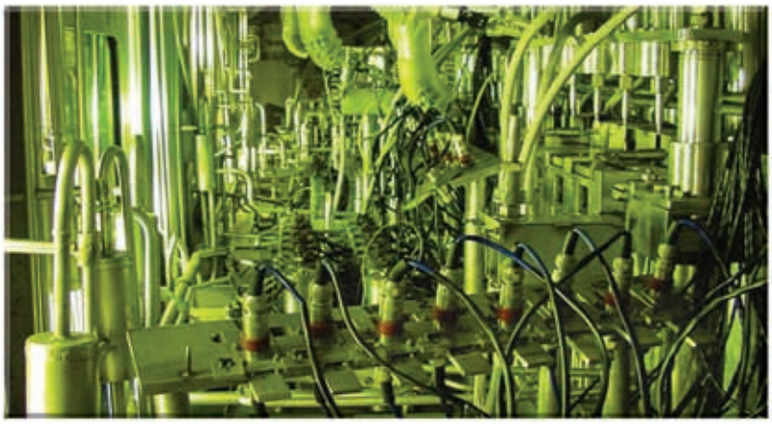
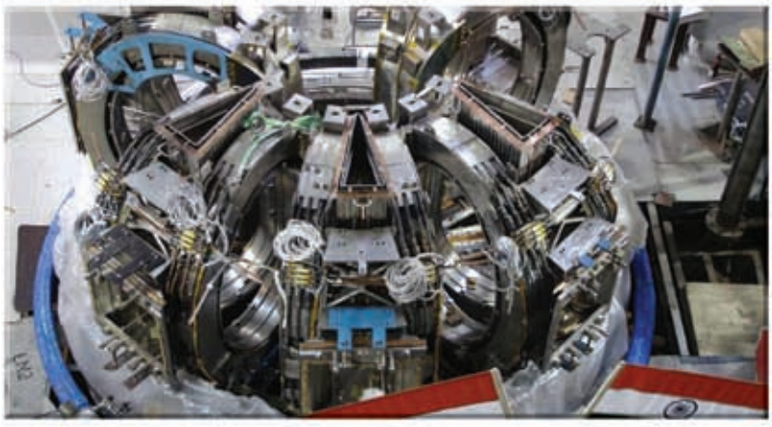
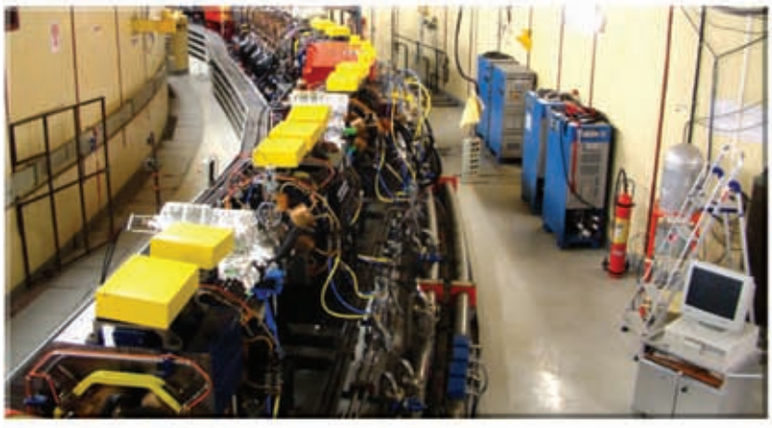






Department of Atomic Energy

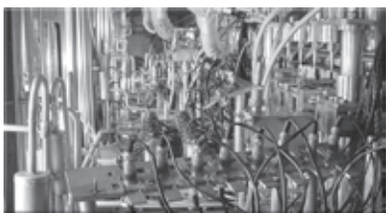
XII PLAN PROPOSALS

REPORT OF THE WORKING GROUP

R&D SECTOR

सत्यमेव जयते

भारत सरकार
Government of India
Department of Atomic Energy



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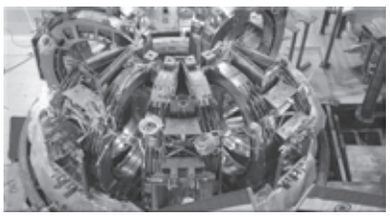

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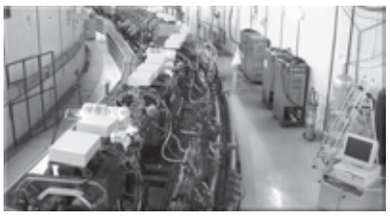


INDUS-2 Tunnel

Hot Cells Facility

New Oilseed Varieties Developed at Trombay

SEPTEMBER 2011

XII PLAN PROPOSALS

REPORT OF THE WORKING GROUP

R&D SECTOR

Government of India
Department of Atomic Energy

CONTENTS

PREFACE

The Department of Atomic Energy (DAE), a premier central government Department, has been following a well-focused mandate of developing and establishing indigenous technological base for deriving sustainable benefits from nuclear applications, both for power production and for a wide range of societal applications. Energy security is a key requirement for continued growth of national development and enhancement of the quality of life of our very large population. Similarly indigenous availability of advanced nuclear and radiation technologies is essential for improving and strengthening health care, agricultural practices, environmental protection, water resources management and materials development for varied applications. Over the years, the DAE programmes have achieved considerable progress resulting in several contributions to all the above areas. The steady growth in DAE deliverables has been facilitated mainly thanks to its R&D endeavours, acquiring capabilities in diverse aspects of nuclear technologies and manufacturing, as well as successfully applying them in building indigenous capabilities.

Thanks to the visionary and pragmatic approach of Dr. Bhabha to the long term needs of energy security of the country, the Department had adopted a three-stage nuclear power programme starting with the commissioning of a number of PHWRs in the first stage. Currently twenty power reactors, with a cumulative installed capacity of 4.78 GW(e), are in operation. It is imperative to adopt all available energy options to meet the ever increasing power demands to sustain India's further growth. In this context, the proposed target installed nuclear power generation capacity is 20 GW(e) by the year 2020. A large number of the R&D sector projects of DAE are accordingly tuned to meet this major goal. The other important factors driving the planning process have been the identification of technology gap areas and development of enabling technologies to address the gaps, safety-related research needs (including ageing management) and upgrades, needs-based development and/or adoption of emerging nuclear technologies and their applications, contemporary international developments in nuclear sciences, human resource requirements and stronger outreach to create better awareness and public perception of nuclear applications.

DAE comprises a well-balanced combination of R&D centres, public sector undertakings, industrial organisations and educational and academic institutions including a number of aided institutions. All of these individually as well as collectively contribute to the overall goals and programmes of DAE. The plan projects of DAE, whether in R&D Sector or in I&M Sector, should be viewed as a seamless effort across different plans to fulfill DAE's mandates, while yet keeping in focus specific thrust areas in each plan period. Periodic multi-level review of the progress of the ongoing five year plan projects as well as assessment of further requirements has enabled the Department to identify priorities to be addressed and approach to be adopted. During XII Plan, the main thrust will be on meeting development needs in fast reactor and allied fuel cycle, enhancing indigenous capability in key areas of accelerator technologies, thorium utilisation plans, safety related analysis and upgrades, and concerted efforts to improve outreach and public perception.

The elaborate exercise undertaken by the Department to formalize its XII Plan proposals was initiated with the meeting of Steering Committee on S & T, constituted by the Planning Commission to formulate

the R&D directions for the XII-plan on April 5, 2011 and the subsequently held comprehensive brain-storming session on 17 May 2011. Thereafter extensive and involved deliberations have taken place through different levels within every Unit of DAE, the Specialist Groups and the Internal Working Group to finalise the XII Plan proposals. The Projects have been assessed in terms of relevance (technical and timeliness), deliverables, viability, benefits to the society and financial outlay with due care taken to review also the continuing Plan projects to be implemented along with the new ones. Theme-wise classification of the R&D topics under seven major programmes will continue to be followed to adequately reflect the entire commitments of the Department to the nation.

Following over six decades of sustained and indefatigable pursuit of its identified goals and targets, the Department has given us the strength to take on fresh challenges and expand its horizon for the greater benefit of the Society. Further, the opening up of the opportunities for international collaboration have also brought in the necessity for directing R&D towards meeting the challenges of maintaining a competitive edge in areas where we acquired indigenous strength through sustained endeavours, and towards this end, bridge any vulnerabilities that may be accentuated in the unsafeguarded domains of our nuclear programme. All the Projects of DAE should be viewed from this perspective. This report, which is an outcome of the extensive deliberations and five levels of rigorous scrutiny, outlines the background and rationale of the new project proposals along with select highlights of the achievements of XI plan projects.

CHAPTER I
EXECUTIVE SUMMARY

The Department of Atomic Energy has been pursuing R&D in nuclear science and engineering and also in advanced mathematics. The Department comprises of several multi-disciplinary research and development centres, aided institutions and closely linked industrial units. Research and development by the R&D units of DAE provide valuable support to sustain and expand the indigenous nuclear power programme and also to develop non-power applications of nuclear technology for use in industry, food and agriculture, healthcare and advanced research. The research centres and aided institutions also lay strong emphasis on frontline basic and applied research, supporting special technologies, and human resource development for sustained growth and establishing the strong linkages with the academic and research community as well as industries in the country. The initiative of the Department to set up Homi Bhabha National Institute (HBNI) as a deemed to be university is another step towards strengthening the linkage between the institutions of the DAE and also with the academic and research community in the country. HBNI is also serving as a facilitator for enhancing the accessibility of DAE's R&D infrastructure and facility to research students from all over the country. Similarly Tata Institute of Fundamental Research has increased the intake of research students after having been declared a deemed to be university. Chapter 2 provides further details about R&D activities of the Department.

At present, activities of the Department are grouped under three sectors - R&D sector, Power sector and Industries & Minerals sector. Categorization of the DAE's R&D activities into seven major programmes MP-1 to MP-7, followed during the previous two Plan periods, will be maintained in the XII Plan with some adjustments. Specialists Groups (SG) constituted for the review and monitoring of R&D project proposals by the various Units of DAE, have proved to be an excellent peer review mechanism, and it was decided to continue with the same approach in the current Plan. For the continuing projects of XI Plan, status of the progress was reviewed. Reasons for delay and factors favouring continuation / foreclosure were also examined, as a result of which it has been decided to continue with 138 projects in the XII Plan. Such reviews have taken place at the level of the Council of the Unit, in the concerned SG, at the IWG Meeting and at the DAE. Some of the major projects have also been reviewed by the AEC. Out of the XI Plan allocation, 85 % is expected to be utilized by March 2012. The shortfall in utilization stems from a few reasons such as delays in extensive construction activities and/or acquisition of land, difficulties faced in import of equipment and obtaining clearances for commencing the project. Some projects were delayed due to their linkages to completion of other projects, which were not completed on time. Continuing schemes amounting to ₹6188.97 crore will spill over to the XII Plan.

Highlights of achievements, accomplished during the XI Plan are briefly given in the Chapter on 'Achievements of XI Five Year Plan' in the document. Indicator for the performance in basic research namely the publications in peer reviewed journals and citation indices are given towards the end of chapter 3.

- Pursuit of Multiple Reactor Technologies
- Safety Upgrades to Address Beyond Design Basis External Events
- Increased Emphasis on Development of Applications of Nuclear Technology for Societal Benefits
- Outreach Programmes to Enhance Public Acceptance
- Strengthening of Linkages with Universities & National Laboratories

The future direction of R&D and priorities are periodically reviewed taking into account the capabilities acquired, based on which new goals are set. The process of formulation of XII Plan was initiated by discussions during the 12th Meeting of DAE-Science Research Council held on 8th July 2010. A detailed exercise to evaluate the capabilities and identification of the gap areas was carried out during the brainstorming session organized by the R&D sector of DAE on May 17, 2011. Following deliberations, priority areas were identified and guidelines to formulate XII Plan proposals were given by the Internal Working Group. DAE has mastered the Pressurised Heavy Water Reactor technology as a part of first stage of nuclear power programme. Need to accelerate the growth of nuclear power led to policy initiative to open up civil nuclear international trade and now it is planned to set up light water reactors. The Department was already pursuing development of fast breeder reactors and reactors for utilization of thorium.

The natural calamity that Japan (Fukushima – Daiichi) on 11 March 2011 has warranted the need to identify and address safety upgrades required as well as support safety research in relevant areas including in addressing challenges due to Beyond Design Basis Accidents. To accelerate growth of nuclear power installed capacity, Department also has to expand outreach programmes, strengthen linkages with universities and lay increased emphasis on non-power applications of nuclear technologies. The lessons learnt from previous Plans have also to be factored in the process of planning. The projects and programmes planned to be pursued accordingly during XII Plan are given in the Chapter on DAE XII Five Year Plan Proposals. Only brief details are given here.

- Special Materials for Reactor Pressure Vessel of Indian PWRs
- Design & Development of the Indian PWRs
- Control Systems and Mechanisms for Advanced LWRs
- New Techniques for Uranium Exploration
- Design & Development for Metallic Fueled Test Reactor
- Microstructural Engineering of Advanced Materials for Fast Reactor and Reprocessing Technology
- Advanced Processes & Equipment for Waste Management Applications
- Novel Options for Back End Fuel Cycle
- Engineering Scale Development of Reprocessing of Alloy Fuels Based on Pyroprocesses.
- Robotics and Automation for Nuclear Fuel Cycle
- Research on Topics Such as Radiation Damage, Decay Heat & Neutron Attenuation in Shield Materials, Reliability Studies on Innovative Passive Systems for Future FBRs
- Applied R&D on Rare-earth Materials
- Physics Studies and Enabling Technology Development for Ion Accelerators
- R&D for High Energy Proton LINAC Based Spallation Neutron Source

Efforts towards ageing management and safety upgrades of all nuclear plants in operation, and incorporating enhanced safety features in the plant to be set up are planned to be continued. Some of

the topics to be taken up in the XII Plan are analysis of safety related issues, endurance studies, degradation studies, development of rehabilitation and remote tooling devices, development of construction technologies, joining technologies, non-destructive examination and investigation of new safety concepts to address extreme external events. As India is embarking on Light Water Reactor programme, it is necessary to develop, design and verify indigenous LWR concepts and broaden vendor base.

The second stage of the Indian nuclear power programme involving setting up of fast breeder reactors along with the associated fuel cycle facilities is essential to utilize the full energy potential of uranium resources in the country as well as commencement of the third stage through establishing the use of thorium. The construction of the PFBR is in an advanced stage and the reactor is expected to be commissioned by the end of 2012. Two 500 MWe MOX fuelled fast reactors are planned to be set up. Metallic fuel deployment with its associated fuel cycle in the fast reactor is the key to reducing doubling time thus accelerating the pace of nuclear power deployment. To ensure expeditious development of metal fueled FBRs, R&D programmes are planned in XII Plan. For validating the design of the fuel subassembly and to gain large scale experience in the fabrication and irradiation testing of metallic fuels, a 120 MWe metal fuelled fast reactor will be designed and is being planned at IGCAR in the XII Plan with construction proposed in the XIII Plan.

The development and demonstration of thorium fuelled Advanced Heavy Water Reactor is an important initiative for thorium utilization and for the third stage of nuclear power programme. This reactor also already embodies several innovative passive safety features that have now assumed added significance internationally following the Fukushima-Daiichi events. A major programme to experimentally demonstrate the available margins to extreme internal and external events will be carried forward in the next Plan period to further add to validation of these advanced safety features, many of which are generic in nature.

- National Level Preparedness for Nuclear & Radiological Emergencies
- Safety Studies Related to PHWRs, AHWR and CHTR
- Safety Upgradation of FBTR
- Safety Assessment and Technology Development for Advanced Reactors
- Environmental studies and Advanced Techniques for Radiation Dosimetry

In addition to AHWR, planning for a Compact High Temperature Reactor (CHTR) is an important step towards the development of advanced reactor technologies required for hydrogen generation. For designing CHTR, consideration of material behavior as well as technologies for utilization of high temperature heat warrant investigations for assessing the performance of structural material in corrosive environment of liquid metal and molten salt coolants. Molten salt is a promising coolant for high temperature application as it also offers the possibility of a thorium based thermal breeder reactor design suitable in the Indian context with a high level of passive safety. The advanced reactor systems including fusion reactor systems require appropriate materials to be specially developed, characterized and compatibility issues resolved. Furthermore, special instruments and sensors also need to be developed for measurement of process parameters in such harsh environment. All necessary studies are being taken up in XII Plan.

India, as a member country of the ITER venture has initiated focused development on all areas relevant to in-kind contribution to be made by India to ITER and has successfully bid for a half port at ITER to test

its Test Blanket Module concept. The test blanket module development for testing in ITER will be a major activity. The Indian concept for TBM is based on building a Lead Lithium Cooled Ceramic Breeder (LLCB).

Research reactors serve the purposes of not only supporting R&D, production of radioisotopes and training, but also provide the test bed for R&D on reactor fuels and materials and validation of computational codes, as for example in shielding design. At present Dhruva is the only research reactor to support such activities in Trombay. Reactor Apsara will be available for research by 2013 after a new core is installed. It is necessary to plan for a new high flux reactor facility in Vizag to meet the demands of research and isotope production. This would be an important area of focus in XII Plan though the new reactor itself will be built only around the end of XIII Plan. The civil and allied works related to the radioisotope processing laboratory will be taken up along with the reactor project in the current Plan. Further planning and development of the radioisotope processing facility will be handled jointly by BARC and BRIT as a new project under XIII Plan. Accelerators and lasers are very powerful tools for basic as well as applied research. Better beam properties and enhanced reliability would help carry out frontline research on probing deeper into the matter as well as carry out the applications with better precision and control. Several new beam lines will be installed at INDUS 2 and the existing ones will be upgraded with modern equipment for supporting high quality research. BARC and RRCAT have formulated project proposals to develop enabling technologies like RF cavity for superconducting high power proton LINACs.

Projects on diversifying the sources of production of radioisotopes based on exploring the application of accelerators and including electron accelerators (involving collaboration of VECC with TRIUMF, Canada) as well as production of some specific isotopes like Strontium-89 in FBTR-IGCAR is proposed. India with over 1.2 billion population has several challenges in ensuring food security and industrial economy. All the possible nuclear contributions to food and agriculture (radiation mutants, food preservation by radiation treatment, better use of water resources etc) as well as in enhancing industrial productivity using radiation-aided industrial process management and trouble-shooting would be supported in XII Plan.

Radioisotopes and their formulations (labelled compounds, radiopharmaceuticals) and radiation sources (isotope sources, gamma plants and electron accelerators) are required for nuclear applications in health care, industry, food security, agriculture, water resources management and research. The XII Plan projects in these topics aim to strengthen DAE support for sustainable adoption and/or expanded deployment of these applications for societal benefits. Continued interactions with stakeholders beyond the DAE including several State and Central Ministries and Organisations would be followed to further promote awareness and outreach. A national hadron therapy facility for cancer treatment and other augmentation plans at ACTREC-TMC will help expand the range and capabilities in radiation medicine.

- Developing Novel Applications of Radiation Technology for Value Addition to Food & Agro Commodities
- National Cancer Grid - Upgradation of Major Nodes
- National Facility for Hadron Beam Therapy
- Biomedical and Societal Applications of Lasers and Laser Based Instruments
- Neighbourhood Welfare Programme
- Expansion of DAE Outreach and Perception Management

In the area of basic research, thrust areas include inter alia nuclear and high energy physics, laser science technologies and applications, condensed matter physics and materials science, separation sciences, hydrogen energy systems, analytical chemistry, radiation chemistry, radiation biology and cancer research, etc. In the area of plasma and fusion physics, the participation in the ITER programme has given an impetus to the R & D efforts in the domestic fusion programme based on ADITYA in IPR, Gandhinagar. Considering the importance of the solar energy, the utilisation and storage of hydrogen energy and the clean coal technologies in the optimum energy mix, components of basic science and technology development relevant to the generic area of advanced engineering technologies have been included in several proposals. There are several features common to these diverse energy systems such as materials, thermal engineering, manufacturing technologies, which are of relevance to relevance to nuclear technologies as well. Similarly basic research in disciplines like physics, chemistry and biology can also be directed towards process development related to energy production, storage and efficient utilisation. Special effort has been made in formulating projects to build enabling technologies and relevant basic research which can cover the entire gamut of advanced energy systems.

Advanced Energy Technologies

- Solar Energy
- Hydrogen Technology
- Ultra Supercritical Technology

DAE continues to increasingly participate in international collaborative ventures. Participation in activities at LHC, CERN, Geneva, has led India to obtain the status of an 'observer state.' Indian participation in the seven Member ITER project will continue during XII Plan. India's participation in ITER has demonstrated our scientific and economic strength to be a partner in mega-science projects and has led to several global groups seeking Indian contributions in their projects, as for example Project X proposed by Fermi Lab in the US. India has joined the multi-national, multi-organisational project, Facility for Anti-proton and Ion Research (FAIR), being set up at Germany.

An extremely high degree of technical excellence and competency of human resources is crucial for the success and sustainability of nuclear programmes. The DAE SRC award scheme has led to some very significant research outputs and will be continued to provide further incentive to competent professionals within and outside DAE. Increasing linkages with the national higher education institutions (Universities, IITs, NITs etc) will be continued so as to ensure availability of quality manpower for inputs to DAE programmes and projects.

The DAE initiative to set up HBNI as a Deemed University has made good progress with close to 100 students having already completed Ph.D. and over 1000 students registered for PhD. In addition, all those who join BARC training school have the option to go in for an M.Tech. or an M.Phil. and a large majority of engineers are opting for an M.Tech. The medium of HBNI is being used to further strengthen linkages with IITs and some Universities. The present methods of collaboration through BRNS and MOUs with select academic institutes will continue to be supported and further strengthened. The scope of BRNS functions will be supplemented by extending additional support from the DAE R&D Units to select R&D organisations and Universities, which would enhance the linkages with academic institutions and also help, achieve greater awareness on the benefits of nuclear applications.

