichy and Hyderabad, where work is underway on coal, solar, wind, as well as general power and electrical equipment. Major private companies involved in R&D include Jyoti Ltd. in Baroda and Tata Research in Bombay.

Industry research institutes such as those in the U.S. are limited in India. The largest ones are in the textiles, tea, jute and wool industries. The engineering industries through their association (AIEI) have an active R&D committee, chaired by the Executive V.P. of Kirloskar Electric Co., a private company in Bangalore. AIEI is providing information to its 1,617 members in both the public and private sectors in R&D registration schemes, fiscal incentives, import facilities, duty exemption, treatment in licensing, and proformae for application and claiming incentives.[12] It has promoted increased liberalization of technology import restrictions and increased productivity by its members.

IV. Current USG Efforts in the Sector

AID in the 1960's sponsored programs to foster technological innovation in the private sector but these were not resumed to any degree upon its return in 1978. The current Alternative Energy Resources Development Project has two components that are aimed at industrial technology R&D and technology transfer. The first component is a collaborative technology exchange program in new coal technologies between BHEL and U.S. private companies, working through DOE's Pittsburgh Energy Technology Center. The second is a planned program of technology transfer in industrial energy conservation technologies between the National Academy of Engineering, most of whose members are in the U.S. private sector, and the Association of Indian Engineering Industries (AIEI).

SFCA (Special Foreign Currency Account) activities involving the National Bureau of Standards may also be underway with Indian institutions relating to industrial technology issues.

V. Constraints to R&TD in the Industrial Sector

India has paid a tremendous cost for its policy of technological self-reliance. It is beginning to realize this fact more sharply as advances in electronics and computer control systems widen the productivity gap even further. Nations that have experienced rapid industrial growth, Japan, South Korea, and Brazil, have had liberal policies toward the import of technology. It is estimated that between 1975 and 1982, 65% of Japanese economic growth was accounted for by technological progress. During that period, Japan signed 32,000 contracts for technology imports worth $9 billion.[13] While comparable data are not available for India, between 1957 and 1982, 7,211 foreign collaborations were approved. Only 639 of these collaborations involved equity participation. The U.S. accounted for 1,416 of the collaborations.[14] About 3,000 technology licensing agreements have been signed over the past two years.[15] India also had 319 R&D collaborative agreements in force in the industrial area as of 1980/81. Of these, 73 or 23% were with the United States, largely in the areas of industrial machinery, electronics, and chemicals.[16]

The constraints to increased technology imports and a larger, more effective domestic industrial R&D effort are many. Some of the more important include:

- the protective and non-competitive environment that Indian companies, many public companies to begin with, operate in;
- the low returns to investment in some sectors due to government price controls;

-- the unreliability of power and infrastructure bottlenecks that lead to poor utilization of capital and labor and wasteful use of energy;

-- the small sales volume of most Indian companies that makes the establishment of laboratories and R&D centers unaffordable; (see Appendix E);

-- the domestic market orientation of most firms that removes the drive to compete in the international market;

-- the prohibition against majority-owned foreign companies that makes U.S. and other foreign companies reluctant to invest and lose control over their technologies;

-- the non-restrictive licensing provisions generally required (i.e., technology brought in under license cannot be restricted exclusively to the Indian market);

-- the low ceiling (generally 5%) on royalty payments (calculated on basis of actual production plus 25% minus "standard brought out" items and 'landed' cost of imported items) plus the 40% tax that is added;

-- the overspecialization of the CSIR system and the absence of effective methods for understanding the technology needs of industry;

-- the important factor of trained managers to understand the process of technological change and adaptation;

-- some feeling that duration of patent protection (as short as three-to-seven years) has limited R&D investment.

VI. Sectoral Program Elements

The basic conclusion reached in this brief review of the overall environment for industrial technology transfer and R&D cooperation is that the key issue for Indian industry is not research and technology development in the strict sense of the term, but rather policy changes allowing easier access to foreign technology and the proper adaptation of the technology to Indian plant conditions. A Business India article rightly argues that India needs to: (1) import technology on a large scale; (2) create the infrastructure for the adoption and development of the imported technology. A U.S. program approach to support these objectives would focus on (a) the technology needed to improve productivity and the requisite policies to promote its adoption at both the macro and specific industry level; (b) improving capacity of management of technological innovation and R&D at the firm and plant level; (c) improving technological capacity in the private A&E community; and (d) reform and rationalization of the CSIR system so it

is more responsive to industry needs.[17] Two areas of significant potential in this regard are energy conservation and industrial pollution. India does not have adequate technological capacity in these relatively new areas which are critical to improved productivity and sustained industrial development. U.S. companies, particularly small companies, may be interested in tie-ups.

Finally, a specific option that might be fruitful to explore is the establishment of a program in the management of technology innovation with the Association of Indian Engineering Industries at their soon-to-be completed headquarters building in New Delhi. The Secretary of AIEI indicated a strong desire of the members to strengthen relations with the U.S. and believed management training was an area for potential collaboration.

A reasonable cost for this sector program would be about $10-20 million over the ten-year period.

These options could be linked to, or combined with (in whole or in part), current proposals to establish a revolving fund of PL 480-generated local currencies in the form of a bilateral industrial research and development foundation or a similar mechanism.

Notes

1 Centre for Monitoring the Indian Economy, Basic Statistics Relating to the Indian Economy, Vol-1, August 1983, Table 14.10.

2 Ibid., Table 14.11.

3 Ibid., Table 14.8.

4 Planning Commission, Government of India, Sixth Five Year Plan, p. 261.

5 Department of Science and Technology, Govt. of India, Technology Policy Statement, January 1983, p. 13.

6 Interview with the former Director General for Technology Development, September 25, 1983.

7 Note that the private R&D expenditure excludes firms that did not seek or were refused approval for R&D tax write-offs. In 1980/81, a total of 470 private firms were recognized by the Central Government as having R&D programs.

8 Department of Science and Technology, Research and Development Statistics 1980/81, p. 29.

9 Ibid., p. 18.

10 "The CSIR Story", Business India, Sept. 12-25, 1983, p. 54.

11 DST, Research and Dev Statistics, op.cit, p. 60.

12 Association of Indian Engineering Industries, Annual Report 1982.

13 Economic and Scientific Research Foundation, Technology Policy, New Delhi, 1983, p. 11.

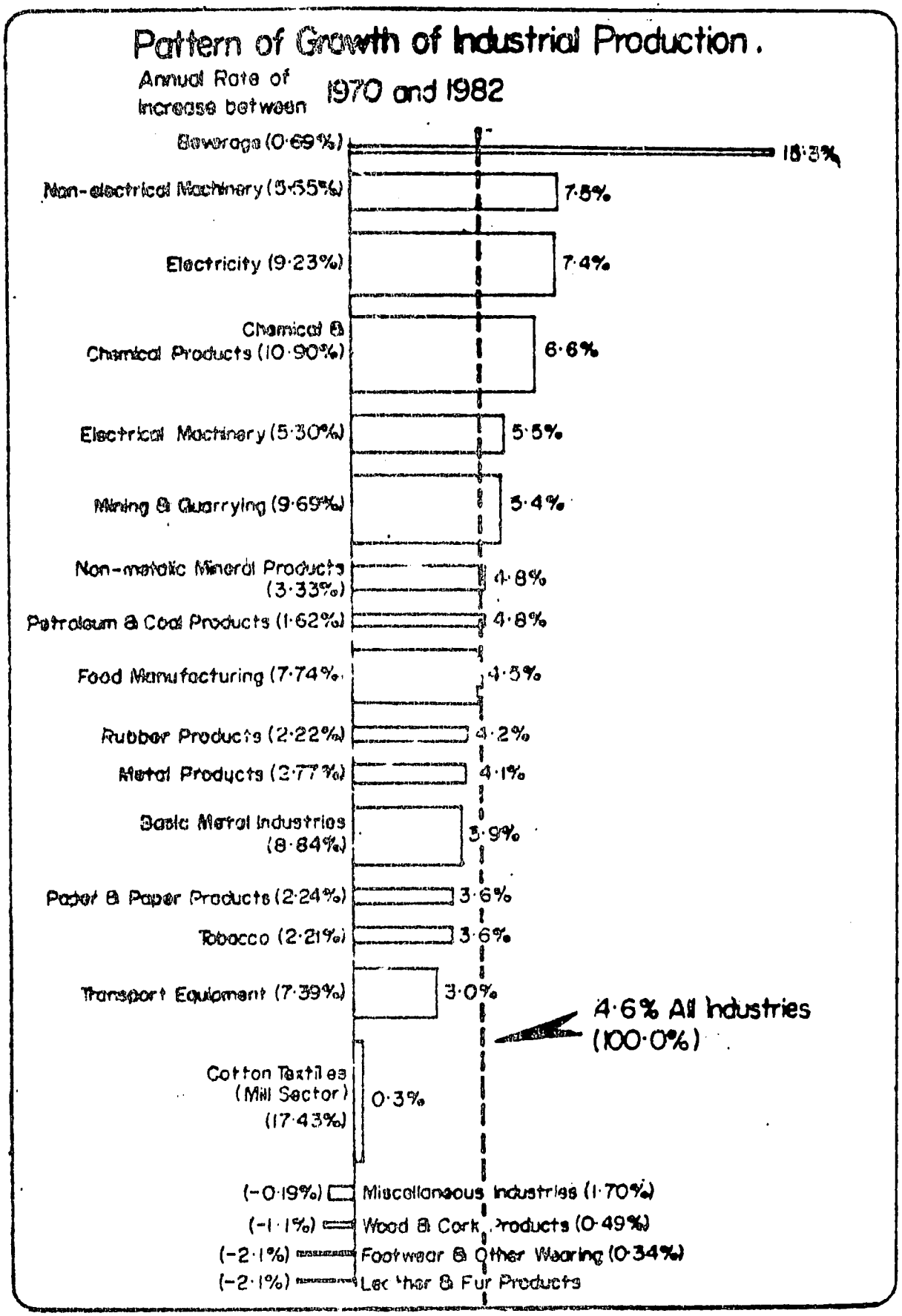
14 S. L. Kapur, "Update on Licensing in India," Facts for Year, July-August 1983, p. 19.