- Global Centre for Nuclear Energy Partnership (GCNEP)
- Increased Emphasis on Human Resource Development and Collaboration with Indian Universities
- Enhancement of Digital Knowledge Resources
- Centre for Outreach, Research and Education
- Enhanced Funding for Extra-mural Research to be Funded through Board Of research in Nuclear Sciences
- Continuation of DAE SRC Award Scheme for Funding Talented Researchers in and Outside DAE units
- Assistance to RMC and Cancer Hospitals

In order to meet the growing number of programmes and projects, it is necessary to strengthen and expand the investments in infrastructure. New campuses coming up, for example of BARC in Vizag and of TIFR in Hyderabad, would involve considerable efforts and resources. The ongoing projects towards strengthening and upgrading existing security systems need to be continued. The Global Centre for Nuclear Energy Partnership (GCNEP) will be set up in Haryana near Delhi, while a good part of these activities will continue also in XIII Plan. In several existing centres, the infrastructural facilities and systems need revamping and/or augmenting.

Chapter 5 gives some details of implementation aspects and financial summary is given in Chapter 6.

The estimated expenditure during the XI Five year Plan is ₹8446.09 crores. The spillover component from XI Five Year Plan (of 138 projects) will be ₹ 6188.97 crores during XII Plan. The new schemes (comprising 258 projects) proposed for DAE during the XII Plan costs ₹24212.45 crores comprising an outlay of ₹17713.72 crores in XII Plan and a spillover component of ₹6498.73 crores in XIII Plan.

Thus the total outlay required during XII Plan for DAE schemes would be ₹23902.69 crores and a spillover component of ₹6498.73 crores in to XIII Plan. This magnitude of outlay proposed by DAE is deemed the minimum essential requirement to meet the targets set up by the DAE to supporting the envisaged growth of Indian nuclear power programme as well as in retaining our nuclear capabilities and transforming our developmental stage competencies to technology leader position in all areas of high relevance to India.

CHAPTER - 2
RESEARCH AND DEVELOPMENT IN NUCLEAR SCIENCE AND TECHNOLOGY

2.0 Introduction

Over the previous plan periods, DAE's technology development pursuits as well as basic science research have made considerable contributions to the Indian nuclear power programme as well as to socio-economic benefits through a range of societal applications. The Department also continues to contribute significantly for national security. The DAE comprises several multi-faceted research centres and closely linked industrial units. Synergy between the DAE laboratories / facilities and industries has provided the vital linkages for successful transfer of valuable technologies and products emerging from DAE efforts by the respective recipient industry or end user.

The DAE follows a consistent and comprehensive approach in expanding national nuclear science and technology capability with a particular focus on building strength and delivery in all areas associated with the use of nuclear technologies including radioisotopes for the welfare of Indian population and national energy security. These include:

- nuclear power reactors and their associated fuel cycle;
- research reactors, production and application of radioisotopes;
- range of advanced technologies needed to support the above programmes;
- basic research in addressing topics to explore new frontiers of science and technology and also support directed research for the development of technology in new directions.

In addition, developing enabling technologies indigenously in tune with projected nuclear power programme requirements is given a very high priority, while continuing to be guided by the 'RDDD principle' (research, development, demonstration and deployment) in relevant fields of nuclear and radiation research and applications. Given the political sensitivity of the nuclear technology in international regime, it is imperative to continue to strengthen domestic programmes so that the Department acquires greater immunity to tackle technology denial regimes. This is all the more essential due to the unique nature of our national nuclear resource profile that consists of a vast thorium reserve and relatively limited uranium reserve. While significant success is notable in both the recently expanded exploration for uranium resources and access to international market for availing commercial uranium supplies, there is still no room for complacency in advancing need-based domestic technology pursuits to meet the long term nuclear power generation targets. Consistent with the approaches adopted during XI Plan, focus of R&D sector support to the nuclear power programme will be maintained on fast reactor and thorium-based technologies. For supporting several of our established nuclear programmes including indigenous PHWR expansion plans, R&D emphasis will be related to mainly the following:

1) enhancing safety upgrade features of the existing and new nuclear power plants and other nuclear facilities;

2) supporting sustainable and effective management of facilities and assets created as well as accelerated expansion of new nuclear power plant deployment;

3) addressing ageing management and related aspects of reactors and nuclear fuel cycle facilities.

Above all, the DAE has to continue to cater to national strategic needs and would be implementing special programmes of vital importance at select units and locations.

The categorization of the DAE's R&D activities in to seven major programmes along with identified specific deliverables for each MP would remain valid for the XII Plan as well. The further classification into sub-programmes and identified specific areas of work has been reviewed and reflects the current requirements and anticipated future trends.

2.1 Power Programme

The per capita electricity consumption in India that stood at around 700 kWh at the beginning of XI Plan period will be nearly 1000 kWh as we embark on XII Plan in early 2012. It is envisaged that the Indian consumption will go further up, to as much as 2500 kWh, by 2031-2032. It is imperative, for the continued economic and social well-being of our country, to harness a well-diversified mix of all sources of energy including nuclear power.

The Indian nuclear power programme is based on the three stage programme which has evolved from the days of Dr H.J. Bhabha. The scheme is designed to ensure long-term energy security to the country making use of indigenous nuclear fuel resources (mainly thorium). The approach involves adopting a closed fuel cycle based on reprocessing of the spent fuel and recovery of fissile material for recycling. This requires certain sequential developments relevant for power plants of each stage and at the same time with plenty of scope and need to make parallel advances in several related developmental activities. The DAE is currently pursuing programmes linked to all the three stages.

The first stage programme has achieved maturity in setting up the natural uranium fuelled PHWRs and related fuel cycle facilities and is in the industrial domain. Currently 20 power reactors (including two BWRs) with an installed capacity of 4780 MWe, while 4 PHWRs (and also 2 PWRs) are under construction. The 540 MWe PHWR design, that was evolved from the rich experience gained in the construction and operation of 220 MWe PHWR systems, led to two plants being set up in Tarapur (TAPS-3&4), where India has been operating since 1969 two BWRs (TAPS-1&2, 160 MWe each) obtained on turn-key basis.

India has gathered experience of over 300 reactor years of safe operation and achieved up to 90% overall capacity factor. The 540 MWe PHWR design has been further up-rated to 700 MWe by permitting limited boiling of the coolant in the same core. All future PHWRs in India are planned to be of 700 MWe capacity and will help utilise the full indigenous uranium potential, equivalent to 10,000 MWe. With the active collaboration between the DAE and Indian industry, the technology for the manufacture of a variety of components and equipment for the nuclear power plants in general and PHWRs in particular has become well established. The construction of the nuclear power plants has been achieved in a time bound manner with gestation period being comparable to or better than international standard.

The second stage programme is based on fast breeder reactors using plutonium-239 as fuel and depleted uranium as blanket. Invaluable operational experience has been gained from the Fast Breeder Test Reactor set up at IGCAR, Kalpakkam and from the indigenous manufacture of components for fast reactors. The second stage pursuit has advanced further with the construction of Prototype Fast Breeder Reactor of 500 MWe capacity at Kalpakkam. Construction is scheduled to be completed by March 2012. Simultaneously, all the associated aspects of fuel cycle requirements are being addressed by the relevant Units within the Department. PFBR is a sodium cooled, pool type, mixed oxide fuelled fast neutron reactor and the first commercial scale fast reactor

designed entirely within the country. The purpose of constructing PFBR is to demonstrate the technological capability and commercial viability of FBR along with its closed fuel cycle. Development of technology for manufacture of critical components pursued in collaboration with the leading Indian industries has led them to demonstrate their capability to manufacture in-reactor components for PFBR. The further growth rate of nuclear power in second stage requires faster additions of FBR, which in turn will be possible when fuel can be bred at faster rate as well as reprocessed quickly for deploying in new reactors as soon as possible. For achieving this, introduction of metal-fuelled FBR at an early date, along with pyro reprocessing technology, is required. Consequently, this is one of the thrust areas of high priority for R&D support under XII Plan.

The third stage launch will be facilitated by the advanced heavy water reactor proposed to expedite transition to thorium based systems. A major technology milestone was reached with the design of AHWR being successfully developed. Pre-licensing appraisal of the proposed 300 MWe AHWR project is now completed and site evaluation is in progress. In parallel, the setting up of Accelerator Driven Systems in addition to AHWR is an important need for thorium use (as well as for nuclear (actinide) waste incineration).

The advanced reactor programme in DAE has been addressing the need to develop solutions such as passive safety systems that address the requirements for large-scale deployment of nuclear power plants in a densely populated country like India. Towards this end, the AHWR has been designed and largely requirements identified to be addressed under XII Plan. The natural calamity that stuck Japan (Fukushima – Daiichi) on 11 March 2011 have highlighted the need to critically re-examine the capability of the nuclear power plants and related fuel cycle facilities to meet the challenges due to Beyond Design Basis Accidents, particularly those of natural origin. Both the regulatory authority AERB and the nuclear power producer NPCIL, established review committees to perform objective analysis of all relevant facets of our nuclear power plants, after taking into account the lessons from Fukushima - Daiichi and to institute appropriate measures as may be found necessary. These safety reviews have led to planning certain safety upgrades as well as launching investigational studies. The findings can lead to identifying technology development needs for the operating facilities and spent fuel storage pools.

Pressurised Water Reactors of Russian origin being set up in Kudankulam (2 X 1000 MWe) will be supplemented by two more such reactors at Kudankulam. Similarly nuclear power plants are envisaged in some other parts of the country under the civil nuclear cooperation agreements with other countries. The civil nuclear cooperation option available now for India is meant for meeting the power demand in a relatively short span of time. This will however only provide an additional element to our capacity, and in some measure, also a catalytic contribution by accelerating the installed capacity in the medium term by facilitated setting up of LWRs of 1000 MWe, or higher size units, with foreign cooperation. Discussions are in progress with various potential foreign vendors for reactor supply on techno-economic viability basis. Four to five nuclear power parks are planned for deploying about 40 GWe of LWRs through civil nuclear cooperation initiative. LWRs based on imported fuel will add to the installed capacity in the first stage in addition to PHWRs.

In contributing to fusion energy development efforts through the Indian membership in ITER project, the domestic industrial and scientific programmes and technological capabilities in many fields including materials, cryogenics, precision manufacturing etc will be greatly strengthened. This is an investment towards future energy security and technology advances and will help to keep us at par with other industrialized nations.

2.2 Radiation Technology and Advanced Technologies

Radiation technology has well-established applications as well as emerging prospects for further enhanced utilization in several areas including health care, food preservation, agriculture, industry and research. The socio-economic benefits accruing to the society are of considerable value. The medical applications of radioisotopes and radiation in general and for cancer management in particular are vital components of health care systems and DAE services in this context are crucial for the end users in India.

Radioisotope products and radiation sources as well as machine-based radiation are utilized in these technology applications. The research reactors at Trombay have been the traditional source of radioisotopes in India, while we are also one of the few countries engaged in large-scale production of cobalt-60 in nuclear power plants. In recent years several medical cyclotron centres have been set up both in public and private sector and these centres produce medical radioisotopes and related radiopharmaceuticals. The high flux reactor proposed in Vizag is an essential requirement to sustain the domestic production and supplies of radioisotopes in future. The use of ionizing radiation to bring about desired changes in materials treated has been growing in India. Electron accelerators complement cobalt-60 based radiation processing plants in this context. Indigenous capability enhancement is notable through the efforts of DAE Units in both hardware (accelerators) as well as applications development and deployment.

In the area of food and agriculture, continued growth in development of genetically modified crop varieties having better yield and pest resistance and enhanced food safety by radiation hygienisation are achieved and both in turn contribute to food security. India with over 1.2 billion population has several challenges in ensuring food security for all and the nuclear contributions should be appropriately supported.

Accelerator and laser based technologies pursued at RRCAT, Indore add another dimension to the nuclear programmes and in their contributions to technology advances and spin off applications. Continuing the DAE's concerted efforts to build advanced technology capability in laser related developments are vital for many fields as well as including in supporting high-tech and state-of-the-art R&D, bio-medical advances etc.

2.3 Basic Research

All the DAE Units and aided institutions have placed a very strong emphasis on basic research in all relevant areas of nuclear sciences and allied topics. This includes inter alia frontier areas in physics, such as nuclear physics, high energy physics, condensed matter physics, plasma physics, astro physics, accelerators and lasers, optics and so on; in chemistry: radiochemistry, radiation and photochemistry, chemical dynamics, laser chemistry and so on; in biology: molecular biology, cell biology, radiation biology, cancer research etc; in agricultural and food sciences; in mathematical and computer sciences. The guidelines for basic research pursuits in DAE include enhancing nuclear and related knowledge pool and strengthening technology development capability and at the same time keeping in mind contributions to the development of cutting edge technologies which are essential for pursuing high quality basic research. In all such pursuits, every possible linkage with one or more major interests of the DAE programmes, be it in power production or non-power areas, is encouraged.

In the field of international collaborations and participation in mega science projects, the participation will be based on cost – benefit analysis. The benefit will be in the form of possibilities, such as access to special facilities, state-of-the-art design development and technologies relevant to our nuclear

programme, early entry in to an emerging frontline research etc. Equitable reciprocal treatment and mutual benefits would be guiding principles of our participation in such initiatives. DAE continues to increasingly participate in LHC activities of CERN, Geneva. Indian participation in the seven member ITER project and related work including many development activities have increased and will continue to be a main focal area of our international role during XII Plan. This has also explicitly shown Indian techno-economic potential to join expensive mega-science projects and led to several groups seeking Indian contributions in their plans and projects, as for example, in US Fermi lab accelerator Project X. India has joined the multi-national, multi-organisational project, Facility for Anti-proton and Ion Research being set up at Germany. DAE is involved in the planning of Indian Neutrino Observatory proposed to be set up near Madurai in association with Department of Science & Technology. INO is open for international participation.

2.4 HRD and Research – Education Linkage

Human resources development endeavours continue to be a key element in DAE programmes. The BARC's Nuclear Training School and its one year orientation course in nuclear science and engineering, now further expanded through a number of other similar training schools of RRCAT, NFC and NPCIL, and the one set up in IGCAR during XI Plan period, would remain the mainstay of high calibre professional inputs to DAE Units and their projects. The setting up of HBNI as a Deemed to be University by DAE has made impressive strides and is an additional means to strengthen the linkages between R&D and technology development in DAE. The DAE - UGC consortium for Scientific Research has enhanced the research-education linkages, by funding research in universities and national laboratories in areas of relevance. The BRNS activities and support to R&D in various fields of DAE interests and relevance have also considerably grown in profile and range of coverage and become another significant source of domestic development and capacity building efforts involving collaborations. The newly created DAE SRC scheme is providing access to funds for basic research. The DAE scientists are also encouraged to undertake major projects under Prospective Research Fund scheme. The DAE SRC scheme will be continued in the XII plan.

2.5 Concluding Remarks

The major strides notable in Indian economy, as well as in the quality of life of our population, would be neither possible nor sustainable without adequate and reliable availability of electricity for all facets of life, be it for society's domestic needs, or for industry, or for security. In light of the environmental impact of large-scale power production, and that too in accelerated manner, it is essential to support and adopt technologies with 'as low a carbon emission as reasonably achievable' to reduce and decelerate global warming and mitigate climate change consequences. It is in this backdrop that the strategy for Indian nuclear power programme has been charted and being pursued

The natural calamity related events that took place in Japan (Fukushima – Daiichi) on 11 March 2011 have attracted international attention and called for measures to allay the concerns on the safety of the nuclear power plants and the spent fuel storage pools. Both the regulatory authority AERB and the nuclear power producer NPCIL, established review committees to carry out objective analysis of the relevant features and systems of our nuclear power plants, after taking into account the lessons from Fukushima, and to institute appropriate measures as may be found necessary. It must be emphasised that nuclear safety is an intrinsic and integral component in all nuclear plants and facilities. Safety is built in - as well as upgraded in course of time - as an inseparable feature of the nuclear plants or

facilities at all stages, right from conceptualization and all the way to decommissioning. For this purpose, an extremely high degree of technical excellence and competency of all the systems and personnel involved is crucial, apart from ensuring that an inherent 'safety culture' is established, well understood and faithfully followed (by all stakeholders involved), as well as continuously monitored and strengthened as necessary. In India, this requirement is very well met by the excellent quality and quantum of human resources available, due to the careful attention given to HR development right from the inception of our nuclear programme.

The path to perfection paved by Dr. Bhabha has taken the Indian Atomic Energy Programme to one amongst the best in the world. The Indian nuclear programme has mature capabilities, technology strength, and is fully geared to harness all the above requisites in meeting the national expectations for its energy security, national security, technological advances and societal well-being. Adequate resources, high quality technology and multi-disciplinary team work are essential features in this pursuit along with the need for cooperation and collaborations, including contributions from industry and academia. The achievements of XI Plan are highlighted in Chapter 3 and the trends and drivers guiding the formulation of XII Plan projects are described in Chapter 4.

CHAPTER 3
DAE ACHIEVEMENTS OF XI FIVE YEAR PLAN

3.0 Introduction

During the XI Five Year Plan, DAE has completed a number of projects and made significant progress in various areas of research and development. A brief overview of the major accomplishments in the plan period covering these activities (only typical examples included; this is not an exhaustive list) is given below.

3.1 MP1: Nuclear Power Programme Stage 1

The R&D support to the first stage of the nuclear power programme covers all relevant topics such as safety-related studies and fuel cycle technology aspects including enrichment, fuel fabrication and reprocessing.

Safety Assessment

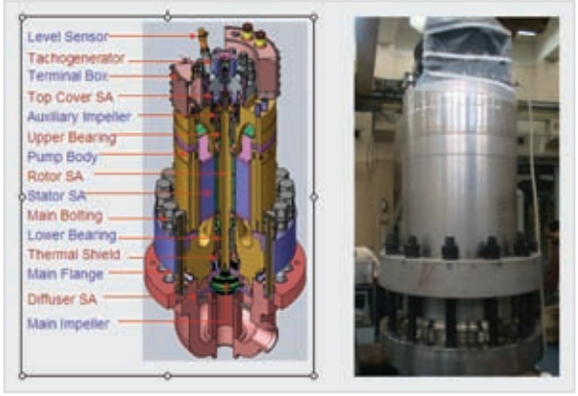
BARCOM, a 1:4 size containment test model has been built to generate database of containment performance evaluation studies, for all functional and structural failure modes and to benchmark the containment analysis computer codes for the postulated design basis and severe accident scenarios. It has been subjected to over-pressure test till the first appearance of crack and the data collected during the pressurisation has been compared with analytical predictions of international round robin exercises.

- Nuclear submarine, ARIHANT was launched in August 2009.
- Steam generating plant was developed and built by the Department.
- First prototype assembly of canned motor pump for compact light water reactor has been successfully manufactured.
- A prototype advanced multi-section high speed rotor with improved separation factors has been developed and tested.

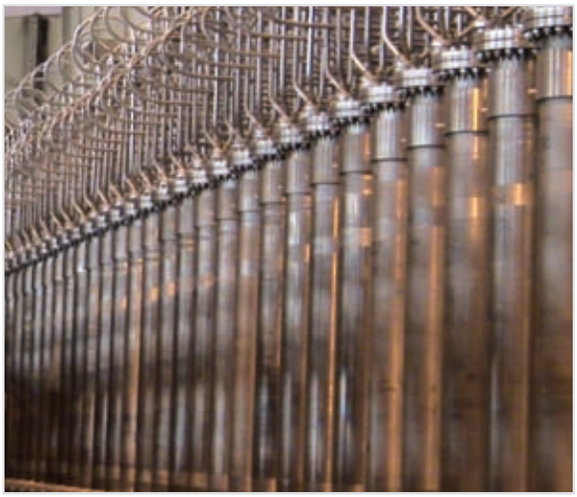
BARCOM Test Model at Tarapur

Front End of Fuel Cycle

For uranium enrichment programme, a number of developments have been made. An experimental



Canned Motor Pump



Gas Centrifuge Cascade

facility for reduction of hex gas to UF_4 by a H_2-F_2 flame reactor has been set up. A process has also been developed for reduction of hex gas to U_3O_8 by steam-hydrogen process. It has been commissioned and kg quantities of stable oxide have been produced.

Uranium exploration is a major activity of the Department. Investigations of Gogi uranium ore and bench scale studies on recovery of uranium from Umra ore have been accomplished. Time-domain

Heli-borne Geological Survey

Electro magnetic (TEM) based sensor and inspection system to carry out land based testing have been developed. Airborne geophysical survey in parts of Proterozoic basins of the country for delineating suitable areas for detailed investigations has been carried out. Reconnaissance, geo-chemical and detailed survey for locating favourable areas for unconformity, iron oxide breccias, quartz pebble conglomerate, sandstone and calcrete type of uranium mineralization are going on. Drilling for establishing the potential of the areas for augmentation of uranium resources is in progress.

For the power reactor thoria reprocessing facility at Trombay, the equipment fabrication has been completed and installation of equipment and piping

Denitration Plant

is in progress. A set-up for evaluating elliptical melter has been deployed and synthesis and characterization of novel solvents have been carried out.

A higher scale denitration plant has been commissioned and three campaigns have been carried out using ammonium nitrate solution.

- Indian Environmental Radiation Monitoring Network (IERMON) incorporating three radiation detectors has been developed
- Nearly 115 new IERMON stations have been set up
- 350 more IERMON stations will be completed by March 2012

Optically Simulated Luminescence dosimeter (OSLD) badge based on α-Al_2O_3:C phosphor along with reader system for personnel monitoring of radiation workers has been developed and 100 OSLD badges have been introduced for field tests in DHRUVA reactor.

3.2 MP2: Nuclear Power Programme Stage -2

The second stage of the nuclear power programme witnessed a major thrust in the XI plan.

Fast Breeder Test Reactor

The FBTR at Kalpakkam operated with excellent performance of sodium components. The unique mixed carbide fuel achieved a record burn-up of 165 GWd/t. the PFBR MOX fuel subassembly tested in FBTR achieved a burn-up of 112 GWd/t against a target of 100 GWd/t without any fuel pin failure. As a part of life extension of FBTR up to the year 2030, the fire water system and main boiler feed pump was replaced and seismic re-evaluation of NSSS components has been completed. For the SNM

Advanced Experimental Facilities for R&D on Structural Material

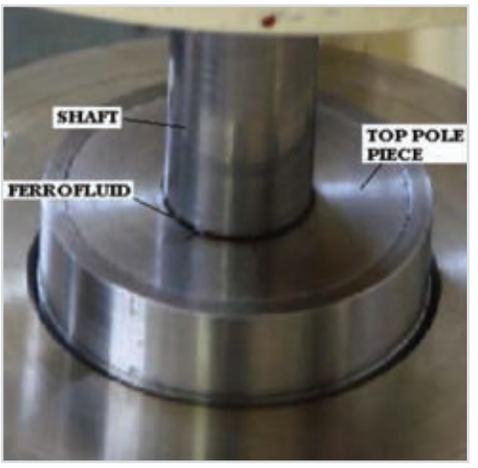
storage and assembly for PFBR fuel, the construction and commissioning of the facility has been completed and submission has been made to AERB for approval. The FBTR was also used for demonstration of production of Sr-89 isotope (by fast neutron irradiation of yttria) for possible medical use.

Reactor Engineering

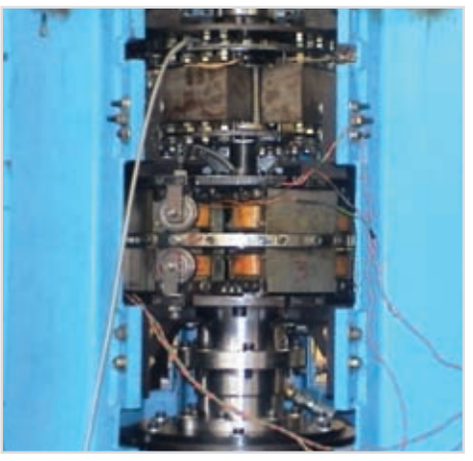
Advanced experimental facilities have been set up for structural mechanics and safety engineering. The seismic qualification of PFBR and FBTR components was carried out. The design optimization of CFBR has been completed. A 100 tonne capacity 6m x 6m shake table is expected to be commissioned by March 2012.

Reactor Technology and Equipment Development & Testing

Natural convection in sodium circuit was demonstrated on the 1:22 scaled model loop of PFBR decay heat removal circuit. As a part of development of Under Sodium Ultra Sonic Scanner, experiments in sodium with PFBR core simulated with 19 dummy assemblies were carried out. A number of techniques have been developed to ascertain the drop time of the diverse safety rods. The steam generator test facility was operated at rated capacity to validate the design and establish instability regimes. An Active Magnetic Bearing to suit a small centrifugal sodium pump was developed. It was integrated with a vertical centrifugal pump and tested successfully at 2900 RPM.



Ferrofluid Seal



Magnetic Bearings

SADHANA Test Facility

PFBR I&C Systems Development

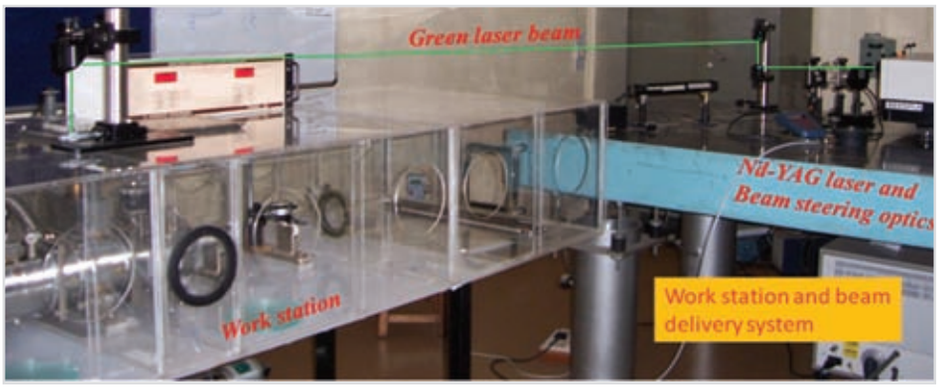
Real-time computer system based on VME32 platform has been designed and developed for deployment in Safety critical and Safety related computer based Instrumentation and Control systems of PFBR.

PFBR Training Simulator

128 Node High Performance Cluster

Plutonium Fuel Fabrication

A laser decontamination system for PFBR fuel pins has been developed and is being used for removal of loose contamination at the MOX fuel fabrication facility. This method of surface decontamination has been found to be much more effective than the previously used ultrasonic cleaning. The plutonium metal preparation facility has been modified for improving its throughput by calcio-thermic reduction of tetra fluoride. Laboratory scale facility for the synthesis of Pu based alloy fuels has been set up. A new facility for the thermo-physical characterization of Pu bearing metallic alloys has also been set up.



Laser Decontamination of PFBR Fuel Pins

Metallurgy & Materials

4.5 m long 9Cr-ODS fuel clad tubes for FBR and RAFM steel for TBM of fusion programme have been indigenously developed. Post irradiation examination of FBTR subassembly and PFBR MOX fuel pin for assessment of beginning of life behaviour has been carried out. Other activities include hard-facing for PFBR grid plate assembly, A TIG welding of 316 LN components and synthesis of stable nano thermal fluids with very high heat transfer.

Fuel Reprocessing

Reprocessing of mixed carbide fuel of FBTR after 155 GWd/t burn-up was successfully carried out. The reconverted plutonium has been used to fabricate fuel for FBTR, which has then been loaded in the core, thus closing the fuel cycle. Special equipment including centrifugal contactors of various capacities have been developed. Hull monitoring by gamma assay and passive neutron counting for fissile material determination has been realized. A test facility for solvent distillation for treatment of degraded solvent has been set up.

Minor Actinide Partitioning from High Level Liquid Waste

The recovery of minor actinides from the high level waste transported from CORAL was demonstrated for the first time in hot cells. High level liquid waste was transported from CORAL in a special alpha tight container.

Developments for PFBR

- Guided wave ultrasonics fuel subassembly hexcan and seal welds
- Remote visual inspection device for CORAL facility
- Raman distributed fibre optic sensor for temperature and leak detection in sodium circuits
- Phased array ultrasonic testing technique for inspection of steam generator.
- Distributed digital control system, diverse safety logic system
- Full scope training simulator

Metallic Fuelled Fast Reactor and Associated Activities

Based on core physics studies, rating of Experimental Metal Fuel Reactor to validate the design of full length fuel and blanket sub assembly in a power reactor of 120 MWe has been finalised. For the sodium bonded metallic test fuel pin fabrication facility, an inert atmosphere glove box train facility has been set up. Sodium wire extrusion using extruder has been demonstrated. Additionally an injection casting facility has been set up. It also consists of demoulding and shearing facility. An automated slug inspection system has also been set up for the purpose.

Engineering Scale Facility for Pyro-processing

For pyrochemical reprocessing development studies and engineering scale demonstration, facility for 1 kg scale has been commissioned. One kg of U metal has been taken in anode and deposited on solid cathode using LiCl-KCl eutectic salt as electrolyte at 773 K.

3.3 Major Programme 3: Nuclear Power Programme – Stage – 3 and Beyond AHWR

An AHWR calandria test facility has been commissioned. A scaled semi-transparent experimental set-up of the calandria has been designed, fabricated and installed in-house. Experiments for moderator flow and shutdown

AHWR Fuelling Machine

AHWR Calandria Testing Facility

system are currently in progress. The AHWR fuelling machine has been manufactured, assembled and tested. Performance testing at the sub-assembly level is complete and the integrated machine has been tested in dry condition with test tools. The AHWR Test Facility building to house the set-up for thermal hydraulics testing and fuelling machine testing will be completed by the end of the XI plan.

Fuel development

For U-233 cleanup project, copper vapour laser systems and the tuneable lasers fabricated indigenously are under installation. Hot-cell fabrication is completed with installation of remote handling equipment, separator and vacuum system.

Thorium Fuel Development

- Production of thorium metal ingot by metallothermic reduction
- Set up for thermodynamic properties measurement by transpiration and solid state emf techniques installed
- Development of automated powder transfer system
- Installation of Swaging set-up
- Production of kg scale metal powder
- Fabrication of 0.5 mm thick metal sheet

Uranium Silicide Fuel Fabrication for APSARA

Facility for fabrication and characterization of upgraded APSARA fuel (U_3Si_2, plate type) has been established. Development of process flow sheet for the fabrication of U_3Si_2 fuel by powder metallurgy route has been completed. Development of flow sheet for the fabrication of fuel plates by picture framing has been developed.Development activities of TRISO fuel for HTR have been completed. The process conditions have been studied and the fuel has been characterized. Beryllia pilot plant has been commissioned and a SiC coating facility set up. Facilities have also been set up to produce high purity vanadium and its alloys in batches of up to 2.5 kg. Design of rotating electrode process for preparation of beryllium pebble and fabrication has been completed.

(ThO_2-1%PuO_2) and (ThO_2-1%$^{235}UO_2$) MOX fuel pins have been fabricated. This cluster will be used for experiments in the AHWR Critical Facility and later loaded into DHRUVA reactor core.

ECR ion source prototype system using dummy plasma chamber and 3-electrodes extraction

assembly with HV and RF power supplies was tested at 40 kV. The plasma chamber and 5-electrode system for final ion source are under fabrication. A 350 MHz RF power supply unit for driving the prototype RFQ (for use in PURNIMA as 14-MeV neutron generator) has been assembled and tested up to 18 kW. Prototype of PURNIMA RFQ is undergoing tests. Sub-systems of high voltage power supply for Klystron have been fabricated and are undergoing testing at IPR.

MP 4: a. Advanced Technologies

- 10 MeV Electron Accelerator made operational
- Development of two stage pulse tube cryocooler capable of temperature of 2.8 Kelvin.
- Novel detector developed by integrating two detectors in one chip for particle identification and energy measurement in physics experiments.
- Setting up of a new Centre for Micro-electronics (CMEMS).
- Development of MEMS based pressure transmitters, currently undergoing testing at NPCIL power plants.
- Development of Compact Laparoscope Manipulator (CoLaM) for control of endoscope during surgery.
- Development of Automated Guided Vehicle

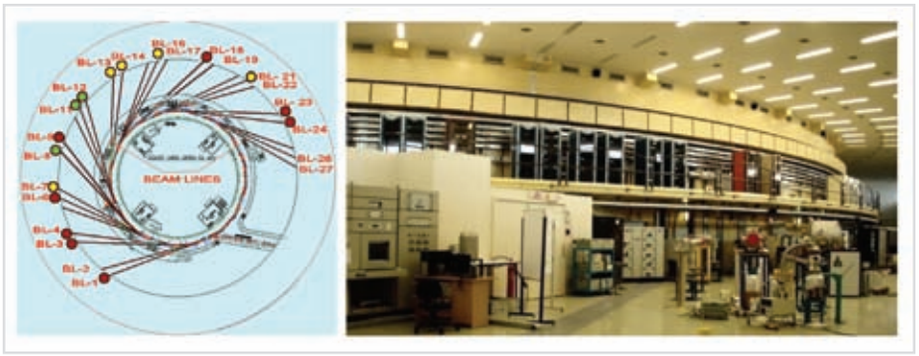
Synchrotron Radiation Sources

Indus-2 operates round the clock at 2 GeV & 100 mA. Six beam lines have been made operational, making the photon beam available to the synchrotron radiation users. Five beam lines have been installed on Indus-1 and are used for a variety of experiments by researchers from Universities, National Laboratories and Academic Institutes.

RRCAT has developed a facility for forming half cells of superconducting Niobium cavities. Single cell superconducting cavities operating at 1.3 GHz have been fabricated which have provided an acceleration gradient exceeding 20 MV/m. RRCAT has developed high power Nd:YAG lasers along with fibre optic delivery system with remote control operation.

Laser Cutting for Bellow Lip

Cutting of Bellow Lip at KAPS



Indus-2

Twenty such laser systems have been commissioned in different DAE units for cutting and welding operations. Nd:YAG laser based cutting technique developed at RRCAT was deployed for cutting of 612 bellow lip weld joints during the En-masse Coolant Channel Replacement (EMCCR) campaign at KAPS.

Indigenous Development of Helium Liquefier

An indigenous helium liquefaction system consisting of reciprocating type Cryogenic expanders, Cryogenic heat exchangers, Joule Thomson expansion valve, and oil removal system has been developed. A liquefaction rate of 6 liters per hour has been

Helium Liquefier

achieved. A Pool type Liquid Helium Cryostat for operating down to 2 K was also designed and developed.

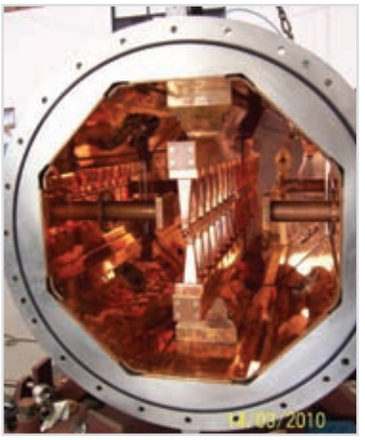
Carbon Coated Sample Pt-C Coated Ring

Platinum loaded carbon aerogels of different morphologies have been developed for their use as catalyst in liquid phase catalytic exchange process that can be used for the production of heavy water.

Development, testing and installation of 31.63 MHZ RF cavity for Indus-1

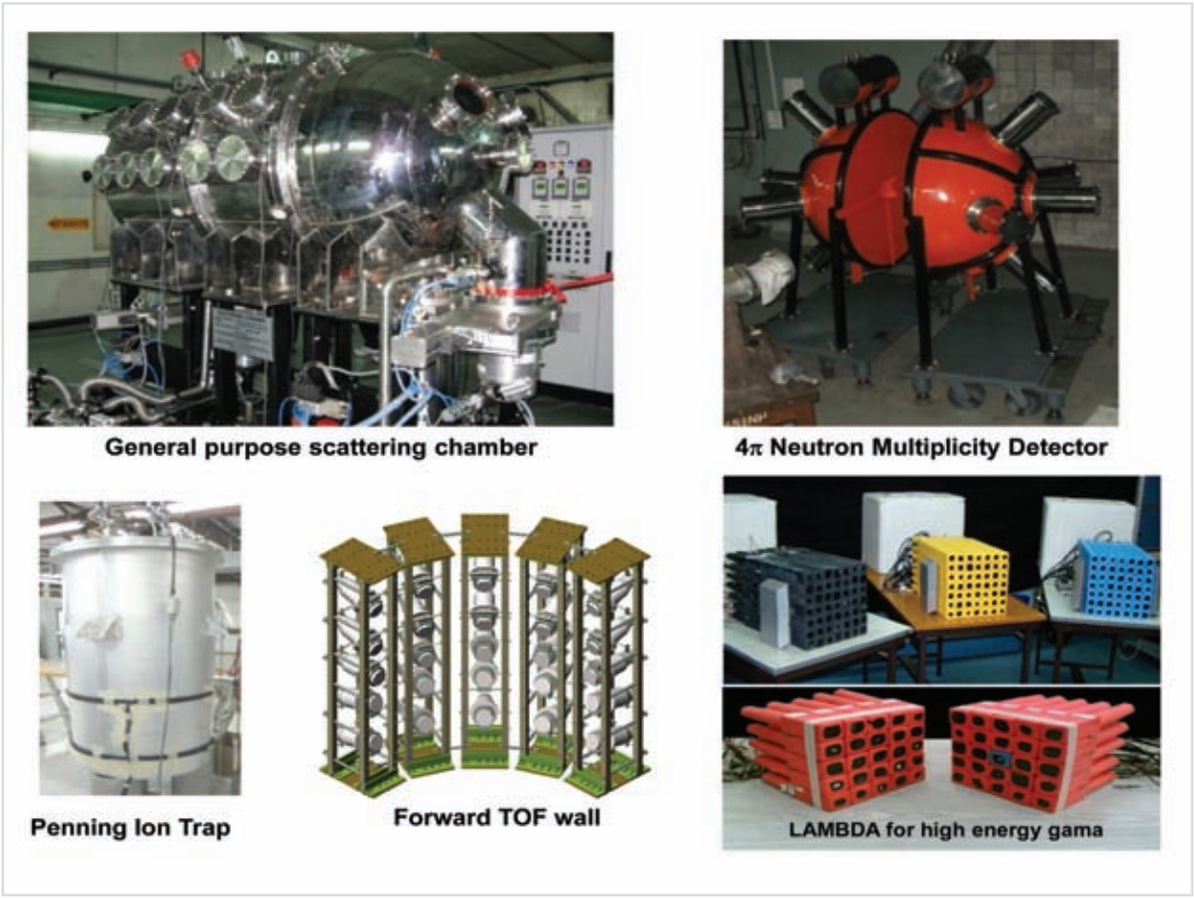
A RF cavity operating at 31.613 MHz has been designed, developed and installed in Indus-1. The cavity compensates for the power lost by the beam due to synchrotron radiation.

The Superconducting Cyclotron was commissioned with ion beams reaching the extraction radius with sufficient intensity. This is the largest SC magnet to be built in the country. Components for the Radioactive Ion Beam project, such as Radio Frequency Quadrupole, Heavy-Ion Linear Accelerators (IH LINAC) have been developed. Micro-Beam Development using a RF ion source for micro-machining has been completed.



IH LINAC

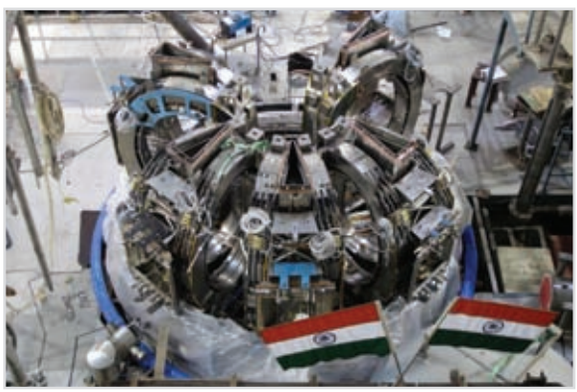
RF Ion Source



Detectors and Experimental Facilities for Cyclotron based Experiments

Basic Plasma Studies

During the XI plan many existing experiments have been upgraded to study the unexplored regimes in these devices viz., Large Volume Plasma Device and BETA (Basic Experiments in a Toroidal Assembly) In theoretical and computational front, many phenomena in tokamak plasmas like excitation of Geodesic Acoustic modes (GAM), turbulent transport, ELM mitigation, Nonlinear dynamics of multiple NTMs etc., have been actively pursued.



Assembly of SST-1

SST-1

The problem areas that emerged from the last commissioning attempt have been identified and remedial steps are being implemented. These include testing of Toroidal Field (TF) magnets, 80K shields, potential breakers, Current leads, vacuum vessel modules and sectors.

Superconducting Magnets for Fusion grade Tokamaks

For SST-1 project, the industrial scale quality superconductors were imported. Subsequently indigenous development has been carried out. Starting from raw materials, technologies and processes leading to the fabrication of long lengths of NbTi based cable-in-conduit-conductor (CICC) capable of carrying 30 kA of current at 5 Tesla had been realized. Testing facilities for cables and strands in high fields, Ester-Bisphenol based radiation resistant insulation system development & associated vacuum pressure impregnation technologies, special purpose winding machine for laboratory scale magnets have also been developed.

4B Radiation Technologies and their Applications:

Efforts towards developing radiation technologies for societal applications such as in agriculture, health care etc. have proved to be successful.

Research in nuclear agriculture has resulted in development of more new crop varieties.

One hundred and twenty NISARGRUNA biogas plants based have been installed in various parts of the country.

BARC has initiated an isotope hydro geophysical survey to identify the groundwater sanctuaries around Anjangaon, Amaravati district and the recharge areas to the Chinchona well field to create artificial recharge by rainwater harvesting. Based on isotope hydro-geophysical investigation at Nimkhed Bazaar of Anjangaon, a lineament running NNE–SSW direction with huge groundwater flow was identified and asked the local authorities to drill a bore hole to a depth of 45 m at identified site on the lineament. The borehole drilled is yielding ~30,000 liters per hour and is a perennial source of good quality of water.

Trombay Oilseed Varieties Released and Notified (2007-10)

Crop	Variety	Released for	Salient Features
Groundnut	TDG-39/ TBH-39	Karnataka Rajasthan	Large seed (70-80g/100 seeds Medium maturity (115-120 days) High oleic acid (60% Vs 40%) *Kharif season*
	RG-51	West Bengal Orissa Bihar & N.E. States	Early maturity (~90 days) High shelling % ((75-78%) *Rabi*-Summer
Mustard	TPM-1	Maharashtra	Yellow seed Tolerant to powdery mildew
Sunflower	TAS-82	Maharashtra	Black seed coat Tolerant to drought

New Trombay Pulse Varieties




TM-2000-2 (Pairy mung)	TM-96-2	TJM 3	TrC 77-4 (Khalleshwari)
Resistant to powdery mildew, suitable for *rabi* and rice fallows	Synchronous maturity, resistant to powdery mildew, suitable for *rabi* and rice fallows	Resistant to mungbean yellow mosaic virus disease, suitable for summer, early maturing	Suitable for *rabi* and rice fallows
Chhatisgarh	Andhra Pradesh	Eastern UP, Bihar, Jharkhand, West Bengal & Assam	Chhatisgarh

Nisargruna Plant

Food Irradiation and Preservation

- Development of technology for packaged food products with improved shelf-life and quality
- Development of packaging materials for radiation processed food.
- Development of food irradiation dosimetry
- Development of method for detection of irradiated food

A hand held, low cost and compact Tele-ECG machine capable of sending ECG waveforms through a mobile phone / laptop has been developed for rural tele-medicine applications and the technology has been transferred for commercial production.