[15] Interview with Dr. Alam, National Council of Applied Economic Research, New Delhi, September 19, 1983.

[16] DST, R&D Statistics, op.cit, p. 31.

[17] The FICCI (Indian Chambers of Commerce) has already agreed to a program with CSIR focusing initially on sugar, pesticides, alkali and fertilizers.

14.9-8



Note: The width of each bar is proportionate to its weight indicated in the brackets with the industry groups and the length indicates the percentage increase between the periods.

TABLE--9

INDUSTRIAL R&D EXPENDITURE BY INDUSTRY GROUPS FROM 1978-79 TO 1980 81

Sl. No.	Industry groups	Public sector				Private sector				Total			
		No. of units	R&D expenditure (Rs. lakhs)			No. of units	R&D expenditure (Rs. lakhs)			No. of units	R&D expenditure (Rs. lakhs)		
			1978-79	1979 80	1980 81		1978 79	1979 80	1980 81		1978-79	1979 80	1980-81
1.	Metallurgical Industries	8	272 01	517 77	746 32	29	337 42	522 76	553.78	37	609 43	1070 53	1300.20
2.	Fuels	3	539 29	608.06	791.01	5	98 92	1 [illegible]	121.07	8	638 21	725.96	912.08
3.	Boilers & Steam Generating Plants	—	—	—	—	—	—		—	—	—	—	—
4.	Prime Movers (Other than Electrical Generators)	—	—	—	—	4	80 83	110.07	175.50	4	80 88	110.07	175.50
5.	Electrical Equipment	9	255 89	375.22	267.33	97	954 35	1212 86	1405 23	106	1210.24	1588.08	1772.56
6.	Telecommunications	3	802 97	1085.42	1233 76	8	153 98	223 00	211 56	11	956.95	1309 42	1445.32
7.	Transportation	1	0 92	4 01	0.14	16	640.82	984 40	1136 95	17	641.74	988 41	1137.09
8.	Industrial Machinery	6	1557 07	2061 93	2269.18	33	553.11	555.92	724.82	39	2110.18	2617.85	2934.00
9.	Machine Tools	1	34 77	49 41	82 00	4	137.54	144 74	144 15	5	172.31	194 15	226.15
10.	Agricultural Machinery	1	12 01	63 57	37 00	4	236 85	230 31	284 75	5	248 86	293 88	321.75
11.	Earth Moving Machinery	—	—	—	—	1	13 95	32 02	30.00	1	13.95	32.02	30.00
12.	Misc Mech Engineering Industries	2	6.40	19 53	28 68	3	9.74	19 06	32 29	5	16 14	38 59	60 97
13.	Commercial, Office, Household Equipment	—	—	—	—	6	25.08	30.89	45.22	6	25 08	30 89	45.22
14.	Medical & Surgical Appliances	1	5.50	5 50	7.75	2	11 10	11.89	10.86	3	16.6	17.69	18.61
15.	Industrial Instruments	2	77 03	80.06	93 12	18	71 74	76.79	111 01	20	148 77	156.85	204.13
16.	Scientific Instruments	—	—	—	—	8	8.55	12.31	15.31	8	8 55	12 31	15.31
17.	Math. Surveying & Drawing Instruments	—	—	—	—	—	—	—	—	—	—	—	—
18.	Fertilizers	4	355.72	322.70	385.24	3	34.56	46.22	49.72	7	390 28	368.92	434.96
19.	Chemicals (other than Fertilizers)	6	85 09	267.39	235.28	99	1530 22	1677.45	1791.49	105	1615.31	1944.84	2026.77
20.	Photographic Raw Film & Paper	1	33 90	38 02	55 00	—	—	—	—	1	33.90	38.02	55.00
21.	Dyestuffs	—	—	—	—	11	213.71	291.03	373 21	11	213.71	291.03	373.21
22.	Drugs & Pharmaceuticals	2	204 11	266 39	197.56	35	880 88	1123.44	1367.39	37	1084.99	1389.83	1564.95
23.	Textiles (Dyed, Printed, Processed)	—	—	—	—	21	317 04	441 87	420.16	21	317.04	441.87	420.16