Domestic and community-sized solar driven desalination units based on membrane technology are developed. A 50,000 litres per day capacity Barge Mounted Desalination Plant based on Reverse Osmosis (RO) technology has been developed and built to produce safe drinking water from sea water for the emergency deployment into water deficit coastal areas.

Health: Life style related diseases are an emergent phenomenon in urban India. This, together with the increase in life expectancy, has contributed to increased number of cases of cancer and also a shift in the pattern of cancer incidence. DAE has very strongly supported the programme of treatment and education in cancer in India. Tata Memorial Centre located at Parel, Mumbai, an aided institution of DAE is the country's premier institute in this field. It comprises of Tata Memorial Hospital and Advanced Centre for Treatment, Education and Research on Cancer located at Kharghar, Navi Mumbai.

During the XI plan the Kharghar Campus has become very active with establishment of

- Bone-marrow transplantation facility
- Installation and validation of the Bhabhatron II teletherapy machine
- Helical tomotherapy machine
- 3-T MRI and active research laboratories in cancer proteomics, genomics and biomarkers.
- State of the art animal house facility in ACTREC which permits experiments on transgenic and immunodeficient mice.
- Axillary Node Biopsy Trial- A low cost intervention to detect axillary disease in early breast cancer

Radio isotopes in early detection of disease spread

A small dose of a radioactive tracer technetium-99m is used for sentinel node imaging of women with breast cancer. Sentinel node imaging is a nuclear medicine examination which identifies for the surgeon the first lymph node to receive lymphatic flow from the breast tumour site. The ability to avoid axillary node dissection using this technique decreases morbidity, expense, and permits the patient to return to normal activity much sooner after surgery.

Department of Cytopathology, Tata Memorial Hospital developed an innovative, easy, rapid and inexpensive alternative technology DAM that is at par with Liquid Base Cytology (LBC) and cheaper compared to conventional Pap test. The technology does not require any special infrastructure or training.

Prosthesis Development

In limb salvage surgery for malignant primary bone tumours, a metallic prosthesis replaces the diseased bone to provide immediate stability and mobility Prostheses available in the international market are not always suitable to the Indian population due to anatomical differences and are expensive. TMC started the limb salvage programme with an indigenously developed affordable stainless steel implant TMH-NICE, designed for Indian anthropometric parameters in collaboration with a local implant manufacturer.

Bone Marrow Transplant programme

ACTREC has become one of the leading Bone Marrow Transplant centres in the country in terms of numbers and complexity of the transplants undertaken (unrelated, umbilical cord and haploidentical transplants) and a very low mortality, comparable to the best centres around the world. Telecobalt unit, Bhabhatron, holds the promise to fulfil a major health need of India and other developing countries. Till date, 16000 patients have been treated on 14 Bhabhatrons operational in the country. At the Radiation Medicine Centre, Medical Cyclotron facility, first of its kind in India to be established in 2002, has produced large quantities of F-18 labelled fluorodeoxyglucose, FDG, the most commonly used radiopharmaceutical for functional imaging of cancers by positron emission tomography.

Software for Text to Sign Language for Hearing Impaired

VECC has developed software for automatic conversion of Text to Sign language. This aid would reduce the barrier that the hearing impaired population faces while communicating with 'normal' people.

Retinotherapy Unit

Laser-based retinopathy:

RRCAT has developed a diode pumped frequency-doubled Solid State Nd:YVO_4 Laser based photo-coagulator for Diabetic Retinopathy. A system has been delivered to a private hospital, and the patients are reporting lesser pain and faster healing.

MP-5 Basic Research - Mathematics, Physical and Chemical Sciences

Foundation of new campus of TIFR at Hyderabad and two major new centres for basic research, International Centre for Theoretical Sciences at Bengaluru and the TIFR Centre for Interdisciplinary Sciences at Hyderabad have been created.

Anupam Adhya Super Computer

As against a XI plan target of developing 50 Teraflops parallel supercomputer, the first phase of parallel supercomputer (Anupam Adhya) has been developed and released to the users. High performance computing facilities have also been set up at BARC,

Vizag (5 Teraflops) and at Anushaktinagar (6 teraflops) and released for users. An IBM blue gene supercomputer with 1024 cores and sustained speed of five teraflops has been commissioned at TIFR for solving problems in lattice quantum chromodynamics.

Physical Sciences:

Seven Telescope HAGAR array was commissioned at the high altitude (4300 m) station Hanle (in Ladakh) for ground-based Gamma -ray Astronomy

7 Telescope array at Hanle

An important aspect in astro-particle physics concerns the origin, composition and spectrum of primary high energy cosmic rays and the underlying particle acceleration mechanisms in the Giga (10^9) eV to Exa (10^{18}) eV range. The GRAPES-3 experiment in Cosmic Ray Laboratory, Ooty is designed to study such high energy particles in the energy range 10^8 to 10^{20} eV by detecting the showers produced by interactions by such cosmic rays in the upper atmosphere

A High Resolution Spectrometer Indian Gamma ray Array consisting of a maximum of 24 Compton suppressed Germanium clover detectors was commissioned at the Pelletron-Linac Facility, TIFR.

Radio galaxy: GMRT discovery of the largest known radio jet

Giant Metrewave Radio Telescope at Khodad near Pune, which works in three major areas of astronomy: the formation and evolution of galaxies, the physics of pulsating neutron stars (pulsars), and the physics of super-massive black holes at the centres of galaxies. Over the decade since its inception, GMRT has yielded fascinating results and new discoveries.

GMRT Discovery of Largest Known Radio Jet

- Installation of General Purpose Scattering Chamber in Pelletron LINAC beam hall
- Commissioning of 5 new beam lines in Pelletron LINAC
- Setting up of clean laboratory for Large Area RPC for CMS detector
- Assembly, testing and delivery of Large Area RPC to CERN for CMS
- New High Pressure Physics Laboratory
- Facility for Laser driven shock experiments
- Development of special purpose gas detectors

Biological Sciences

The understanding of mechanism of basic biological processes involved in response to radiation and other abiotic stresses is crucial to the utilization of microbes for bioremediation of radioactive waste, development of stress resistant crop plants, prediction of success in cancer radiotherapy as well as for explaining the lack of deleterious health and biological effects in people living in High Level Natural Radiation Areas (HLNRA). Some of the XI Plan projects in DAE addressed these issues.

- In HLNRA and LLNRA of Kerala, more than 1,30,000 newborn so far been surveyed for congenital malformations
- No difference in their frequency in the children born in HLNRA and NLNRA.
- Studies on the micronuclei frequency in the newborns to reveal DNA damage also did not show any differences between the two areas.
- Transcriptome analysis of adults from HLNRA of Kerala coast revealed that 212 genes are differentially expressed.
- Higher expression DNA repair related genes in the population from HLNRA found.

In BARC work was carried out on the proteomics of Deinococcus radiodurans the most radio resistant organism known. More than 100 new proteins have been observed after exposure to high dose of radiation.

Deinococcus was genetically engineered to express PhoN, an acid phosphatase gene from Salmonella and such engineered bacteria could precipitate uranium to the extent of 95% from a 2 mM solution. Another phosphatase gene PhoK (alkaline phosphatase) could also be used for this purpose. The three dimensional structure of PhoK has been elucidated by X-ray crystallography. Radio-resistance has been demonstrated in cyanobacterium Anabaena. It's response to oxidative stress is being evaluated. Another cyanobacterium Synechococcus elongatus was shown to have uranium accumulating capability.

Biological Studies for Medical Applications

- Studies on systems for development of diagnostics of Alzheimer's
- Studies on cellular mechanisms of stress-induced modulation
- Studies on memory and networks
- Neurobiology of depression
- Adaptive changes in unicellular alga reinhardtii

An interesting phenomenon of protein cycling during post-irradiation recovery was discovered. Role for pyrolloquinoline quinone (PQQ) in radio-resistance of this organism was discovered. Transfer of PQQ synthase gene to radiosensitive bacteria E. coli rendered them resistant to radiation. A set of promoter sequences have been identified which could be associated with the expression of critical genes for radio-resistance. A multiprotein complex involved in DNA repair has been observed.

Solar Test Facility

A 2 MWth Solar Test Facility (SOTEF) is being developed at BARC. Major component of this facility such as Integral Receiver and Heliostat with associated sun tracking controls have been fabricated and tested. In the next phase a 350 kW solar power tower with 120 heliostats is being designed to be set up at BARC.

Integral Solar Receiver

Heliostat

Major Programme 6
Research-Education Linkages

DAE recognizes the impact that a strong linkage between research and education can have on the development of science and technology.

The Board of Research in Nuclear Sciences and UGC-DAE Consortium for Scientific Research stand out as important initiatives of DAE in the direction of linking research with education.

Besides, the R&D units of DAE host a large number of university students every year for carrying short-term projects. This exposes the students to the state of the art laboratories and R&D environment.

By setting up the Homi Bhabha National Institute, a Deemed to be university, DAE has opened new vistas for linking education with research which includes imparting education in research environment. Though the main thrust of HBNI is on post-graduate education, its integrated MSc programme under the aegis of National Institute for Science Education and Research at Bhubaneswar stands out as an attempt to impart undergraduate education in a research environment.

The Mumbai University-DAE Centre for Basic Sciences which conducts integrated MSc programme is also an example of DAE's commitment to link education with research.

Besides conducting academic programmes under its own umbrella, HBNI is playing an important role also in linking R&D and education in DAE with other academic institutes in the country and abroad. It has signed MoUs with several Indian academic institutes and with some institutes abroad for academic collaboration. The Institutes in the country with which MoUs have been signed include: IIT-Bombay, IIT-Madras, Institute of Chemical Technology, Matunga, Mumbai, TIFR, Indian Statistical Institute, Kolkata and Jadavpur University.

The foreign institutes with which MoUs for academic exchange have been signed include University of Virginia, USA and The Commissariat à l'énergie atomique (CEA), France.

The scope of education-research linkage through HBNI is being expanded by identifying and carrying projects of common interest with the academic institutes. As a first step in that direction, dialogue is ongoing to finalise a MoU with Indian Institute of Science (IISc), Bangalore.
Besides HBNI, most of the other autonomous institutes also actively encourage research-education linkages through various programmes.

Setting up of National Institute of Science Education and Research was announced on August 28, 2006 at Bhubaneswar. It has already started functioning as a full fledged autonomous institution of DAE. The two principal goals of the Institute are 1) pursue frontier research and 2) to provide high quality education in Basic Sciences. The institute offers Integrated M.Sc programme in Biology, Chemistry, Mathematics and Physics. The first batch of Integrated MSc students joined in September 2007. NISER has also initiated PhD programmes from 2009.

Recognizing that early exposure to a research environment leads to retention of students in the basic sciences, TIFR conducts an annual summer programme called the Visiting Students' Research Programme (VSRP). Selected students from all over the country spend two months carrying out research in chosen projects under the supervision of the faculty of TIFR. Over 700 students participated in the VSRP at TIFR in the XI Plan period.

Homi Bhabha Centre for Science Education (HBCSE), TIFR

HBCSE's mission is to improve the quality of science education in India. HBCSE has made efforts to reach out to students and teachers from around the country through print materials developed for the purpose, a large number of workshops and camps etc. A series of 27 videos on Astronomy was developed and distributed to 22 schools and 500 teachers in Maharashtra.

National Initiative on Undergraduate Science (NIUS):

This unique talent nurture programme for undergraduates in science, launched as a mid-term plan project of the X Plan, got a boost when the dedicated NIUS facility was created and inaugurated on 29 April 2009. The facility includes a 130-bed hostel, furnished classrooms and laboratory spaces which are currently in the process of development.

Board of Research in Nuclear Sciences (BRNS):

BRNS continues to support new research proposals, particularly applied research, from various universities in the country.

The aims are to:

- Identify and fund R & D programmes and projects.
- Award fellowships to pursue doctoral programmes.
- Award research grants to young scientists.

HBNI Campus at Anushaktinagar

Elevated Water Reservoir

Academic Block of NISER

- Organize symposia on topics of relevance and interest to DAE as well as in frontier areas of science and technology.
- Extend financial support to symposia and conferences organized by professional bodies and other agencies.
- Establishment of chairs in universities and other institutions of higher learning.
- Create infrastructure facilities for advanced research.
- Identify/create and support centres of excellence.

BRNS is a unique funding agency in the country as a large majority of projects funded by it are collaborative and have a principal investigator from the university system and a principal collaborator from one of the DAE units.

National Institute for Science Education and Research (NISER):

The academic programme of NISER, which became functional during the XI-plan period, is designed to provide strong foundations to students through core courses, before they embark at the threshold of research in the field of their choice. The institute offers integrated M.Sc courses to young brilliant students in the disciplines of Mathematics, Physics, Chemistry and Biology.

Major Programme 7 – Infrastructure and Housing

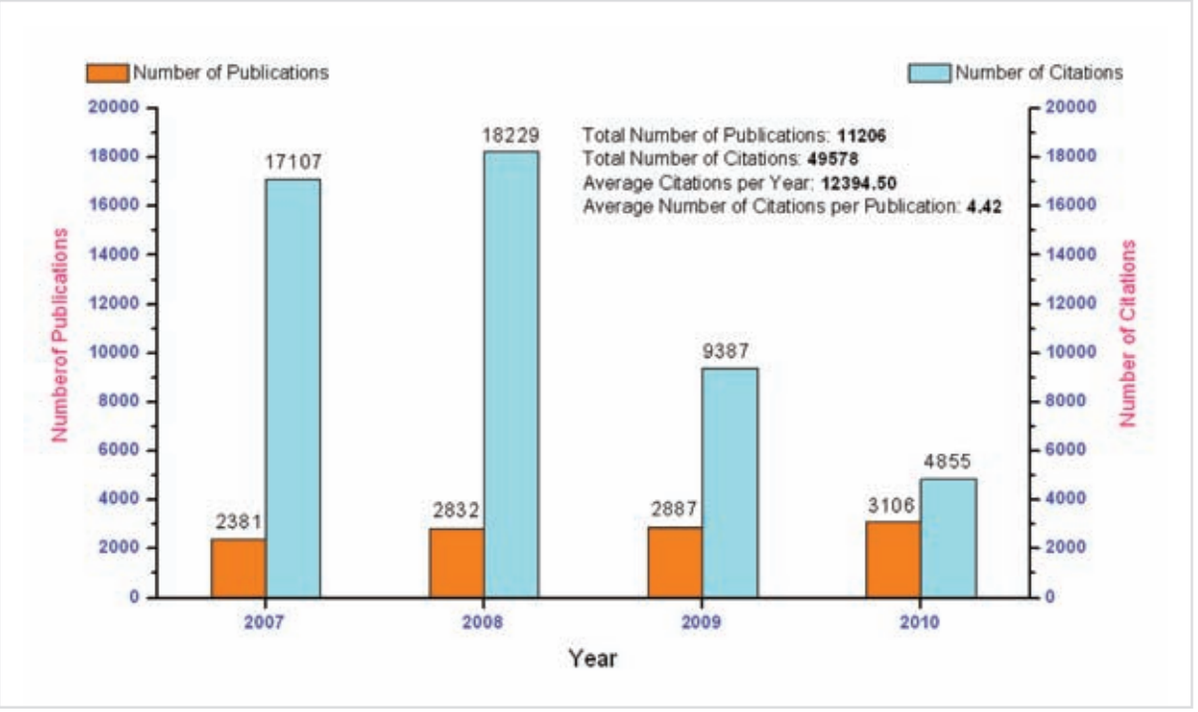
The heritage building (Old Yacht Club) was renovated during the previous plan. In addition residential quarters for AMD at Bengaluru and Jaipur were constructed, BARC services were upgraded, infrastructure development was carried out for Phase-IV of RRCAT, and Tsunami relief works were carried out at IGCAR. Renovation of various school buildings, infrastructure development Phase-V of RRCAT, up gradation of services for IGCAR and Anushaktinagar colony, additional buildings for IPR, building for NCBS and purchase of land for cancer hospital at Vizag was carried out.

SCIENTIFIC PRODUCTIVITY AND IMPACT OF DAE INSTITUTIONS

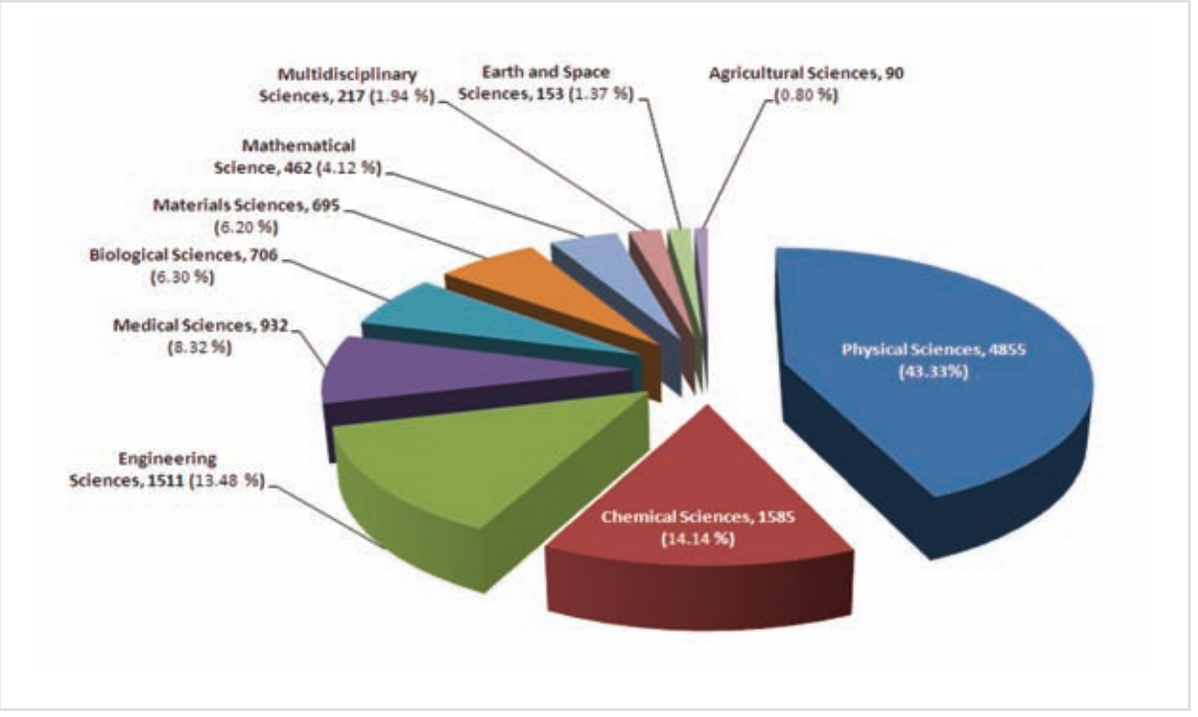
This report is an analysis of the journal publications of the following thirteen (13) DAE institutions: BARC, TIFR, SINP, IGCAR, RRCAT, TMC, IoP, IMSc, HCRI, VECC, IPR, AMD and NISER. A total of 11206 publications were published by 13 major DAE institutions during 2007-2010. These publications received a total of 49578 citations during the period. The average number of publications published per year was 2801.50 and the number of citations per publication during the period was 4.42.

Table 1: Distribution of Publications and Citations of DAE Institutions

Institutes	Number of Publications	Average Publications/Year	Number of Citations	Average Citations /Publication
BARC	3733	933.25	12584	3.37
TIFR	2206	551.50	16856	7.64
IGCAR	1115	278.75	2303	2.07
SINP	944	236.00	4110	4.35
TMC	749	187.25	1674	2.23
RRCAT	549	137.25	1668	3.04
HRI	458	114.50	3885	8.48
IoP	400	100.00	2286	5.72
IMSc	354	88.50	1364	3.85
VECC	330	82.50	2241	6.79
IPR	312	78.00	563	1.80
AMD	48	12.00	36	0.75
NISER	8	2.00	8	1.00
Total	**11206**	**2801.50**	**49578**	**4.42**



Year-wise Distribution of Publications and Citations of DAE Institutions during 2007-10



Subject-wise Distribution of Publications of DAE Institutions during 2007-2010

CHAPTER 4
DAE XII FIVE YEAR PLAN PROPOSALS

4.0 Introduction

A broad based Organisation like the DAE having multiple functional units with seamless boundaries has multidimensional mandate to pursue myriad of diverse but well-focused activities, all aimed at successfully executing a comprehensive programme in nuclear sciences and technology. This aspect of the mandate has been well defined in its long term vision articulated during 1990s and further refined and emphasised in its collective vision document during 2004 when a brain storming conclave was organized in BARC. This collective vision document provided the necessary direction the Department was expected to chart to identify and realise its targets during XI and subsequent Plans. While the XI Plan activities laid the necessary groundwork, the R&D activities encompassing all branches of nuclear sciences and technology envisaged to be taken up during XII Plan are expected to be built up on this foundation. It may be mentioned that majority of milestones of XI Plan were reached, the R&D targets achieved, the infrastructure established and deliverables realised.

4.1 Formulation Process for XII Plan Projects

A multilayered assessment strategy has been adopted for formulating the XII Plan proposals in the R&D Sector of each Unit of DAE. "Bottom-up" approach has been followed. A group of scientists/engineers engaged in their specialized field of activity form the basic unit from whom the R&D proposals were solicited. These were then collated at the Division level. The Division vetted these proposals. These vetted proposals received from different Divisions were then consolidated at Group level as Apex Projects having a definite theme. These were then thoroughly discussed in the respective Group Boards in terms of technical content, feasibility of realizing the targets as well as financial budget. While each Apex Project will have an Apex project coordinator, each of the Divisional proposals included in that Apex Project will be executed by coordinators. These Apex Projects were debated in Trombay Council, BARC for BARC Apex Projects (or at the highest decision making Bodies of other Units of DAE for their Apex Projects). If necessary the Apex Projects were referred back to the respective Group Boards for revision either in technical content or the financial budget. The revised Apex projects were again discussed in the highest Bodies of respective Units of DAE. A total of 258 Apex Projects have been finalized. For better coordination and overseeing, these Apex projects were grouped under various themes within 7 main Programmes of the Department. These 7 Major Programmes and the themes are given in the Annex IV.

Next stage of scrutiny of the Apex projects was the review by Specialists Groups constituted exclusively to review, assess and merge/modify similar themes from different Units of DAE. The Specialists Group assessed each Project in terms of the criteria:

(i) sequel to and scope and status of XI Plan
(ii) relevance to the Department
(iii) budget
(iv) overlap of programmes with other Apex Projects being reviewed
(v) development of infrastructure and expertise, and
(vi) impact and benefit to the Society

The list of Specialists Groups and the Apex Projects themes under their purview and the terms of reference are given in Annex V.

The recommended Apex Projects from the Specialists Groups were then presented at and thoroughly assessed by the Internal Working Group of DAE for R&D Projects. The composition of the IWG (R&D) and the terms of reference are given in Annex III.

4.2 A Brief Description of Major Programmes

The mandate of the Department is to develop and deploy technologies for the production of nuclear power and to harness applications of radiation and isotope technologies for societal benefit. To fulfil this mandate, several technologies need to be developed and it is necessary to carry out basic research to provide a strong foundation to ongoing developments and to spur new developments. To meet all these objectives, human resource development is the most important. Thus all the topics listed earlier are interrelated.

4.3.1 Major Programme 1: Nuclear Power Programme – Stage – 1

Keeping in view the expanding nuclear power programme with larger number and variety of plants in operation, and ageing of the operating plants, it was realized that "Technology Development / R&D Efforts" are essential to strive for continued enhancement of nuclear safety, reduction in unit-energy-cost of nuclear power and reduction in construction completion time and cost of future projects.

Thrust Areas of Technology Development

- Safety Study Experiments
- New reactor process/equipment development
- Product development/indigenization
- Rehabilitation Technologies & Remote Tooling
- Construction Technologies
- Endurance Studies
- Ageing & Degradation Studies

Some of the specific development jobs undertaken and/or in progress are

- Setting up experimental test facilities such as NPCIL Thermal Hydraulic Test Facility (NTHTF) for validation of safety analysis codes developed in-house. Similarly AHWR Test facility (ATF) is housed in an Integrated Test Facility (ITFT).

- Setting up Hydrogen Recombiner Test Facility (HRTF): This is also a first-of-its-kind experimental test facility. Efficacy of the Passive catalyst recombiner devices being developed for mitigation of hydrogen that would find its way into the containments of nuclear reactors during a postulated design basis accident will be tested in this facility.

- Setting up of Fuelling Machine Integrated Test Facility (FMITF) is primarily for calibration & qualification testing of the Fuelling Machines of 700MWe units. Provisions are also made in the design for testing coolant channel inspection machines. AHWR FMTF is also being setup inside ITFT.

- Experimental Primary Containment Clean-up System Loop (PCCS) for safety studies.

- Safety experiments like simulation of new design like Passive Decay Heat Removal System and Containment Spray system.

- Study of Impact between Calandria Tube & Guide Tube during dynamic interaction.

- Coolant Channel Mock up Facilities have been established. Experiments were conducted for evaluation of energy absorption by Integrated Yoke Studs-Yoke-Feeders assembly of Standardized 220 MWe PHWR Units.

- Setting up of Reactivity Devices Test Facility (RDTF).

- One Way Rupture Discs (OWRD) for 700 MWe for isolation of ECCS from PHT system was successfully developed and qualified. Further, similar OWRDs are being developed for AHWR.

- Self-Powered Neutron Detectors (SPNDs) with 3 pitch length for 700 MWe PHWRs are being specifically developed.

- Remote inspection, maintenance, emergency handling and refurbishment / repair technologies including based tools & special imaging techniques for EMCCR as well as critical problems faced in different units.

- Environmental ageing test facilities comprising thermal chambers, humidity chamber, and gamma irradiation chamber are established and testing of components is taking place. LOCA Chamber test facility for testing PHWR as well as VVER components is also set-up recently.

- Flow Assisted Corrosion (FAC) loop for ageing and degradation studies.

- Indigenization of plant components/ equipment/ systems.

- Development of techniques and technologies for plant decommissioning,

Some of the future envisaged activities for the XII Plan include:

- Commissioning of ATTF, NTTF, AHWR FMTF and 700MWe FMTF

- Indigenous development of equipment such as Primary Coolant pumps, Compressors, Control Valves, Tube Fittings, Pressuriser heaters and a large number of I&C related hardware such as sensors, transmitters, manifolds etc.

- Inputs and experimentation for reactor process systems and equipment designs

- Development of technologies for Construction time minimization such as Automatic edge preparation and welding of large piping, automated inspection, developing concrete steel composite structures

- Replacement of Long Cobalt absorber for future PHWRs

Deliverables that would be realised include:

- Creating major facilities/thermal hydraulic loops/ Environment Qualification facilities.
- Design/verification of indigenous LWR concepts
- Creating state of the art laboratories/resource centres for –
  - NDT/Inspection technologies
  - Automated welding technologies
  - Automated tools/Laser based systems
- Converting all of the Nuclear Power Plants of NPCIL into Integrated Engineering Environment and 3D modelling.
- Creating a ready infrastructure/documentation for Export model and related marketing.
- Investments to boost indigenization of hitherto imported items.
- Investments to broaden the vendor base.
- Post Fukushima investigation of new safety systems/concepts for incorporation/back-fitting into Indian NPPs.
- Collaborative R&D projects with International organizations such as COG for Pressure Tube Life Management and other projects related CANDU/ PHWR technology.
- Supporting the ideas/requirements of operating units Working on Ideas/Methodology/ technologies and related developmental activities for construction time minimization of NPPs.

4.3.2 Major Programme 2: Nuclear Power Programme - Stage 2

The second stage of the Nuclear Power Programme involves setting up of fast breeder reactors along with the associated fuel cycle facilities. This stage is essential to effectively utilize the uranium resources in the country, rapidly enhance the power production through nuclear reactors and establish the use of thorium on a large scale in the third stage.

The construction of the PFBR is in an advance stage and the reactor is expected to be commissioned by the end of 2012. Following the PFBR, a number of 500 MWe MOX fuelled fast reactors are planned to be set up. The experience in design and construction as well as operation of PFBR is being utilized to further enhance the economics and safety features of the future MOX reactors. Accordingly, R&D activities encompassing design optimization, hydraulics studies of the reactor pool, validation of design of shut down systems (including a new passive shut down system) through sodium testing, improvements in fuel handling machine, use of ferritic steel as the principal material of construction in the secondary sodium system and safety experiments towards severe accidents have been planned. It is also planned to have indigenous development of electrical and instrumentation items for future reactors so as to result in reduction in cost and import substitution.

The R&D activities in the XII plan will also deal with sodium fuel chemistry with the aim of developing processes for sodium removal from sodium bonded metallic fuel, development towards fabrication of minor actinides containing MOX fuels through SOLGEL route and direct oxide reduction for plutonium metal production. To enhance the burn-up that can be achieved with the fuel, the development of cladding and wrapper material including the associated manufacturing and inspection technologies will be taken up. Towards the enhanced burn up goal of 200 GWd/t, 18 Chromium Oxide dispersion strengthened steel is planned to be developed. Also materials development is planned for high nitrogen austenitic stainless steel 316 LN and boron addition to 9 Cr-1 Mo type steel (grade 91) for structural materials for long design life of reactor component with improved creep properties. Technologies for in-service inspection with emphasis on under-sodium inspection, post- irradiation examination, irradiation experiments and remote handling for the fast reactor components and fuel cycle facilities and repairs are planned to be developed to enhance confidence in operation for long life.

Towards life extension of the FBTR up to the year 2030, important safety systems namely diesel generator and sodium pump drive are planned to be replaced to meet the current safety standards. It is also proposed to replace the reactor core reflectors as these have reached the end of life. A special fuel fabrication characterization laboratory and NUMAC facilities are proposed to be set up to replace the existing Radiometallurgy and chemical characterization facilities at Trombay (which fabricates the fuel for FBTR), according to the prevailing safety norms, and to enhance NUMAC activity. The FBTR will be used as a tool to produce radioisotopes for medical applications, and studies will be undertaken during XII plan to establish the production and separation schemes for some of the isotopes, notably ^{32}P.

To ensure the expeditious development of the metal fuelled FBRs, R&D programmes on irradiation performance of metallic fuels are planned in XII plan. For validating the design of the fuel subassembly and to gain large scale experience in the fabrication and irradiation testing of metallic fuels a 120 MWe metal fuelled fast reactor is planned at IGCAR. This reactor would validate the design and manufacturing of full length fuel and blanket subassembly that would be used in a power reactor. The design of the reactor is planned in the XII plan and construction is planned

in the XIII plan.

The closing of fuel cycle of reactors through reprocessing and refabrication is an important requisite for the effective utilization of the fissile material resources. R&D on reprocessing and waste management is essential for effecting improvements in the processes to make them more efficient, reduce waste volumes and simplify waste management. During the XII plan, R&D on a variety of aspects including processes and equipment development, modelling and pilot plant scale demonstration will be pursued to realize robust schemes for the back end of the fuel cycle. The demonstration of recovery of the minor actinides from the high level waste by first recovering the actinides and lanthanides (bulk separation) and then separating the actinides from the lanthanides (group separation) will be an important element of R & D in the XII plan. Other enabling elements to be addressed will include development of centrifugal extractors and other contactors of various capacities and design, equipment for continuous dissolution of fuel, development of waste forms and their characterization, tools for measurement of actinides in waste, etc.

While the PUREX process will be used for reprocessing of the oxide fuels used for thermal reactors as well as fast reactors, the metallic alloy fuels which are expected to be deployed in fast reactors beyond 2025, will have to be processed by pyrochemical schemes followed by remote fabrication of the fuels. Studies on electro refining of Pu and its alloys, and demonstration of key elements of the pyroelectrochemical process on an engineering scale with uranium alloys, will be thrust areas in XII plan.

To aid the above applied developmental activities, a number of basic research programmes are also under the anvil. These include the studies on radiation damage in clad and structural materials, thermophysical and thermochemical properties of fuels, novel solvent extraction systems and chemical sensors.

Fast Reactor Programme

- Completion of programme on life extension of FBTR
- Setting up of new fuel fabrication and characterization facility for FBTR
- Design optimization of future FBRs for cost reduction and enhanced safety
- Development of electrical and instrumentation items for future fast reactors
- Development of ODS cladding and 9 Cr- 1 Mo wrapper material
- Enhancement of capacities for sodium testing of components and experimental validation of shut down systems
- Development of advanced technologies for in-service inspection for use in reactor and fuel cycle facilities
- Design of 120 MWe experimental metal fuel fast reactor.
- Equipment and process development and modelling for fuel reprocessing
- Setting up of engineering scale facility for metallic fuel cycle development
- Basic research on fuels, in-core shielding materials, cladding and structural materials, sodium fires and severe accident phenomena in reactors.
- Test irradiation of minor actinide containing targets in FBTR

4.3.3 Major Programme 3: Nuclear Power Programme – Stage – 3 and Beyond

With the first stage getting matured and second stage of programme on its way, it is imperative to develop and demonstrate the technologies relevant to the third stage of the programme. The three thrust areas identified in this direction are: (1) design, development and demonstration of mainly thorium fuelled AHWR, study on structural materials that could be viable for use in CHTR and R&D related to safety research for Fusion Reactor materials. The proposals under this major programme are designed with these identified areas as their focal points. Accordingly, design and development of various reactor concepts such as AHWR and CHTR is underway.

Work towards the design and development of the AHWR was initiated and continued in the IX, X and XI plan periods leading to a significant development in all the relevant technologies as needed for launching this programme. The design and development has undergone the peer review and a pre-licensing appraisal. This reactor also already embodies several innovative passive safety features that have now assumed added significance internationally following the Fukushima-Daiichi events. A major programme to experimentally demonstrate the available margins to extreme internal and external events will be carried forward in the next plan period to further add to validation of these advanced safety features, many of which are generic in nature.

Fuel Handling System is a major system for on power refuelling in AHWR. It comprises the key components such as Fuelling Machine (FM), inclined fuel transfer machine, under water equipment, fuel storage facility, and hydraulic system.

Prototype FM has been manufactured and FM Test Facility is being established. Performance evaluation of FM will be done to validate the design. Design of FM will be improvised based on its performance results and the manufacturing experience. New equipment like underground spent fuel transfer system will be designed. Some of the scaled models of the fuel handling equipment will be manufactured and tested.

Oil Hydraulic System of FM will be converted to Water Hydraulic System to avoid any risk of fire hazard in AHWR. Evaluation studies of fire resistant hydraulic fluids will also be carried out to reduce the fire load and increase the safety due to high temperature environment of current oil hydraulic systems. A Feeder Coupling Replacement Machine will be developed for AHWR. Underwater manipulator will be developed for inspection and maintenance of storage bay liner. Tribological data for special material pairs will be generated. Development of depth sensing and vision system will be completed for manipulators.

CHTR design is an important step towards the development of technologies for high temperature reactors required for hydrogen generation. CHTR design poses many challenges particularly from consideration of material behaviour as well as technologies for utilization of high temperature heat. Structural material needs to be investigated for their performance in corrosive environment of liquid metal and molten salt coolants. Molten salt is a promising coolant for high temperature application as it also offers the possibility of a thorium based thermal breeder reactor design suitable in the Indian context with a high level of passive safety. Thermal-hydraulics of liquid metals, molten salts and ultra-supercritical coolants needs to be understood for their application to reactor designs. In addition, special instruments and sensors need to be developed for measurement of process parameters in such high-temperature and corrosive environment.

The evolution and development of advanced nuclear

reactor systems in the not so distant future centres on nuclear fusion reactor systems as a technologically viable option. The technological feasibility of harnessing fusion power in a controlled and commercially viable manner is critically dependent upon establishing the engineering proofs and working out safety parameters for a number of concepts that include both materials and processes. The availability and deployment of a variety of materials in multitude of forms for both structural and functional reasons and processes for integrating the materials and devices in the envisaged fusion reactor system is being actively established in every serious pursuit of fusion power research all over the world. Metals, alloys and ceramics in various forms have been identified and are being examined, evaluated and adopted for major structures and functions in the fusion reactor and components. India is among the very few of the countries of the world that are technologically very active in the area of fusion power research, and India is a member country of the ITER. Among the many areas where focused research has been initiated in this context is the design and testing of Test Blanket Module (TBM) concept based on building of Lead Lithium Cooled Ceramic Breeder (LLCB). Materials and related research on technology development has proceeded significantly. It is time to consolidate and organize the advantages already achieved in to a comprehensive research and development program tackling the urgent as well as important issues where technological leadership needs to be quickly developed. Selected materials, process and safety issues have been included and success in these will power rapid indigenous development and progress in related technologies and contribute to timely completion of building the Indian concept of LLCB Test Blanket Module, among other things.

The higher capacity plants and advanced nuclear reactor systems including fusion reactor systems need suitable materials to be specially developed, characterized, compatibility issues solved. The need is to develop the facilities for coatings and compatibility studies for Fusion Reactor candidate materials, development of Laser-based welding, surface engineering and micromachining technologies, processing and characterization of advanced ceramics in the context of nuclear applications, development of glass-ceramics/nano-composites for components development and testing, R&D related to safety research for Fusion Reactor materials and processes specific to ITER are all significant and are key components for TBM development and fusion reactor capability building. By participating in ITER project, India can leapfrog two-decades into design, fabrication and first-hand operating experience of many core systems for future national fusion reactor projects. This will ultimately provide excellent training opportunities to the scientists, engineers and industries in a variety of areas to match international norms of excellence in the areas of Fusion technology. Considering India's large energy needs in future and the huge energy gap that still remains after exploitation of all other energy sources, our gaining technological capability in fusion energy will be of considerable long term benefit to provide clean and sustainable energy solution to the nation.

For the last few years, the activities involving development, preparation, processing and characterization of advanced materials are pursued. The flow sheet for preparation of various materials has been indigenously developed and the materials were produced in small quantities. The refractory metals like Nb, Mo, Ta, W and their alloys are identified as suitable structural materials for our ambitious programme on new generation high temperature reactors such as HTR, ADS, and Fusion devices. After sustained research and development activities on some of these metals and alloys, the capabilities have been acquired for preparing the pure metals and alloys in smaller quantities. Experience has been gained on solving technological challenges for preparation and processing of these alloys.

Further, coatings that enable enhanced performance of these alloys under high temperature oxidising environments have been developed. The coating methodology as well as the testing procedure has been identified. Borides of refractory and rare earth metals like TiB_2, HfB_2, EuB_6, LaB_6, NbB_2 have emerged as potential materials for control rod and shielding application in advanced / high temperature / compact nuclear reactors. Scaling up the production of the metals such as Nb, Mo and V of high purity is proposed. Pertinent R&D activities for scale-up are planned. Facilities for increased production of these materials will be created.

Another important objective is to carry out safety studies of the AHWR and CHTR. Several activities on this front have been proposed in the XII Plan. The key areas are: (1) Feasibility of using End Shield cooling system of AHWR as a "Core Catcher", (2) material data generation and development of design methodology for core structural materials such as graphite and refractory alloys for use in the CHTR and (3) reactor physics experiments in AHWR-CF and other research reactors and ADSS related experiments in Sub-critical facility. It is also proposed to generate material database for the advanced reactors by our indigenous efforts as well as participation in International Collaboration like Joules Horowitz Reactor, Halden etc.

4.3.4 Major Programme 4: Advanced Technologies and Radiation Technologies and their Applications

(A) Advanced Technologies and their Applications

Accelerators and lasers have immense applications in industry and medical fields. They are, of course, very powerful tools for basic as well as applied research in a variety of scientific areas. Researchers and other users of these facilities have been continuously demanding better beam properties and enhanced reliability. This allows them to carry out frontline research while probing deeper into the matter and carry out the applications with better precision and control. In order to keep pace with the rest of the world and to introduce newer beneficial applications, several projects are proposed to be taken up in the XII plan.

In the field of nuclear physics research, extension of the Radioactive Ion Beam (RIB) facility at VECC, incorporating a variety of superconducting as well as normal accelerators, will allow the experimentalists to carry out frontline experiments related to study of nucleo-synthesis in the universe, structure of exotic nuclei, explosive stellar events etc. There is also a proposal to construct large RIB facility of international status over the next 2-3 plan periods. This will start a new era of nuclear physics research in the country.

Several upgradation / modernization projects in the XII plan will significantly enhance the beam quality and reliability of the INDUS-2 accelerator at RRCAT, the largest accelerator in the country. Introduction of advanced devices such as superconducting undulators and wigglers in the ring will offer newer beam characteristics thus opening up new areas of research in material science, condensed matter physics, biology, medicine etc. Several new beam lines will be installed and the existing ones will be upgraded with modern equipment for better quality research. Modernization schemes with state-of-the-art technologies have been proposed also for the Pelletron Accelerator Facility of TIFR / BARC, cyclotrons at VECC, FOTIA facility at BARC and the Tandem / Electron Resonance Source (ECR) based accelerator facilities at IOP.

The above mentioned projects, apart from making the facilities modern and powerful, will also lead to development of advanced technologies and import substitution. There are projects at RRCAT to develop 60 kW solid state amplifiers to replace the

klystron-based RF systems. This will be a unique development and initial R&D has already been successfully done. Advanced control systems and beam diagnostics set ups will be developed for superior beam properties for INDUS-2 at RRCAT. There are similar projects at TIFR. In view of the importance given to indigenous development of advanced RF systems / components for accelerators, BARC, RRCAT and VECC have all proposed to take up projects to strengthen these fields in all aspects, namely, electrical, electronic and mechanical. BARC and VECC have proposed to further enhance development of state-of-the-art sources for protons as well as heavy ions to produce intense beams for research and applications including those related to the important accelerator driven sub-critical systems (ADS).

It is important to note that all the accelerator centres have proposed projects for developing superconducting RF, superconducting magnets, low temperature cryogenics and associated systems on large scale. Self- reliance in these important and advanced areas of technology is crucial for the DAE's R&D programmes including ADS. Major activities are proposed to be taken up by BARC, RRCAT and VECC in collaboration with IUAC, New Delhi. There is a special emphasis on indigenous development of large helium liquefier/refrigeration systems at all these units. The superconducting RF cavities require cooling down to 1.8-2K temperature.

BARC and RRCAT have formulated well defined project proposals to develop enabling technologies for superconducting proton linacs for production of high power beams. These technologies will facilitate construction of a 200 MeV proton linac capable of delivering several mill amperes of beam current for ADS applications at BARC. RRCAT proposes to, eventually, construct a world-class, accelerator-based spallation neutron source facility for material science and condensed matter research. This facility will also be used for ADS studies, nuclear physics research and research in other multi-disciplinary areas. VECC also proposes to develop the superconducting RF cavities to contribute to the national programme in this high technology area.

BARC and VECC have also proposed to develop advanced electron accelerators to deliver high power beams for production of high fluxes of neutrons by photo nuclear reactions. While BARC propose to extend its present capability of room temperature electron linacs, VECC will further the development of superconducting linacs in collaboration with the international accelerator laboratory TRIUMF in Canada. RRCAT will commission an electron accelerator-based irradiation facility in public domain for treating vegetable and fruits.

A unique and advanced infra-red free electron laser (IR-FEL) based facility will be made operational at RRCAT for material science research. BARC will develop comprehensively all technologies for design, manufacture and deployment of high power industrial electro-accelerator. Some advanced areas of research include terahertz time-domain spectroscopy of condensed matter, studies on various magnetic and superconducting materials etc.