24.	Paper & Pulp (incl. Paper Products)	1	3.[illegible]	3.54	5 47	12	161 28	99.50	144.34	13	165.25	103.04	149.81
25.	Sugar	—	—	—	—	5	9 05	11.63	37.70	5	9.05	11.63	37.70
26.	Fermentation Industries	—	—	—	—	—	—	—	—	—	—	—	—
27.	Food Processing Industries	—	—	—	—	6	50.27	111.54	160.45	6	50.27	111 54	160.45
28.	Vegetable Oils & Vanaspati	—	—	—	—	3	8 21	11.59	19.50	3	8.21	11.59	19.50
29.	Soaps, Cosmetics, Toilet Preparations	—	—	—	—	7	261.35	279.97	298.98	7	261.35	279.97	298.98
30.	Rubber Goods	1	3.42	3.76	3 95	4	146.32	167.59	221 17	5	149.74	171.35	225.13
31.	Leather, Leather Goods & Pickers	—	—	—	—	—	—	—	—	—	—	—	—
32.	Glue & Gelatin	—	—	—	—	—	—	—	—	—	—	—	—
33.	Glass	—	—	—	—	3	17 56	19.04	23 42	3	17 56	19 04	23.42
34.	Ceramics	—	—	—	—	9	148.89	131.15	135 66	9	148.89	131 15	135.66
35.	Cement & Gypsum Products	—	—	—	—	2	363.80	414.09	207.37	2	363.80	414 09	207.37
36.	Timber Products	—	—	—	—	2	16.60	11.09	10.40	2	16.60	11.09	10.40
37.	Defence Industries	7	1227.85	1520 42	2429.46	—	—	—	—	7	1227.85	1520 42	2429.46
38.	Miscellaneous Industries	3	40.68	17.17	74.91	10	93 75	92 45	129 97	13	134 43	109 62	204.88
	Total	62	5518.60	7341.17	8983.27	470	7587.52	9214.57	10393.43	532	13106.12	16555.74	19376 70

Source: Data compiled by DST.

TABLE—3

EXPENDITURE ON R&D BY SOURCE AND BY PERFORMER FROM 1976-77 TO 1980-81 AT CURRENT AND CONSTANT PRICES WITH 1970-71 AS THE BASE

Sl. No.	Year	Expenditure on R&D by source (Rs. Crores)		Expenditure on R&D by performer (Rs. Crores)	
		at current prices	at constant prices	at current prices	at constant prices
1.	1976-77	379.07	227.40	374.16	224.46
2.	1977-78	436.64	253.20	430.62	249.72
3.	1978-79	542.68	309.27	528.60	301.30
4.	1979-80	649.47	324.71	638.54	319.27
5.	1980-81	715.08	321.75	701.19	315.53

Note:— For working out R&D expenditure at constant prices, GNP price deflators have been used.
Source:— Data compiled by DST.

TABLE—4

R&D EXPENDITURE BY MAJOR SCIENTIFIC AGENCIES UNDER THE CENTRAL GOVERNMENT

Sl. No.	Name	R&D Expenditure (Rs. Lakhs)						
		1958-59	1969-70	1973-74	1976-77	1978-79	1979-80	1980-81
1.	Department of Atomic Energy	775.63	2072.06	2445.53	5831.74	6082.32	6781.46	7623.24
2.	Council of Scientific and Industrial research	509.94	1868.07	2500.77	4125.71	5592.39	5918.99	7281.79
3.	Defence Research and Development Organisation	150.00	1454.39	3428.97	5065.00	6678.61	9662.91	7970.00
4.	Indian Council of Agriculture Research	372.29	1377.08	2408.42	3739.24	5603.56	7739.81	6599.27
5.	Indian Council of Medical Research	50.50	156.46	170.00	423.00	533.54	598.50	842.08
6.	Department of Science and Technology	22.13	73.88	213.67	1121.20	2389.83	2603.56	3537.30
7.	Department of space	—	—	1909.22	3892.45	4552.74	4421.13	5270.85
8	Department of electronics	—	—	97.53	422.01	511.47	750.25	431.35
	Total	1880.74	7001.94	13174.21	24620.35	31945.46	38476.61	39555.88