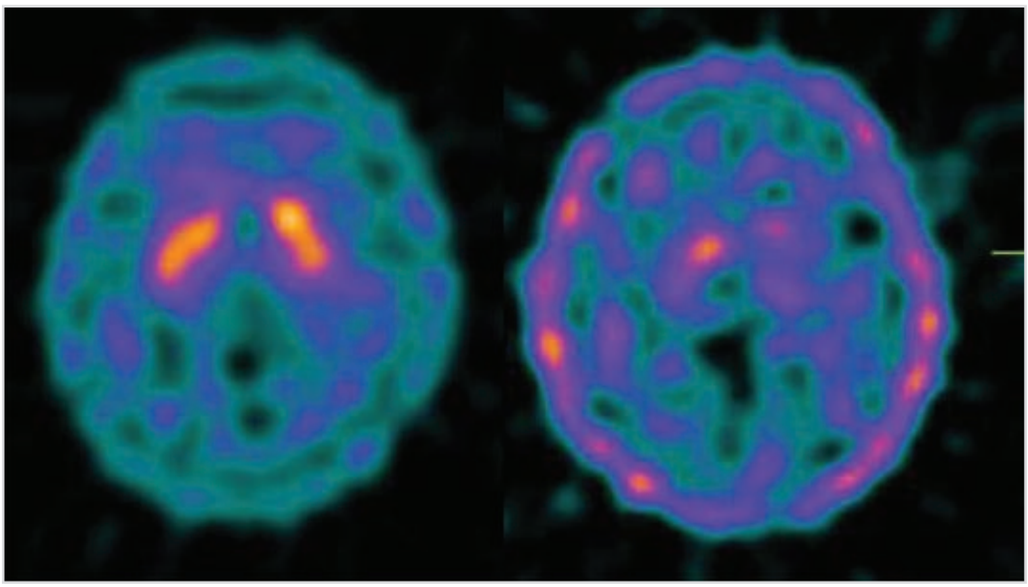
BARC and RRCAT form the largest and most active R&D Centres for lasers in the country. Several XII plan schemes involving development of advanced solid state and metal vapour laser systems for enhanced applications are proposed to be taken up. These laser systems have direct applications in DAE's nuclear power programme in addition to other industrial applications. Basic atom optics and laser spectroscopy studies for deeper understanding are also proposed to be carried out as basic research activities. Projects will also be taken up for development of high power lasers and to study laser-plasma interaction in high energy density as well as ultra-high intensity regimes. For this purpose, the highly advanced technology of laser glass is being developed indigenously along with other

organizations such as CGCRI. Further, in this connection, development of various other complex components and diagnostic systems for high power lasers will be carried out. These developments will also lead to creation of ultra-high intensity laser plasma interaction facility by upgrading the 150 TW laser to PW level. BARC will develop advanced high power tunable lasers which are robust for industrial scale applications. These are some enabling science and technology areas for advanced fields of laser fusion and laser-based acceleration of charged particles making accelerators very compact devices.

Projects will also be taken up at BARC and RRCAT to further advance the ongoing biomedical and societal applications of lasers and laser-based instruments. These applications include biomedical imaging, biomedical diagnosis, photodynamic therapy, optical micromanipulation of cells and nano-biophotonics. More advanced laser-based instrumentation for remote inspection and meteorology in high radiation environments will be developed. BARC and RRCAT will develop more advanced laser-based instrumentation for remote inspection and metrology in high radiation environments. Some of these crucial instruments are for FBTR fuel pins inspection, plutonium measurements etc. TIFR groups have proposed to carry out several advanced atomic physics experiments using sophisticated laser as well as ion sources.

(B) Radiation Technologies and their Applications

The non-power applications of nuclear energy has been and is being exploited in as diverse fields of societal relevance as health, agriculture, biology, radiation processing of materials, isotope hydrology, food preservation and industry. The benefits accrued are both economical and societal.



SPECT using ^{99m}Tc-TRODAT1. The scintigraphic images of a normal person (left) as well as a patient suffering from with parkinsonism (right)

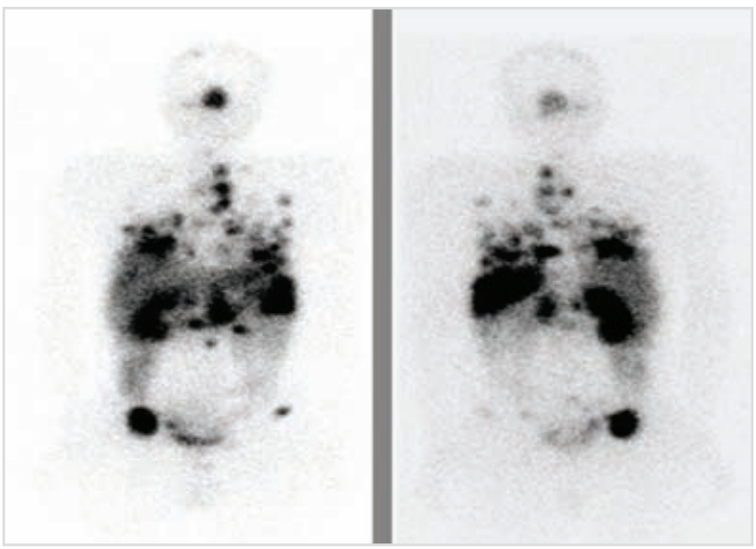
(i) Health

The application of radioisotopes in medicine for diagnosis as well as therapy is growing at a steady rate. The diagnostic applications using ^{99m}Tc derived from ^{99}Mo/^{99m}Tc generator for single photon emission

tomography (SPECT) constitutes the major part followed by the use of ^{18}F for positron emission tomography (PET).

The use of new radionuclide generator systems for separating clinical grade isotopes for diagnosis as well as therapy is another major development. ^{68}Ga from $^{68}Ge/^{68}Ga$ generator for making PET radiopharmaceuticals and ^{90}Y from $^{90}Sr/^{90}Y$ generator for making therapeutic radiopharmaceuticals are important developments.

A few diagnostic and therapeutic radiopharmaceuticals labelled with the above isotopes are now finding applications in the management of cancer. Treatment of cancer using radioactive sources implanted near the cancer is also effectively used for cancer management. Seed sources of ^{125}I are used for the treatment of ocular and prostate cancer.



Scintigraphic image of patient injected with ^{177}Lu-DOTA-TATE using $^{177}LuCl_3$. Image is 48 hour post-therapy showing extensive metastatic pheocromcytoma.

The radiopharmaceuticals development is becoming more intricate needing elaborate biological evaluation of the products both at development and production stage. The biological evaluation is conducted in vivo in animals using small animal imaging cameras and/or in-vitro using cell lines maintained in clean rooms. Enhancing the facilities for the biological evaluation is important for carrying out front line research in the development of both diagnostic and therapeutic radiopharmaceuticals.

An important requirement in radiopharmaceuticals production is compliance with current Good Manufacturing Practices and needs to be implemented as per regulatory recommendations. Consequently, the facilities used for manufacturing raw material radioisotopes need commensurate upgradation to be compliant with the regulations stipulated for active pharmaceutical ingredient (API).

Driven by the rising commitment to the national need for cancer care, and a 100% increase in patient registration from 25000/year to 50,000/year for new cancer patients at the Tata Memorial Hospital , in the XII plan it is proposed to upgrade the laboratory, research and treatment facilities in TMH and ACTREC. This will require acquisition of several new equipment such as intraoperative CT-MRI, PET-MRI, and creating a centre for hematolymphoid tumour management and diagnosis. Research facilities will be augmented by setting up nuclear medicine programme in cancer in collaboration with BARC. A new 18-20 MeV cyclotron will be set up by BARC for the production of not only F-18 –FDG, but also radiopharmaceuticals labelled with F-18, C-11, I-124, I-123 and Cu-64.

At VECC, Kolkata, development of new radiopharmaceuticals from cyclotron produced radioisotopes (Ga-67, Tl-201) will be initiated and related animal studies and clinical trials of such

radiopharmaceuticals will be carried out at RRMC-VECC, Kolkata.

It is known that the pattern of cancer incidence changes with geographical area. It is therefore important to carry out extensive region-specific epidemiological studies. An institute of epidemiology to be set up under the XII plan will meet this longstanding need. It is also proposed to start new cancer registries in the area of present and proposed nuclear power plants and in Nagpur, Pune, Aurangabad and Goa. This will help derive the basal rates of cancer in these sites and monitor any further changes, if any, brought about by nuclear power generation activity. A National Cancer Grid will be created to streamline cancer patient care, education and research including the cancer epidemiology to guide healthcare policy. This would rope in nodal centres in the east (B. Barua Cancer Institute, Guwahati and TMC Kolkata) and create a clone of Tata Memorial Hospital in Visakhapatnam.

Another new advanced facility to be created is a National Hadron Beam therapy unit for cancer patients and especially to look after childhood cancers with doubling of cure rates without causing any morbid second cancers and radiation related side effects crippling their adulthood. This unique facility would address the treatment of majority of the childhood cancers across India who need this unique treatment. On the human resource development front a dramatic increase in the uptake of post graduate level doctors for cancer care annually from 8 to 36 (350%) maintaining the tradition of training over 60% of the national workforce for cancer and mentoring cancer care and HR in all AIIMS like institutes.

Cancer research in Tata Memorial Hospital has resulted in cost-effective intervention (costing less than ₹100) in breast cancer. This is the first Indian trial in breast cancer that has had such dramatic results. When implemented across India and globe would save thousands of lives. Effort is on to replicate the same research in other cancers.

DAE has a unique Contributory Health Service Scheme (CHSS) for serving and retired its employees

New Trombay Oilseed Varieties...

TPM-1	TAS-82	TBG 39/ TDG 39	TG 51
Yellow seed, tolerant to powdery mildew	Black seed coat, tolerant to drought	Large seed	Early maturity, High shelling%
Maharashtra	Maharashtra	Rajashtan, Karnataka	Orissa, WB, Bihar, NE States

and their dependents. In Mumbai more than 85,000 CHSS beneficiaries would get a better healthcare on account of the proposed refurbishment of BARC hospital

(ii) Agriculture

Another important activity of the Department which has immense societal benefit is nuclear agriculture for increased agricultural produce. The XII Plan project proposes application of nuclear and biotechnological approaches for crop improvement for societal benefit. Some of the directions in basic research include,

- Genetic characterization of radiation induced mutants of cereals, pulses and oilseeds.
- Identification and mapping of genes for biotic and abiotic stresses, yield and quality in crop plants.
- Development of genetic populations for identification of quantitative trait loci.
- Understanding the basis of tolerance and investigation of molecular signatures involved in biotic and abiotic stress.
- Genetic transformation for incorporation of stress tolerance genes.
- Screening and identification of plants for remediation of pollutants.
- Structural and activity studies of insecticidal and mosquitocidal proteins
- Preparation and characterization of bio/ nanocomposite matrix for biosensor applications.

Nisargruna biogas technology is developed for processing biodegradable waste resources. Around 120 Nisargruna plants have been installed during XI plan in many parts of the country. In addition to food waste, biological sludge (designated as hazardous) generated in textiles, paper and food industries is processed in Nisargruna plants at 6 places and is converted to useful by-products.

(iii) Industry

Emerging direction of the basic research in the area

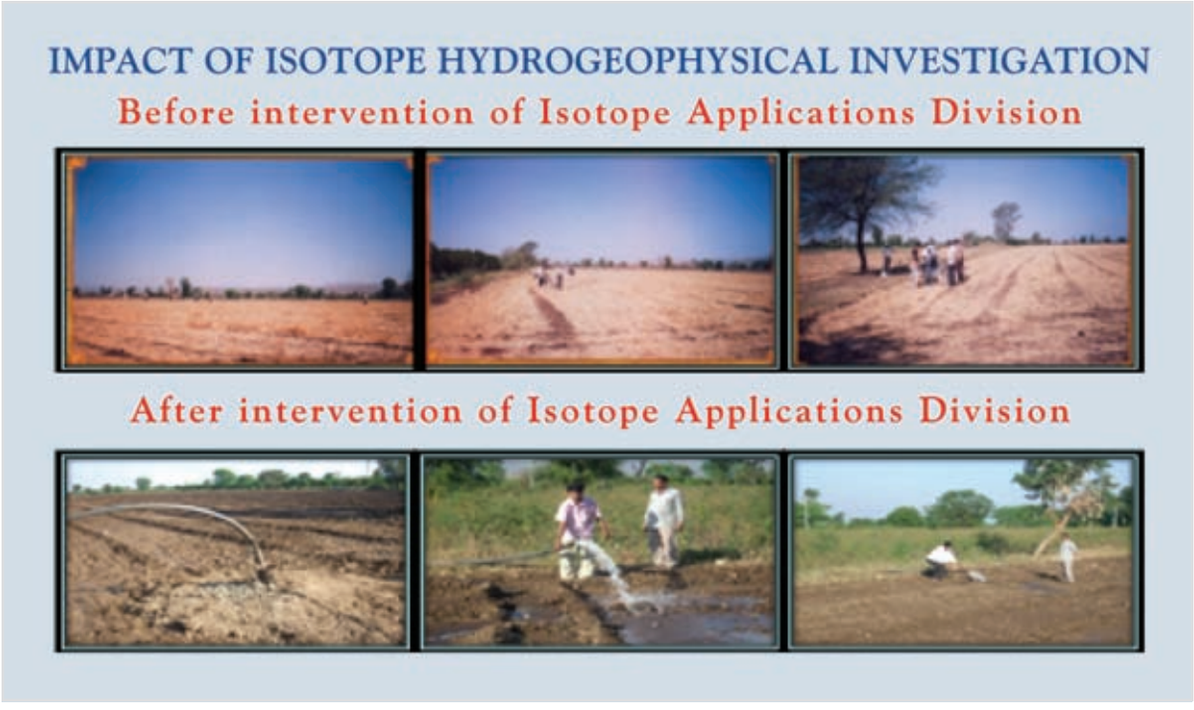
Nisargruna plant at Baddi, Himachal Pradesh

of advanced radiation technologies and their industrial applications are mainly in innovative computational methods for industrial non-destructive examination, process diagnostics and geo-hydrological investigations. Radioisotope based imaging technologies as applied to industrial diagnostic techniques e.g., emission and transmission tomography based non-destructive assay and high-energy radiation based radiological investigations will be future mainstay of nuclear waste drum inspections and other complex assemblies which are relevant to the core programmes the Department of Atomic Energy. High energy X-ray based digital industrial radiography with automatic defect recognition, high-volume data archival and fusion of various NDE protocols are some of the other emerging technologies. Radioisotope based process tomography is being developed and adapted worldwide for various chemical and process industries for generating accurate and reliable data on structural and functional behaviour of the system.

Development and applications of Radioactive Particle Tracking (RPT) technique for flow visualization including development of suitable high-temperature nanotracers and Thin Layer Activation Analysis (TLA) for wear and tear monitoring form another emerging area.

(iv) Isotope hydrology

In the area of isotope hydrology, the emerging techniques to trace the source of pollutants, their pathways and predict their spatial distribution and temporal changes in contaminant pattern are by using isotopes such as ^{15}N,$^{18}O(NO_3^-)$, $^{18}O(SO_4^{2-})$ etc. Application of isotopes such as ^{37}Cl, ^{34}S and ^{11}B are to provide additional information such as investigating possible contribution from anthropogenic sources and getting better insight into the salinisation processes. An important part of continental water balance in coastal areas includes submarine groundwater discharge



Identification of groundwater sanctuaries and recharge areas in Amaravathi, Ratnagiri, Raigad and Buldhana districts under BARC-AKRUTI program

(SGD). Though poor, current estimates of SGD range from about 5-12% of continental runoff. The environmental isotopes such as ^{222}Rn, ^{226}Ra, etc. along with hydro-chemical methods are used for understanding the submarine groundwater discharge processes.

In addition to these, research programmes on recharging springs and water bodies in hilly areas and difficult terrains also form an important activity of radiation technologies for societal benefits

(v) Radiation processing

It's well established that using radiation as tool for processing of materials can lead to economically viable products, with unique properties. However arriving at a radiation processed product requires a through understanding of not only of radiation sources but also of the effect of radiation caused on materials. The planned project is aimed at establishing the dose rate, dose distribution, through puts and under beam geometry for 5 MeV EB at different machine parameters. The information gathered from dose measurement investigations will be utilized for sterilization of medical products, food preservation, processing of lingo-cellulose biomass waste for efficient bio-fuel production, modification of polymeric materials & surfaces and treatment of toxic chemical pollutants present in industrial and municipal water streams. Radiation processing of lingo-cellulose waste has attracted world wide attention because of abundance of waste and rising energy requirement around the world. Modification of polymers and coatings using radiation can lead to clean, aesthetic high purity and long lasting products. Studies on radiation treatment of toxic pollutants in industrial and municipal waste water will be undertaken in view of strongest known oxidizing and reducing species generated on radiolysis in aqueous medium. Efforts will be made to develop a protocol consisting of combination of radiolytic and conventional treatment for complete mineralization of toxic pollutants.

4.3.5 Major Programme 5: Basic Research

One of the Raisons d'être of DAE since its inception has been basic research. The Department encourages and derives its sustenance from various research activities both directed research and curiosity driven research. While directed research is aimed at finding solutions/applications to different programmes and activities of the Department, curiosity driven research is towards intellectual investment for understanding the fundamental processes and advancement of knowledge in basic sciences.

(i) Chemical Sciences

In the field of Advanced Chemical Sciences, the researchers with a broad spectrum of interests look to the future and share their vision for how their own fields may develop in the proposed plan projects.

Active Fields of Research in Chemical Sciences

- Chemistry of materials for energy, environment and health
- Basic and Applied Research in chemistry
- Research and Development of Special materials
- Development & Application of Membrane Technology
- Technology Development Related to Special Materials Project
- Trace, Ultratrace Analysis and Isotope Production (TULIP)
- Development of stable isotopic material and their application
- Chemical Syntheses and Theoretical Studies

These are designed in the interdisciplinary basic and applied areas having interface between chemistry, chemical engineering, which are linked with energy, materials, nuclear reactor systems, front and back end of fuel cycle, waste management, and other important programmes of DAE for their targeted applications.

In the exploration of chemistry of materials for energy, environment and health, synthesis plays a central role. It is proposed to understand the structures and characteristics of substances in minute details at the atomic and molecular levels, and to create new compounds with desirable properties and functions. Various aspects will be pursued for generation of useful database of thorium based fuels, glasses / glasses-ceramics, ultra pure cesium iodide and diamond films for radiation detection, energy conversion materials, nano-materials for sensor and separation application, understanding of the long range transport of very low levels of transuranics and Cs, Sr, etc. Another goal of the proposal is preparation of selective extractants for fission products, room temperature ionic liquids, organics for advanced technologies, functionalized materials for separation science and new therapeutic drugs.

The proposed programs in Basic and Applied Research in Chemistry deal with the fundamental chemical processes resulting from intense radiation, high temperatures, and extremes of acidity & redox potentials. The information obtained from these studies will help to understand degradation of coolant, corrosion of the core materials, gas generation in the core. The R& D work carried out will also be useful to develop methodologies for efficient, targeted separation processes, effective storage of nuclear waste and understanding of physico-chemical evaluation of oxidative stress induced by radiation and other agents. Newer processes will be developed to mitigate biofouling, nitrate and sulphate waste treatments using biofilm and chemical decontamination for removal of antimony and Co-60. A Centralised Reference Material Bank will be established for QA/QC required in various DAE programmes. Understanding of ultra fast processes will be made by developing various techniques like CRDS, CARS, HD-SFG, molecular beam REMPI with ion imaging, vibrational correlation and far-infrared spectroscopy. The synergy between experiment and theory is envisaged in most of the areas. At IGCAR, basic research will be carried out in attaining a better understanding of reprocessing chemistry besides augmenting the analytical chemistry facilities to handle a larger variety of samples with improved limits of detection and precision.

R&D on special materials aim at fulfilling the mandate by taking up applied research related to different stages of nuclear fuel cycle including nuclear material accounting and control. Highlights will be the development and demonstration of technologies such as sol-gel for new types of fuels for advanced reactor systems like CHTR, AHWR and ITER. This programme will also constitute various aspects of nuclear and actinide chemistry research. At SINP, excitation function data will experimentally be generated for production of proton rich clinically important radionuclides and development of their separation methods in the proposed proposal of TULIP. Biomonitoring data on cosmogenic radionuclides in high and low altitude, especially on cosmogenic radionuclide Be-10 will be carried out.

Understanding the mysteries of life has always been a driving force in scientific research; and reflects on the infinite opportunities for chemists at the biology interface. Such studies provide rich information concerning the high specificity of cellular processes and the dynamic interactions that define them. The Chemical Sciences Group at TIFR will focus on many areas of biophysical chemistry, bioinorganic chemistry, chemical dynamics, and materials chemistry. Researchers will be addressing issues such as structure-function relationship of nucleic acids and

proteins, dynamics of protein folding and mis-folding, chemical basis of neuronal communication, various biochemical pathways in living cells as well as metabonomics, fluorescent and MR sensors for clinical applications and mechanical forced aided chemistry.

BARC has developed several thermal and membrane based desalination technologies and water purification devices as a part of its research and development efforts in the XI Plan for societal benefits. Based on these achievements, Development & Application of Membrane Technology, will be further continued for indigenous membrane development for different applications like capillary (hollow fibre) module and sorbent development, demonstration facility for membrane systems for selective separations in nuclear / process streams, brine management alongwith effluent treatment. India is now recognised as the leader in the heavy water production. To give a thrust to the non-nuclear application of heavy water, it is proposed to set up spinning band water distillation system and efficient electrolyser with and re-combination unit for production of O-18 enriched water for medical application. Stress has also been laid for generating various intellectual assets in terms of procedures for deuterium labeling of useful compounds.