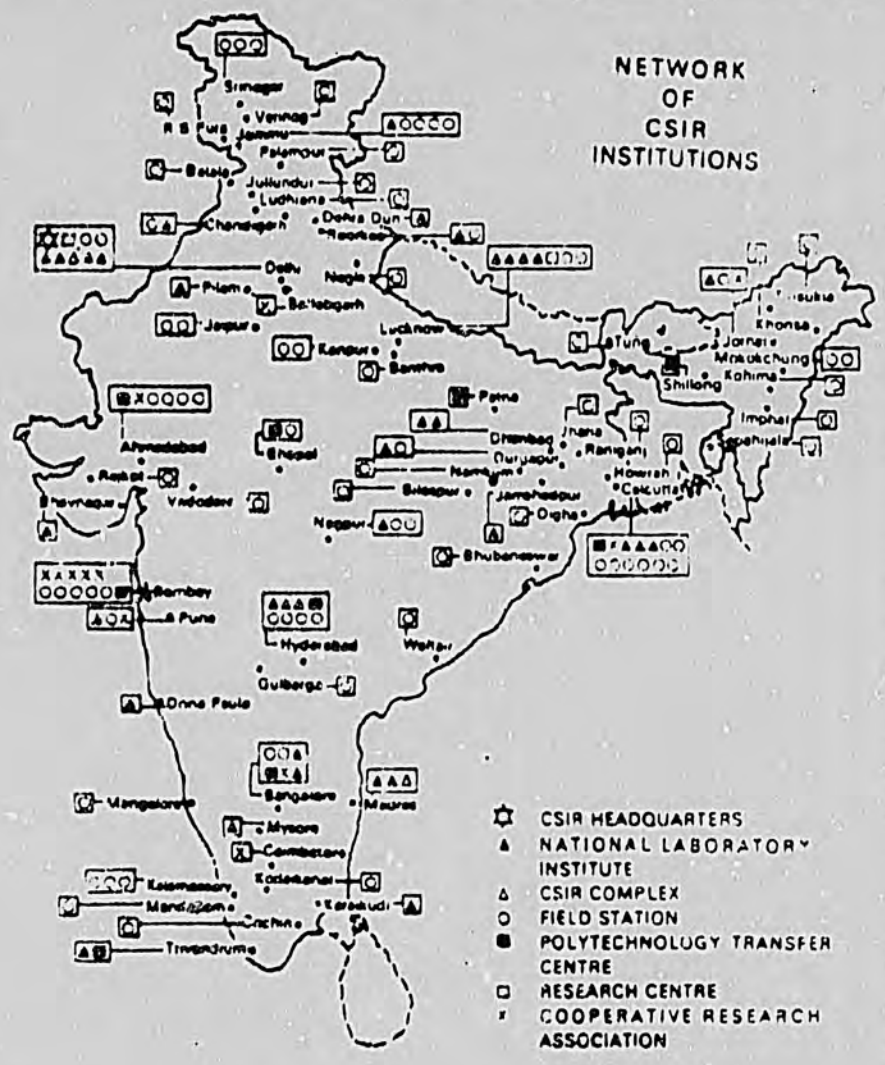
Source:— Data compiled by DST.

Major CSIR establishments

Council of Scientific & Industrial Research, New Delhi
Central Building Research Institute, Roorkee
Central Drug Research Institute, Lucknow
Central Electrochemical Research Institute, Karaikudi
Central Electronics Engineering Research Institute, Pilani
Central Food Technological Research Institute, Mysore
Central Fuel Research Institute, Dhanbad
Central Glass & Ceramic Research Institute, Calcutta
Central Leather Research Institute, Madras
Central Institute of Medicinal & Aromatic Plants, Lucknow
Centre for Cellular & Molecular Biology, Hyderabad
Centre for Biochemicals, Delhi
Central Mining Research Station, Dhanbad
Central Road Research Institute, New Delhi
Central Scientific Instruments Organisation, Chandigarh
Central Salt & Marine Chemicals Research Institute, Bhavnagar
Indian Institute of Chemical Biology, Calcutta
Indian Institute of Petroleum, Dehra Dun
Indian National Scientific Documentation Centre, New Delhi
Industrial Toxicology Research Centre, Lucknow
National Aeronautical Laboratory, Bangalore
National Botanical Research Institute, Lucknow
National Chemical Laboratory, Pune
National Environmental Engineering Research Institute, Nagpur
National Geophysical Research Institute, Hyderabad
National Institute of Oceanography, Goa
National Institute of Science, Technology & Development Studies, New Delhi
National Metallurgical Laboratory, Jamshedpur
National Physical Laboratory, New Delhi
Publications & Information Directorate, New Delhi
Regional Research Laboratories at, Bhopal, Bhubaneswar, Hyderabad, Jammu, Jorhat, Trivandrum, Structural Engineering Research Centres at Roorkee and Madras.

Co-operation Industrial Research Associations:

Electrical Research & Development Association, Vadodara Tea Research Association, Calcutta



and castable polymers; pesticides like endosulfan, monocrotophos, dimethoate, ethion, etc; speciality papers; catalysts; leather and leather auxiliaries; electronic components; etc. are also noteworthy.

Except in drugs and chemicals, they were technologies meant for small producers. As far as big industry was concerned, CSIR had not really delivered. However, defending the achievements of Indian science, and ex-CSIR scientist, V. S. Arunachalam, science adviser to the defence ministry, says "In India, both outstanding achievements and outstanding horrors are taken for granted. In the newspapers people read about the launching of a satellite and also bribe-burning, and they take both of them for granted."

RATIONALISATION PROCESS

That may or may not be so. However, the fact is that irrespective of its past achievements or non-achievements, the CSIR is now undergoing a major process of rationalisation. The number of research projects in the laboratories is going to be reduced to about a third of their present strength. Between, June 1982 and June 1983, for example, the total number of projects came down from 1,800 to 1,500. And the aim, apparently, is to bring their number down to only 500.

In addition, there will be about 10 major projects, which according to CSIR headquarter sources "should ideally take up 70 to 80 per cent of the total resources of the CSIR. These major projects would be in the areas of micro-electronics, materials, coal and coal-chemicals, microbiology, and oceanography. And these will all be multi-laboratory multi-agency (e.g. government departments, public sector enterprises, etc.) projects and their budgets will be contributed to by the various agencies involved. The planned budgets of each one of these projects over a seven to ten year period are expected to be much higher than the present annual budget of the CSIR.

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more expenditure, which means $0.3 million of expenditure approximately. Industrywise the distribution is as follows :

Table VII

Distribution of R&D Units (Industry-wise)

	Total	Units (with Rs. 25 lakh or more R&D)	(2) as % of (1)
Chemicals and Pharmaceuticals	167	52	31.1
Textiles	25	7	28.0
Miscellaneous	63	22	34.3
Electricals and Electronics	158	24	15.5
Mechanical Engineering	107	29	27.1
Ceramics	10	3	30.0
Metallurgical Engineering	20	4	20.0
Paper	17	1	5.9
Total :	564	142	25.2

Source : Scientific & Technological Institutions in India, Department of Science & Technology, 1981, p. 21 to 37.

Eighteen of these incurred R&D expenditure of Rs. 1 crore or more in 1980-81, 5 of them having spent more than Rs. 2 crore each. Similarly, of the 296 Scientific and Technological institutions under the Central Government, 198 incurred Rs. 25 lakh or more expenditure in 1979-80. Twenty of these are public sector undertakings. Only eleven of the 154 Scientific and Technological institutions under State Governments incurred during 1978-79/1979-80, Rs. 25 lakh or more R&D expenditure. During 1980-81, 11 public sector undertakings spent more than Rs. 1 crore each on R&D, 5 of them Rs. 5 crore or more and 2 of them Rs. 10 crore or more.

2.13 While all this is encouraging, Indian R&D would, for quite some time, be primarily oriented to absorbing the technology that is imported, improving raw materials, cutting down energy consumption and the like or as would facilitate greater de-packaging of imported technology and not oriented to "frontline" research. A policy of defensive R&D has to be distinguished from competitive R&D. Japan, which had paid $9-10 billion for the import of technology, was till recently only interested in absorbing the imported technology, innoveting if at all, in a minor way. Having

ANNEX F: LIST OF MAIN DOCUMENTS REVIEWED

1. AID, Forestry and Development in Asia (forthcoming).

2. Association of Indian Engineering Industries, Annual Report 1982.

3. Bharat Bhushan, "The CSIR Story," Business India, September 12-25, 1983, p. 50-59.

4. B. Bowonder, "Deforestation in India," International Journal of Environmental Studies, 1962.

5. Centre for Monitoring the Indian Economy, Basic Statistics Relating to the Indian Economy, Vol. 1, August 1983.

6. Op.cit., Current Energy Scene in India, May 1983.

7. Centre for Science and Environment The State of India's Environment, 1982: A Citizen's Report, New Delhi, 1982.

8. Economic and Scientific Research Foundation, Technology Policy. New Delhi, 1983.

9. F. A. Long, "Science and Technology in India: Their Role in National Development," in India: A Rising Middle Power, edited by John W. Mellor, Chapter VIII, pp. 221-258.