In yet another development of indigenous technology to supplement the supply of fission-moly for nuclear medicine, the expertise gained by the Department for isotope separation will be applied to obtain enriched Molybdenum-98. A bench scale facility will be established for indigenous development of MoF6 and upgradation of Molybdenum-98 isotope using High Speed Machine technology. The upgradation of Molybdenum-98 will have considerable societal impact, through the healthcare. In line with this, technology development for production of fluorochemicals and knowhow for dry route reconversion of process gas have been proposed. The work for Integrated Dry Route reconversion of process gas is a technology that will be used for obtaining metal in the solid oxide / fluoride form, for its further processing, without the generation of a large quantity liquid waste. This will be a step towards development of 'Green Technology'.

The scientists at NISER are planning to focus on Chemical Syntheses and Theoretical Studies which will develop organic semiconductors and photovoltaic solar cells and provide basic knowledge base and human resource development. During this plan period, a state-of-the-art analytical facility will be developed which will be available to DAE users. The DAE-ICT Centre for Energy promotes inter-disciplinary research in Chemical Engineering.

Facilities Established and International Collaborations

- High temperature corrosion facility
- Picosecond pulse radiolysis facility with semiconductor photocathode gun
- Ultra-high vacuum port at the 3MV Tandetron
- Pilot level bioreactors for removal of conventional pollutants from the nuclear fuel cycle operations
- Optical cell for radiation chemistry of water at HTHP
- State-of-the-art analytical facility and centralised reference material bank
- Pulsed positron beam line
- Pilot plant for enriched molybdenum-98
- Development of efficient separation system for 18-O enriched water
- Design and simulation of functional nanoporous materials; Participation in Super heavy Element (SHE) studies

(ii) Physical Sciences

In the field of Advanced Physical Sciences, the emphasis will be on investigation of phenomena taking place over different length and time scales, using probes scaling the energy and the intensity frontiers. The research in this field will be multidisciplinary in nature with strong interface with mathematics, chemisty, biology and engineering sciences. While the main focus will be on understanding matter at extremes- structure and dynamics, a large number of the programmes will also come under the category of directed basic research with long term interest to society and industry. For purusing these research programmes in frontier areas, the exisiting facilities will be augmentated and new state of the instrumentation will also be developed. In addition to the exploitation of reactor, accelerator and laser facilities in the country, advanced international facilities will also of be employed for the various research programmes. DAE researchers will also be participating in building several upcoming international mega science facilities.

In the area of astrophysics, the world class facility GMRT will be upgraded with improved sensitivity expanding the scope of its utilisation. The advanced high energy gamma ray telescope facility, MACE will be installed and commissioned at Hanle. The focus of astrophysics programmes will be on observations spanning a range of wavelengths. The LHC is expected to deliver protons at the design value of 7 TeV in the near future. The relativistic heavy ions at the highest energies will also be available for investigation of nuclear matter at extremes of temperature and density to create in the lab the conditions that existed at the time of creation of the universe. The high energy physics community will be carrying out experiments under the ALICE and CMS collaboration. Stringent test of the standard model, discovery of the Higgs, hadron to quark matter phase transition, even physics beyond the standard model, string theory and super symmetry will be the themes of this field of research. The creation of the centre for nuclear theory will be a notable feature during this plan. The lattice QCD related computational activity will get a boost with the setting up high performance computing facility approaching a petaflop. The activities of the centre for astro- particle physics will include dark matter search as a part of the PICASSO collaboration. The nuclear physics activities will be continued with the cyclotrons at VECC and the Pelletron + SC LINAC at TIFR. The FRENA facility will be commissioned at SINP and initial experiments will be carried out in nuclear

Facilities planned for astrophysics and nuclear physics

- Installation and commissioning of the MACE telescope at Hanle
- Upgradation of the GMRT with enhanced sensitivity
- Participation in Dark Matter research in PICASSO
- Augmentation of the astrophysics/cosmic ray facilities
- Commissioning of the FRENA facility for nuclear astrophysics
- Utilisation of superconducting cyclotron, room temperature cyclotron and Pelletron+ SC LINAC, FOTIA for nuclear physics programmes
- Commissioning of charged particle and neutron arrays at VECC and BARC
- Utilisation of international Radioactive Ion Beam facilities for nuclear physics research
- Participation in LHC based high energy physics programmes
- Initiation of work on the India based Neutrino Observatory
- R & D on SiPM, GEM and other detectors

astrophysics. Researchers working in both nuclear and high energy physics will be contributing to the upcoming detector activities at FAIR – CBM, PANDA, NUSTAR, R3B.

Physics of materials and development of materials having desired properties will be major programme of the DAE. Novel methods of making materials and sophisticated methodologies to characterize the materials with powerful tools will be a recurring theme of this field of research. Investigations will make use of the reactor based neutrons, versatile lasers and the synchrotron radiation source spanning a range of wavelengths. Investigation of Nuclear materials, functional materials, meta materials, materials for fusion research and for ADS, nano and novel materials, strategic materials will be vigorously pursued. Study of materials under high pressure and magnetic fields, dynamic range of temperatures and intense radiation and corrosive environment will all be carried out with DAE objectives. Synthesis of new compound semiconductors, fabrication of quantum confined structures like wells, wires, dots, nano photonics, nano structures, nanocomposites, nanocrystalline materials, programmes based on the THz spectroscopy, strongly correlated systems, soft condensed matter, macromolecualr crystallography, will be some of the thrust areas. High intensity,ultrashort laser interaction with matter and generation of ions and neutrons, atomic and molecular physics aspects of nuclear fuel,ultra fast laser TOF mass spectroscopy, development of spectroscopic techniques for nuclear power programmes,VUV spectroscopy of stable and unstable molecules of interest to astrophysics, environmental sciences,photoionisation/dissociation of atoms, molecules, clusters and aerosols, spectroscopy of materials in the visible, infrared and teahertz spectral regions will be some of the highlights of the physics programmes cutting across different branches. In the area of plasma and fusion physics, the participation in the ITER programme has given an impetus to the R & D efforts in the fusion programme based on ADITYA and SST-1. The TBM development will be another major activity of the Indian groups.

Development of analytical and vacuum instruments, thermoelectric devices, HPGe detectors, exploitation of SQUID applications, bio and gas sensors, strategically important crystals, organic solar cells, medical imaging, fast neutron and X-ray based

Applications of Synchrotron Radiation, Lasers and Material Research

- Commissioning of the beam lines – XPS,ARPES,PEEM
- Beam line for Protein crystallography at INDUS-II
- Setting up high intensity ultra short laser facility for laser plasma studies and for generation of energetic ions and neutrons
- Investigation of materials under extremes of pressure, temperature and magnetic fields
- Development of materials having desired properties
- Multi wavelength investigation of materials
- Novel methods of synthesis and advanced methods of characterization of materials of interest to basic research and nuclear power programmes
- Development of TBM for the ITER programme
- Indigenous development of analytical instruments, mass spectrometers, devices, sensors, crystals; Neutron and X ray based tomography

tomorgraphy for various applications will be some of the highlights of the developmental activities that will be taken up during the XII plan.

(iii) Biological Sciences

The major thrust of on biological research in our country is in the areas of genetics, molecular biology, biophysics, bioinformatics, neurobiology, developmental biology, infectious disease and cancer. From DAE's point of view radiation biology is equally important. In all these areas several analytical and experimental tools and sophisticated high value high throughput equipment based on principles of physics, chemistry, electronics and informatics have proved extremely useful. Equipping the biological research laboratories with such state of the art technology is essential for high quality research and to put India on the global map. In recent years NCBS has emerged as one such institution comparable with some of the leading institutions in cellular and molecular biology research. Biological scientists at all the DAE institutes have made very significant contributions in terms of large number of high value publications in reputed journals. Biological sciences also represent a continuity of thought process and urge to probe different biological phenomena in a fundamental way. Therefore, the scientific goals of the XII plan proposals in most cases seek to extend that quest for knowledge of molecular mechanisms underlying a variety of biological processes related cell fat, survival, death transport, signalling, chromatin modelling, gene expression etc.

In BARC the studies on radiation resistance of Deinococcus radiodurans and Anabaena will be extended to understand the mechanism of programmed cell death and regulation of single strand binding protein gene. Protein-protein, DNA-protein and small RNA interactions in D. radiodurans in response to radiation and desiccation stress will be investigated. This will be complimented by structural studies in Anabaena and D. radiodurans under stress conditions using Transmission Electron Microscope (TEM). Analysis of oxidative stress responsive genes, micro RNAs and DNA repair genes will be undertaken in rice under abiotic stress conditions. Evaluation of bioremediation potential of native metal tolerant isolates and genetically engineered strains will be carried out. It is proposed to develop a miniaturized micro-electrode based DNA detection system, a DNA chip for detection of pathogenic microbes.

In recent years, microRNA has emerged as a major regulator of gene expression. The role of microRNA in radio-sensitivity of cells will be evaluated. Targeting of cell cycle check point kinases will be attempted to modulate radiosensitivity of tumour cells. Radiation induced redox changes in terms of glutathionylation of both prosurvival and proapototic proteins will be assessed. Other proposed basic studies will include role of tumour microenvironment on tumour growth and progression and DNA repair kinetics and cellular and molecular effects of heavy metal toxicity and development of novel strategies for their decorporation.

Micro RNA profiling, dynamics of chromatin structure, proteomic studies and assessment of polymorphism in DNA repair genes in lymphocytes of population residing in HLNRA will be undertaken to understand the effects of chronic low level irradiation. Clinical cytogenetics, molecular studies on Down syndrome cases and deep sequencing of DNA in HLNRA population is also proposed to be carried out. Development of cell repository of lymphocytes collected from human samples with chromosomal constitutional anomalies will be established. The possibility of using ?-H2AX foci as a bio-dosimeter will be explored. The present national molecular crystallography facility in SSPD, BARC has aged and several equipments need to be replaced. It is proposed to create a National Structural Biology Facility (NSBF) in place of the present NMCF by procuring additional equipment like automated protein purification system and X-ray diffraction equipment. Among the new proteins to be probed is the Bin, a binary insecticidal protein isolated from Bacillus sphaericus which will give insights into larvicidal activity.

A laboratory will be setup at ACTREC for Radiation Biology and Molecular Biology of Stress Responses. Proton beam irradiation facility will be created to understand bystander effects of radiation.

Department of Biological Sciences, TIFR will continue its effort to get a deeper understanding of the molecular mechanisms and physiological processes that underlie cellular remodelling, transport, development and fate determination, DNA damage and repair, cell death, host-parasite interactions, behaviour, aging etc in experimental models like fruitfly, zebra fish, yeast, Chlamydomonas and rodents. This will generate knowledge of mechanical insight into fundamental biological problems and human disorders with potential for development of novel therapeutics, state of the art biological research facilities and training of internationally competitive manpower. Insights into pathophysiology of malaria, cancer, diabetes, depression and autism will be obtained.

At NCBS, basic questions related to protein structure and function, DNA damage and repair, laser induced cellular damage, DNA based nanodevices, cell and tissue differentiation, signalling in cancer cells, cell death in immune system, endocytosis, mitochondrial dynamics and organelle remodelling, evolutionary ecology and conservation etc. will be addressed.

To develop knowledge and deep understanding of these intricate biological phenomena at molecular level and their genetic regulation, excellent research infrastructure and well trained manpower for modern biological research are required. NCBS aims to emerge as the most visible biological research institute in the country with a high international standing. For this purpose, international collaborative research and training programmes and scientific exchanges will be pursued to facilitate capacity building at the interface of science, history and humanities. NCBS also proposes to develop joint training programmes with iCEMS, Kyoto, IFOM, Milan, and MRI- University of Stanford, USA. This will result in generation of trained manpower for the biotechnology sector.

To support this effort, it is necessary to establish and provide instrumentation and platform technologies in centralized facilities to support research in modern biology. These will include augmentation of the facilities like central imaging facility, computing facility, and library, electronic and mechanical workshops. X-ray and NMR facilities, bioinformatics and genomic facility in the old as well as new building.

At ACTREC-TMC, it is proposed to recruit 8 new principal investigators in new areas of cancer biology, augment advanced instrumentation core and create core imaging facility. Further, augmentation of comparative oncology programme will be achieved by creation of next generation sequencing facility. A programme on circulating tumour cell and chromatin biology will be initiated to establish the oncogenic and metastasis inducing potential of chromatin. A nuclear medicine programme and stem cell research programme will be started. It is also necessary to set up a clinical trial phase I unit, the first of its kind in India.

At SINP, Kolkata basic research related to protein folding, assembly of biomolecules, and interactions of larger molecules with smaller molecules (drugs) will be undertaken to understand the mechanism of protein aggregation diseases including prion disease. Proteomics and genomics of signalling in haematological and neurodegenerative disorders will be carried out using tools like stem cells, microRNAs and animal models. Development of biosensors using conducting polymer based nanostructural materials for early detection of cardiomyopathy and nanoparticle gamma dosimetry will be carried out. Another set of proposed investigations relate to deciphering regulatory mechanisms in cellular processes of transcription, DNA replication, signalling and apoptosis. These will help generate knowledge about profiles of micro RNAs, coding and noncoding RNAs in protozoa, epigenetic regulation, histone acetylation in DNA replication in Leishmania and protein interaction dynamics. To support this activity, facilities such as ESI-MS, Ultrafast spectroscopy, FRET imaging and next generation DNA sequencer are proposed to be setup.

NISER, an academic institution has recently recruited a young faculty with wide research interests in gene regulation, disease susceptibility, immunology and cell biology of different model systems. It is proposed to carry out basic biological research in protein synthesis, membrane dynamics, neuronal signalling, immunity and disease biology and to develop collaborative programmes with mathematics and computer science departments for system biology projects. These initiatives will lead to new strategies for rational drug design, identification of bioactive compounds, understanding of neurotoxicity of anaesthetics, stress dependent disease susceptibility. In turn, this will be reflected in the quality of human resources to be developed in this institute.

4.3.6 Major Programme 6: Research-Education Linkages

DAE recognizes the impact that a strong linkage between research and education can have on the development of science and technology. The Board of Research in Nuclear Sciences, and UGC-DAE Consortium for Scientific Research stand out as important initiatives of DAE in the direction of linking research with education. The scope of BRNS functions will be supplemented by extending additional support from the DAE R&D Units to select R&D organisations and Universities, which would enhance the linkages with academic institutions and also help, achieve greater outreach and awareness on the benefits of nuclear applications.

Besides, the R&D units of DAE host a large number of university students every year for carrying short-term projects. This exposes the students to the state of the art laboratories and R&D environment. By setting up the Homi Bhabha National Institute, a deemed university, DAE has opened new vistas for linking education with research which includes imparting education in research environment. Though the main thrust of HBNI is on post-graduate education, its integrated MSc programme under the aegis of National Institute for Science Education and Research at Bhubaneswar stands out as an attempt to impart undergraduate education in a research environment. The Mumbai University-DAE Centre for Basic Sciences which conducts integrated MSc programme is also an example of DAE's commitment to link education with research.

The Global Centre for Nuclear Energy Partnership being planned in Haryana is another important initiative of DAE to strengthen that linkage.

Besides conducting academic programmes under its own umbrella, HBNI is playing an important role also in linking R&D and education in DAE with other academic institutes in the country and abroad. It has signed MoUs with several Indian academic institutes and with some institutes abroad for academic collaboration. The Institutes in the country with which MoUs have been signed include:

1. IIT-Bombay,
2. IIT-Madras,
3. Institute of Chemical Technology, Matunga, Mumbai,
4. TIFR,
5. Indian Statistical Institute (ISI), Kolkata,
6. Jadavpur University.

The foreign institutes with which MoUs for academic exchange have been signed include:

1. Jefferson Laboratory, University of Virginia, USA, and 2. The Commissariat à l'énergieatomique (CEA), France.

The scope of education-research linkage through HBNI is being expanded by identifying and carrying projects of common interest collaboratively with the academic institutes. As a first step in that direction, dialogue is ongoing to finalise a MoU with Indian Institute of Science (IISc), Bangalore. Similar dialogue could be taken up with other institutes. Overall objective is to use the medium of HNBI for strengthening the linkage between institution of DAE and university system in the country and abroad.

HBNI will continue to strive for strengthening the research-education linkage.

4.3.7 Major Programme-7: Infrastructure & Housing

Creation of new and maintenance of existing infrastructures is essential to provide necessary support to carry out extensive and expanding R&D activities of the Department. Since the various existing infrastructure are more than 30 years old, it is proposed to renovate/ upgrade the same to increase the life span of the infrastructure, safety, reliability of the facilities and to support the additional facilities developed during the period. Repairs of structures, up-gradation of electrical and mechanical services including rain water harvesting, alternate power supply etc. in existing campus of BARC, Anushaktinagar colony, campus of IGCAR, RRCAT, AMD etc. are proposed now. In order to support new R&D activities, it is proposed to construct infrastructure like Engineering Halls, Field laboratory, Computer buildings and housing for BARC at Vizag, for IGCAR at Anupuram, for AMD at Bangalore, for NISER at Bhubaneswar. As a part of security measure, up gradation of existing security system of various units including creation of information centres are proposed, considering constant security threat on the establishment and premises of Atomic Energy. Department also propose to provide infrastructure support for establishing new campus for basic sciences at Hyderabad for TIFR, at Chennai for IMSc, for high technology research at Gandhinagar for IPR.

In addition, it is proposed to complete continuing projects like up-gradation of engineering services for BARC, Quarters for CISF, Residential quarters, crèche facility for employee, Convention centre, Administrative Training Institute, Hostel for trainees at Anushaktinagar, Infrastructure for R&D facilities at Vizag, residential quarters at Anupuram for IGCAR, Establishment of Infrastructure facility at Chennai, Training Centre at Hyderabad for AMD, Inter disciplinary centre & International centre for Theoretical Science for TIFR, laboratory for SINP at Kolkata etc.

Proposed Infrastructural Facilities

- Upgradation of Electrical, Mechanical, Civil Engineering Services & other Utility Services for BARC
- Construction of Engineering Hall, Field Lab, Security Infrastructure, Computer Centre, Residential Township and other infrastructure at Vishakhapatnam
- Information Centre at various DAE Establishments
- Global Centre for Nuclear Energy Partnership
- Construction of 500 Flats of Type V(E), Infrastructure for Improvement of Security System of DAE Premises under DCSE
- Construction of Housing for BARC (F) at Anupuram
- Infrastructure for IPR and VPP-IPR
- Civil Projects at TIFR Hyderabad Campus
- Staff Housing for TIFR
- Housing for Patients and Residents Compliance for TMC
- Infrastructure Developments at VECC Campuses

LIST OF CONTINUING SCHEMES
(EXPECTED TO BE COMPLETED BY SECOND YEAR OF XII PLAN)

(₹ In crore)

PIC No	Project Title	Estimated / Sanctioned Cost	XI Plan Expend.	XII Plan Outlay
X-R&D-BAR-1.04-0100	Back End Fuel Cycle Development Studies	79.65	73.51	6.00
X-R&D-BAR-3.02-0100	Thorium Fuel Cycle Technology Development and U233 Clean Up	101.33	88.69	10.00
X-R&D-VEC-4.05-0200	Setting up 30 MeV Medical Cyclotron	160.18	65.59	98.25
X-R&D-BAR-5.02-0200	Sub-TeV Light Experiments (SUBTLE)	49.43	38.90	15.00
X-R&D-VEC-5.02-0100	Superconducting Cyclotron Utilisation Project	48.77	41.88	6.89
X-R&D-BAR-5.06-0100	Development of Indus-2 Beam lines for various Applications	70.80	51.70	20.00
X-R&D-CAT-5.11-0100	DAE CERN Collaboration in Joint Participation in Advanced Accelerators and Novel Accelerator Technologies	17.50	12.00	5.50
X-R&D-DEM-6.01-0100	Construction of Convention Centre & Guest House	53.10	27.00	26.16
XI-R&D-BAR-1.01-0100	R&D for Heavy Water Reactors	45.50	33.30	7.00
XI-R&D-BAR-1.02-0100	R&D for Improved Rotor Performance	89.00	38.27	55.00
XI-R&D-AMD-1.03-0100	Augmentation of Airborne and ground geophysical capabilities	258.69	145.00	113.69
XI-R&D-AMD-1.03-0500	Uranium investigation for Iron Oxide Breccia, Quartz Pebble Conglomerate, Sandstone and Calcrete Type of Uranium deposits	35.00	20.35	14.65
XI-R&D-BAR-1.05-0200	Environmental Studies	35.50	35.95	7.00
XI-R&D-IGC-2.01-0100	Providing Infrastructure for SNM storage and Fuel assembly in FBTR complex	11.89	10.19	1.70
XI-R&D-IGC-2.01-0400	Engineering development and testing for FBR	53.54	45.31	8.23
XI-R&D-IGC-2.01-0600	Continuing structural mechanics experiments with State of Art instrumentation	52.90	48.90	4.00
XI-R&D-IGC-2.01-0800	State of art modern design office	10.07	8.33	1.74
XI-R&D-IGC-2.03-0200	Design and development of I&C Systems for FBR	13.28	12.49	0.79
XI-R&D-IGC-2.03-0300	Fuel chemistry	19.64	17.68	1.96
XI-R&D-IGC-2.04-0100	Back end fuel cycle (Chemistry research for the development of advanced re-processing and waste management techniques)	13.01	9.83	3.18
XI-R&D-IGC-2.04-0200	R&D in FBR fuel reprocessing	43.59	28.26	15.33
XI-R&D-IGC-2.04-0300	Measurement tools for the assay of fissile material	13.52	7.52	6.00
XI-R&D-IGC-2.05-0100	Development of technology for inspection, irradiation experiments and remote handling for FBRs	38.20	32.00	6.20
XI-R&D-IGC-2.06-0100	Radiological safety studies	23.32	19.62	3.70
XI-R&D-BAR-3.02-0100	Thorium Technologies	47.00	10.81	36.00
XI-R&D-BAR-3.04-0100	Development of Low Energy High Intensity Proton Accelerator (LEHIPA) for front-end of ADS driver	87.00	26.63	55.00
XI-R&D-VEC-3.04-0100	Development of High Current Cyclotron for ADSS	37.00	2.50	8.50
XI-R&D-BAR-4.01-0100	Research Reactors	71.74	31.75	36.00
XI-R&D-IGC-4.05-0100	Upgradation of medical facilities at Anupuram/Kalpakkam	16.95	5.93	11.02
XI-R&D-TMC-4.05-0900	Transcriptome Profiling in Cancer	5.68	1.00	4.68
XI-R&D-CAT-4.08-0100	Improvements in Indus Accelerators	57.45	29.15	28.30
XI-R&D-CAT-4.08-0200	Indus-2 Beam line Development Programme : Phase III	44.50	37.50	7.00
XI-R&D-CAT-4.08-0300	Development of Superconducting Cavities and Associated Technologies for High Energy Accelerators and their applications	91.35	46.00	45.35
XI-R&D-CAT-4.08-0400	High current H Injector Linac for SNS	83.35	23.00	60.35
XI-R&D-CAT-4.08-0500	Proton Synchrotron Sub Systems	41.20	17.96	23.24