10. GOI, All-India Institute of Medical Sciences, Annual Report 1981-82.

11. GOI, Central Drug Research Institute, Lucknow, Annual Report 1981-82.

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ANNEX G: LIST OF PERSONS INTERVIEWED

ADMINISTRATIVE STAFF COLLEGE OF INDIA, HYDERABAD

Mr. M. Narasimham, Principal
Mr. B. Bowonder, Chairman, Center for Energy, Environment and Technology;

ALL INDIA INSTITUTE OF MEDICAL SCIENCES

Dr. H. D. Tandon, Director
Dr. G. P. Talwar, Director, Indian Institute of Immunology

ALL INDIA RICE RESEARCH PROJECT

Dr. R. Seetharaman, Project Director

CENTER FOR POLICY RESEARCH

Mr. Pai Panandeker, Director

CENTRAL WATER COMMISSION

Mr. Pritam Singh, Chairman
Mr. H. S. Krishnaswamy, Member
Mr. Gokhul Prasad, Member

COMMISSION ON ADDITIONAL SOURCES OF ENERGY

Dr. M. Dayal, Additional Secretary

COUNCIL OF SCIENTIFIC AND INDUSTRIAL RESEARCH

Mr. G. S. Sidhu, Director General
Mr. K. N. Joshi, Head, International Collaboration Unit

DANFOSS (INDIA)

Mr. J. C. Kapur, Chairman

DEPARTMENT OF COMMERCE

Mr. Abid Hussain, Secretary

DEPARTMENT OF ECONOMIC AFFAIRS

Mr. S. Sundar, Joint Secretary
Mr. J. S. Baijal, Additional Secretary
Mr. K. A. Krishna Moorthy, Under Secretary

DEPARTMENT OF ENVIRONMENT

Dr. T. N. Khoshod, Secretary

DEPARTMENT OF NON CONVENTIONAL ENERGY SOURCES

Mr. B. W. Swarup, Secretary
Mr. S. R. Faruq, Joint Secretary
Mr. Ramesh Grover, Joint Secretary
Mr. Ajit Gupta, Principal Scientific Officer
Dr. Sumita Kandpal, Joint Secretary
Dr. Sumita Kandpal, Joint Secretary

DEPARTMENT OF SCIENCE AND TECHNOLOGY

Dr. S. Varadarajan, Secretary
Dr. M. M. Dayal, Chief Energy Advisor
Dr. J. Dhar, Deputy Director, International Cooperation
Dr. Ramachandran, Deputy Director
Dr. Manju Sharma, Director

DEPARTMENT OF TECHNICAL DEVELOPMENT

Mr. Satya Pal (Former Director General)

ENERGY INDIA

Rabindra S. Grewal, Managing Director

FEDERATION OF INDIAN CHAMBERS OF COMMERCE AND INDUSTRY

Dr. D. H. Pai Panadiker, Secretary General

FENNER INDIA

P. C. Sud, Executive Director

FOOD AND AGRICULTURE ORGANIZATION

Mr. J. G. Rumeau, Representative
Mr. Hans V. Hend, Agricultural Economist

FORD FOUNDATION

Dr. Lincoln Chen, Representative
Dr. Peter Bentley
Dr. Robert Chambers

FOUNDATION TO AID INDUSTRIAL RECOVERY

Dr. S. Ramachandran, Director
Dr. N. C. B. Nath

U. P. GARRET CORPORATION

Dr. John Fallen

HINDUSTAN AERONAUTICS LTD.

Dr. Roy Choudhury, Consultant

HINDUSTAN PREFAB LTD.

G. K. Majumdar, Chairman

INDIAN AGRICULTURAL RESEARCH INSTITUTE

Dr. H. K. Jain, Director

INDIAN COUNCIL OF AGRICULTURAL RESEARCH

Dr. O. P. Gautam, Director General
Dr. R. M. Acharya, Deputy Director General
Dr. N. S. Randhawa, Deputy Director General
Dr. P. N. Rau, Secretary
Dr. Manaraj Singh, Deputy Director General

INDIAN COUNCIL OF MEDICAL RESEARCH

Dr. Badri Saxena, Deputy Director General

INDIAN INSTITUTE OF FOREIGN TRADE

Mr. Vithal Babu, Deputy Director General

INDIAN INSTITUTE OF IMMUNOLOGY

Dr. G. P. Talwar, Director

INDIA INSTITUTE OF SCIENCE, BANGALORE

Dr. D. Sen Gupta, Professor, Electrical Engineering

INDIAN INSTITUTE OF TECHNOLOGY

Dr. K. S. Gopalakrishnan, Deputy Director
Dr. P. D. Grover, Professor of Chemical Engineering
Dr. S. S. Mathur, Director, Center for Energy Studies

INSTITUTE OF MARKETING MANAGEMENT

Dr. Jagjit Singh, Secretary General

INTERNATIONAL CROPS RESEARCH INSTITUTE FOR THE SEMI-ARID TROPICS

Dr. L. D. Swindale, Director General
S. P. Ambrose, Principal Government Liaison Officer
Dr. C. R. Jackson, Director for International Cooperation
Dr. J. S. Kanwar, Director of Research

INTERNATIONAL DEVELOPMENT RESEARCH CENTRE (OTTAWA)

Mr. Ashok Desai, New Delhi Representative

MINISTRY OF AGRICULTURE

Mr. C. L. Bhatia, Inspector General for Forests
Dr. Nilu Chatterjee, Program Economist
Dr. N. J. Joshi, Deputy Director General of Forests
Mr. J. R. Saha, Director, International Cooperation Division

MINISTRY OF ENERGY

Satish Chandran, Secretary of Power
Lin Laddha, Joint Secretary
Kamalahar Mishra, Joint Secretary
D. S. Ramesh, Joint Secretary

MINISTRY OF HEALTH AND FAMILY WELFARE

Mr. S. S. Sidhu, Secretary
Dr. D. B. Bisht, Director, General Health Services
Mr. R. P. Kapoor, Additional Secretary
Mr. C. V. S. Mani, Additional Secretary
Mr. S. K. Sudhakar, Joint Secretary
Mr. S. K. Syiem, Director, U.S. Aided Project

MINISTRY OF IRRIGATION

Mr. M. G. Padhye, Secretary
Mrs. Shovna Narayan, Under Secretary
Ms. Priya Prakash, Joint Secretary

NAGALAND

Rajinder Singh Bedi, Chief Liaison Officer

NATIONAL BOTANICAL RESEARCH INSTITUTE

Dr. H. C. Chaturvedi, Scientist-in-Charge,
Tissue Culture Laboratory
Dr. G. S. Srivastava, Director, Hydro-Carbon Plans, and Head,
Plant Introduction and Acclimitization Techniques

NATIONAL COUNCIL FOR APPLIED ECONOMIC RESEARCH

Dr. I. Z. Bhatty, Director General
Dr. Anwar Alam, Assistant Director General

NATIONAL COUNCIL OF POWER UTILITIES

Mr. J. C. Shah, President

NATIONAL INSTITUTE OF COMMUNICABLE DISEASES

Dr. A. N. Raichowdhury, Director

NATIONAL INSTITUTE OF HEALTH AND FAMILY WELFARE

Dr. Somnath Roy, Director

NATIONAL PRODUCTIVITY COUNCIL

Mr. V. Raghuraman, Director, Fuel Efficiency

PLANNING COMMISSION MEMBER FOR SCIENCE AND TECHNOLOGY

Dr. M. K. Menon

PUNJAB AGRICULTURAL UNIVERSITY

Dr. Sukhdev Singh, Vice Chancellor
Dr. K. S. Gill, Director of Research

RAIL INDIA TECHNICAL AND ECONOMIC SERVICES LTD.

R. Parthasarathy, Managing Director

ROORKE INDIA

Dr. Thapar, Director, Mini Hydro Center

RURAL ELECTRIFICATION CORPORATION

M. Venkataratnam, Chairman
N. K. Jangalwa, Technical Director
N. Sriram, Finance Director

TATA ENGINEERING RESEARCH INSTITUTE

Mr. R. K. Pauchari, Director

UNIVERSITY GRANTS COMMISSION

Mrs. Madhuri Shah, Chairperson

VALLABHAI PATEL CHEST INSTITUTE

Professor A. S. Paintal, Director
Dr. A. K. Prasad, Virologist

WORLD BANK

Mr. Richard G. Grimshaw, Chief, Agriculture Division