(₹ In crore)

PIC No	Project Title	Estimated / Sanctioned Cost	XI Plan Expend.	XII Plan Outlay
XI-R&D-CAT-4.08-0600	Infrastructure for Evaluation and Qualification of Advanced Accelerator Subsystems	43.35	22.35	21.00
XI-R&D-CAT-4.08-0700	International Collaboration in Advanced Accelerators like X Ray Free Electron Laser (XFEL) and International Linear Collider (ILC)	40.00	12.00	28.00
XI-R&D-VEC-4.08-0100	Design, analysis and development of high-β multi-cell superconducting RF linac cavity	15.00	10.50	4.50
XI-R&D-BAR-4.11-0300	Manufacturing Technologies	68.70	33.50	33.00
XI-R&D-IGC-4.11-0200	Development of hardware & computer based systems for reactor Instrumentation and Control	25.00	22.50	2.50
XI-R&D-VEC-4.11-0100	Non-cryogenic helium purification and Seismic related gas assaying	12.20	7.05	5.16
XI-R&D-VEC-4.11-0200	Superconducting Magnetic Energy Storage System Technology Development	30.00	5.17	15.00
XI-R&D-BAR-5.01-0100	Enhancement of Computing Power and Connectivity	95.50	65.98	30.00
XI-R&D-BAR-5.01-0200	Computing Facility at Vizag : Phase-I	50.00	17.93	35.00
XI-R&D-HRI-5.01-0100	Special Years in Mathematics	1.61	1.60	0.01
XI-R&D-IGC-5.01-0100	Centre for advanced visualization & computational intelligence	30.20	27.20	3.00
XI-R&D-CAT-5.01-0100	Scientific Infrastructure	23.00	18.50	4.50
XI-R&D-VEC-5.01-0100	Advanced Computing and Automation	50.00	20.00	30.00
XI-R&D-BAR-5.02-0100	National Facilities for Neutron Beam & Astrophysics Research	52.21	10.55	38.00
XI-R&D-BAR-5.02-0200	Research in Frontier Areas in Nuclear Physics	27.25	16.69	11.00
XI-R&D-HRI-5.02-0100	Scientific Computing and Networking	9.96	9.33	0.63
XI-R&D-HRI-5.02-0200	High Performance Scientific Computing	11.28	9.10	2.18
XI-R&D-HRI-5.02-0300	Scientific Human Resources Training	4.01	3.45	0.56
XI-R&D-HRI-5.02-0400	Regional Centre for Accelerator-based Particle Physics (RECAPP)	3.68	2.60	1.08
XI-R&D-TFR-5.02-1000	Inter Institutional Research Programme II (Strong field Science)	10.00	2.05	7.95
XI-R&D-TFR-5.02-0700	Radio Astronomy I	13.65	16.50	5.50
XI-R&D-TFR-5.02-0800	Radio Astronomy II, Research Initiative & Instrumentation and New Tech.	14.05	17.60	2.95
XI-R&D-TFR-5.02-1100	Inter disciplinary Areas	24.79	26.13	48.37
XI-R&D-TFR-5.02-1200	Research Facilities	42.85	66.40	8.10
XI-R&D-VEC-5.02-0100	Advanced Radioactive Ion Beam Facility Project	70.00	57.93	13.00
XI-R&D-VEC-5.02-0200	Advanced Detector Facilities	12.50	6.10	6.40
XI-R&D-VEC-5.07-0100	Augmentation of Technical Facilities	39.00	5.72	33.28
XI-R&D-IGC-5.09-0300	Setting up of advanced materials characterisation facilities for comprehensive materials studies	19.00	17.70	1.30
XI-R&D-VEC-5.09-0100	Studies of radiation damage in nuclear structural materials by particle irradiation using accelerators	14.00	8.61	5.39
XI-R&D-TFR-5.11-0100	High Energy Physics II	9.00	11.06	5.44
XI-R&D-TFR-5.11-0200	High Energy Physics III (International Collaborations)	13.00	12.21	0.79
XI-R&D-TFR-5.11-0400	Participation in International Liner Collider (ILC) Programme and related Advanced Accelerator R&D	2.60	1.26	1.34
XI-R&D-VEC-5.11-0300	ALICE Operation and Utilization	20.25	12.35	7.90
XI-R&D-DAE-6.01-0100	Global Centre for Nuclear Energy Partnership	147.00	124.00	23.00
XI-R&D-DEM-6.01-0100	DAE Administrative Training Institute	23.34	2.00	21.34
XI-R&D-IGC-6.01-0100	IGCAR Training School	18.77	13.77	5.00
XI-R&D-IGC-6.01-0200	Fast Reactor Training Centre	18.47	13.47	5.00
XI-R&D-DAE-6.05-0200	Enhancement of Anunet and DAE Grid	23.00	18.05	4.95
XI-R&D-DAE-6.05-0300	Enhancement of Regional WLCG Grid	23.65	20.65	3.00

(₹ In crore)

PIC No	Project Title	Estimated / Sanctioned Cost	XI Plan Expend.	XII Plan Outlay
XI-R&D-AMD-7.01-0100	Construction of Office Complex (Phase-II) at Shillong, Guest House at Guwahati and R&D Laboratory-cum-Liaison Office at Kolkata	16.47	2.10	14.37
XI-R&D-AMD-7.01-0100	Creation of Human Resource Development (HRD) Facilities	22.50	2.27	20.00
XI-R&D-BAR-7.01-0200	Upgradation of Existing Engineering Services	90.00	60.86	30.00
XI-R&D-BAR-7.01-0400	External Engineering Utility Services for BARC, Vizag	148.00	10.00	128.00
XI-R&D-BAR-7.01-0500	Upgradation of Electrical & Mechanical Utilities at BARC	17.00	3.22	13.00
XI-R&D-BAR-7.01-0600	Construction of New Engineering Halls at BARC, Trombay	148.55	13.53	128.00
XI-R&D-DEM-7.01-0400	Providing Crèche facility for employee's children	6.65	1.65	5.00
XI-R&D-HRI-7.01-0100	Equipping & Furnishing of Conference Centre	0.98	0.25	0.73
XI-R&D-HRI-7.01-0200	Civil & Infrastructure Development	20.00	8.10	17.53
XI-R&D-IGC-7.01-0100	Augmentation of infrastructure facilities at Kalpakkam township	47.30	27.08	20.22
XI-R&D-IGC-7.01-0200	Providing infrastructure facilities at IGCAR plant site	22.37	15.94	6.43
XI-R&D-IGC-7.01-0300	Augmentation of electrical services for IGCAR	36.68	27.77	8.91
XI-R&D-IMS-7.01-0200	Extension & Modernisation of Library	6.60	2.40	4.20
XI-R&D-CAT-7.01-0100	Infrastructure Development Phase V	40.91	29.36	7.60
XI-R&D-CAT-7.01-0200	Upgradation of existing Infrastructures at RRCAT	3.91	2.01	1.90
XI-R&D-VEC-7.01-0100	Infrastructure Development at VECC (Salt Lake and Rajarhat)	12.00	9.03	2.97
XI-R&D-DEM-7.02-0100	Residential Qtrs. for CISF Persons	47.64	24.00	23.64
XI-R&D-DEM-7.02-0200	Construction of hostel for Trainees of HBNI/BARC Phase I and II	104.94	7.70	97.24
XI-R&D-DEM-7.02-0300	Restoration, renovation of old houses Phase-I	126.00	40.00	86.00
XI-R&D-HRI-7.02-0100	Housing	7.63	5.00	8.38
XI-R&D-IGC-7.02-0100	Construction of housing, public buildings and other infrastructure facilities at Anupuram	79.04	25.52	53.52
XI-R&D-TMC-7.02-0100	Housing :- Construction of Hostel in Chembur	13.00	2.00	11.00
	TOTAL	4090.67	2233.85	1917.17

LIST OF CONTINUING SCHEMES
(EXPECTED TO EXTEND BEYOND SECOND YEAR OF XII PLAN)

(₹ In crore)

PIC No	Project Title	Estimated / Sanctioned Cost	XI Plan Expend.	XII Plan Outlay
X-R&D-IPR-3.07-0100	ITER India	2500.00	1100.00	1167.00
X-R&D-BAR-4.12-0400	Additional BARC Campus	1079	432.02	650.00
XI-R&D-BAR-1.03-0100	R&D support in Front End Fuel Cycle	79.35	29.99	50.00
XI-R&D-BAR-1.04-0100	R&D in Back-End processes	94.50	32.73	60.00
XI-R&D-BAR-1.05-0100	Safety Related Research	88.20	49.05	40.00
XI-R&D-BAR-3.01-0100	Advanced Nuclear Reactor Development	137.85	71.28	64.00
XI-R&D-BAR-3.03-0100	High Temperature Reactor Development Programme at Vizag	93.00	2.35	90.00
XI-R&D-BAR-3.05-0100	High Temperature Materials	42.50	14.64	20.00
XI-R&D-BAR-3.05-0200	Special Materials for High Temperature Reactors at Vizag	95.00	2.71	92.00
XI-R&D-BAR-3.05-0300	Fusion Reactor Material Development	35.00	6.01	15.00

(₹ In crore)

PIC No	Project Title	Estimated / Sanctioned Cost	XI Plan Expend.	XII Plan Outlay
XI-R&D-BAR-3.06-0100	Hydrogen Energy	47.00	13.55	33.00
XI-R&D-BAR-4.01-0300	Indian Participation in Jules Horowitz Reactor Cadarache, France	90.00	91.16	30.00
XI-R&D-BAR-4.03-0100	Nuclear Agriculture	48.00	12.38	37.00
XI-R&D-BAR-4.05-0100	Augmentation of Healthcare Services	74.00	22.92	50.00
XI-R&D-GIA-4.05-0100	Development of cancer Care Facility at Shillong and Ranchi	59.00	10.00	49.00
XI-R&D-TMC-4.05-0600	Centre for Cancer Epidemiology	31.00	19.7	11.30
XI-R&D-BAR-4.06-0100	Desalination & Water Purification Technologies	77.00	14.34	60.00
XI-R&D-BAR-4.08-0100	Accelerator & ADS Technologies	95.25	34.02	65.00
XI-R&D-BAR-4.10-0100	Special Materials Development	450.00	146.92	325.00
XI-R&D-BAR-4.11-0100	Nuclear Instrumentation & Radiation Detectors	86.50	44.52	40.00
XI-R&D-BAR-4.11-0200	Advanced Electromagnetic Technologies	94.00	38.96	50.00
XI-R&D-BAR-4.11-0400	Scientific & Medical Equipment Development	93.50	59.95	28.00
XI-R&D-DAE-5.02-0100	Development of Site Infrastructure and Prototype for INO	65.83	30.00	35.83
XI-R&D-TFR-5.02-1300	Engineering Technical Services	28.00	12.62	5.38
XI-R&D-TFR-5.02-1400	Common Services	48.25	35.31	12.94
XI-R&D-BAR-5.03-0100	Energy Conversion	67.00	30.86	30.00
XI-R&D-BAR-5.04-0100	Radiation Effects in Biological Systems	37.80	18.40	20.00
XI-R&D-BAR-5.09-0100	Advanced Functional Materials	81.50	47.16	40.00
XI-R&D-VEC-5.11-0200	International Collaboration in Intermediate Energy Nuclear Physics	2.00	0.50	1.50
XI-R&D-BAR-6.01-0200	DAE-UICT Centre for Chemical Engg. Education & Research	75.00	50.62	25.00
XI-R&D-DAE-5.11-0100	DAE's participation in FAIR Project	133.00	32.00	101.00
XI-R&D-IOP-6.01-0100	NISER	755.31	330.00	425.31
XI-R&D-BAR-7.01-0100	Security & Emergency Infrastructure	88.00	40.33	45.00
XI-R&D-BAR-7.01-0300	Replacement of Facilities with Permanent Structures	94.00	17.80	73.00
XI-R&D-DEM-7.01-0700	Extension of V.S Bhavan	46.57	0.57	46.00
XI-R&D-IGC-7.01-0500	Establishment of infrastructure facilities at Chennai phase-II	75.00	0.25	74.75
XI-R&D-IMS-7.01-0300	Refurbishment of Students' Hostel & Guest House	5.00	0.50	4.50
XI-R&D-SIN-7.01-0100	Infrastructure Development	45.25	6.80	63.45
XI-R&D-TFR-7.01-0200	Interdisciplinary Centre	73.51	48.03	25.48
XI-R&D-TFR-7.01-0500	International Centre for Theoretical Sciences	83.86	46.50	37.36
XI-R&D-DEM-7.02-0400	Construction of 356 houses in Anushaktinagar	114.00	3.00	111.00
XI-R&D-IGC-7.02-0200	Construction of Efficiency Plus Apartments at Anupuram Township	73.50	5.50	68.00
	TOTAL	7482.03	3005.95	4271.80

MAJOR PROGRAMME - I NUCLEAR POWER PROGRAMME - STAGE – I

(₹ in Crore)

PIC No	Project Title	Estimated / Sanctioned Cost	XII Plan Outlay	Spill over
XII-R&D-BAR-1.02-0100	Control Systems and Mechanisms for Advanced LWRs	78.00	33.00	45.00
XII-R&D-BAR-1.02-0200	Setting up Prototype Manufacturing Centre (PMC)	120.00	29.00	91.00
XII-R&D-BAR-1.02-0300	Development of Special Materials for RPV of Indian PWR (IPWR)	40.00	15.00	25.00
XII-R&D-AMD-1.03-0100	Investigation of unconformity-related and strata bound types of Uranium mineralisation	68.00	59.80	8.20
XII-R&D-AMD-1.03-0200	Exploration for proterozoic vein and phenerozoic sedimentary types of Uranium mineralization	56.50	56.50	0.00
XII-R&D-AMD-1.03-0300	Airborne and ground geophysical surveys, remote sensing & GIS studies for exploration of uranium	230.00	216.90	13.10
XII-R&D-AMD-1.03-0400	Upgradation of laboratory facilities with state-of-the art instrumentation for uranium exploration	54.47	54.47	0.00
XII-R&D-AMD-1.03-0500	Design and Development of enterprise level geospatial atomic minerals exploration database and facility for ore deposit modelling	15.00	15.00	0.00
XII-R&D-AMD-1.03-0600	Augmentation of infrastructural facilities for prospecting and exploration activities	10.00	10.00	0.00
XII-R&D-BAR-1.03-0100	Demonstration of Recovery of U and Other Metals from Other Sources	74.00	74.00	0.00
XII-R&D-BAR-1.03-0200	Facilities for Fuel Development, Characterisation and Fabrication	65.00	55.00	10.00
XII-R&D-IGC-1.03-0100	Design and development of airborne time domain electromagnetic (TDEM) system	5.00	5.00	0.00
XII-R&D-IGC-1.04-0100	Advanced corrosion assessment and coating technologies for FBR and Reprocessing applications	26.30	24.30	2.00
XII-R&D-BAR-1.05-0100	Radiation Safety Related Research for Nuclear Facilities	57.00	57.00	0.00
XII-R&D-BAR-1.05-0200	Development of National Level Preparedness for Nuclear & Radiological Emergencies	33.00	26.00	7.00
XII-R&D-BAR-1.05-0300	Environmental studies and Advanced Techniques for Radiation Dosimetry	75.00	67.00	8.00
XII-R&D-BAR-1.05-0400	Experimental Studies for Ageing & Life Extension of Nuclear Components	65.00	50.00	15.00
XII-R&D-BAR-1.05-0600	Safety Studies Related to PHWR, AHWR and CHTR	108.00	70.00	38.00
XII-R&D-DAE-1.05-0100	Emergency Response Centre	6.00	6.00	0.00
XII-R&D-BAR-1.06-0100	Development of Advanced Processes & Equipment for Waste Management Applications	244.00	224.00	20.00
	Total	1430.27	1147.97	282.30

MAJOR PROGRAMME - 2 NUCLEAR POWER PROGRAMME - STAGE – 2

(₹ In Crore)

PIC No	Project Title	Estimated / Sanctioned Cost	XII Plan Outlay	Spill over
XII-R&D-IGC-2.01-0100	Indigenisation of instruments / Components for FBRs	6.00	6.00	0.00
XII-R&D-IGC-2.01-0200	Augmentation of central workshop division	12.00	10.50	1.50
XII-R&D-IGC-2.01-0300	Sodium technology complex	73.00	61.00	12.00
XII-R&D-IGC-2.01-0400	Testing of components for CFBR	62.00	62.00	0.00
XII-R&D-IGC-2.01-0500	Engineering R&D for sodium systems	30.00	30.00	0.00
XII-R&D-IGC-2.01-0600	Design validation and safety demonstration of innovative SFR	66.00	55.00	11.00
XII-R&D-IGC-2.01-0700	Experimental studies on radiation damage, decay heat & neutron attenuation in shield materials and reliability studies on innovative passive systems for future FBRs	4.00	4.00	0.00
XII-R&D-IGC-2.01-0800	Civil engineering R&D for fast reactors	4.70	4.20	0.50
XII-R&D-IGC-2.01-0900	Development of design for metallic fuelled test reactor for supporting the commercialization of Fast Breeder Reactors ensuring higher growth	25.00	25.00	0.00
XII-R&D-IGC-2.01-1000	Site related technical activities at Kalpakkam complex	5.00	5.00	0.00
XII-R&D-IGC-2.01-1100	Safety upgradation of FBTR	69.00	69.00	0.00
XII-R&D-IGC-2.01-1200	Electron Accelerator Based Photo-neutron Sodium Gamma Facility for FBR Shield Design Experiments	10.00	10.00	0.00
XII-R&D-IGC-2.01-1300	High performance & data communication facilities for FBR design and basic research	72.00	72.00	0.00
XII-R&D-IGC-2.02-0100	High performance materials and fabrication technologies for nuclear steam supply system	71.60	70.40	1.20
XII-R&D-IGC-2.02-0200	Microstructural engineering of advanced materials for Fast Reactor and Reprocessing technology	54.85	53.30	1.55
XII-R&D-VEC-2.02-0900	Advanced experimental facilities for the materials science beam-line activities at the DAE medical cyclotron, Kolkata	17.00	17.00	0.00
XII-R&D-BAR-2.03-0100	Special Fuel Fabrication and Characterisation Laboratory	330.00	100.00	230.00
XII-R&D-IGC-2.03-0100	Chemistry of liquid metals and sensors	11.50	11.50	0.00
XII-R&D-IGC-2.03-0200	R&D on chemistry of nuclear materials	31.70	31.70	0.00
XII-R&D-IGC-2.04-0100	Engineering scale development of pyroprocesses flow sheet for alloy fuels	40.00	37.00	3.00
XII-R&D-IGC-2.04-0200	Demonstration facility for MA partitioning at FRFCF	11.50	9.50	2.00
XII-R&D-IGC-2.04-0300	Metal fuel cycle demonstration facility - Engineering consultancy for design	20.00	10.00	10.00
XII-R&D-IGC-2.04-0400	Novel options for back end fuel cycle	36.00	33.50	2.50
XII-R&D-IGC-2.04-0500	Augmentation of infrastructure for RCL Operation, Safety and Security	15.75	15.75	0.00
XII-R&D-IGC-2.04-0600	R&D on advanced fuel cycles for fast reactors	15.00	13.00	2.00
XII-R&D-IGC-2.04-0700	Augmentation of facilities for process, equipment and system development for Fast Reactor Fuel Reprocessing	80.00	70.00	10.00
XII-R&D-IGC-2.05-0100	Irradiation performance assessment and development of remote handling, robotics, NDE and ISI tools for FBRs and fuel cycle facilities	84.05	75.70	8.35
XII-R&D-IGC-2.05-0200	Total quality management for robust back end fuel cycle facilities and CFBRs	17.50	17.50	0.00
XII-R&D-IGC-2.05-0300	Post Irradiation Examination Facility for MFTR – Engineering Consultancy for PIE facility and development of fuel transfer systems and dismantling equipments	5.00	4.00	1.00
XII-R&D-IGC-2.06-0100	Augmentation of Health Physics Services and Development Activities related to Calibration, Simulation, Accident Dosimetry, Radiation safety and Research	57.50	55.00	2.50
XII-R&D-IGC-2.06-0200	Industrial safety & environmental research	16.50	16.50	0.00
	Total	1354.15	1055.05	299.10

MAJOR PROGRAMME - 3 NUCLEAR POWER PROGRAMME - STAGE – 3 AND BEYOND

(₹ In crore)

PIC No	Project Title	Estimated / Sanctioned Cost	XII Plan Outlay	Spill over
XII-R&D-BAR-3.01-0100	Fuel Handling System for AHWR	36.00	30.00	6.00
XII-R&D-BAR-3.01-0200	Robotics and Automation for Nuclear Fuel Cycle	55.00	44.00	11.00
XII-R&D-BAR-3.01-0300	Safety Assessment and Technology Development for Advanced Reactors	105.00	80.00	25.00
XII-R&D-BAR-3.02-0100	Development of Advanced Processes and Equipment for Recycling Application	169.50	140.00	29.50
XII-R&D-BAR-3.05-0100	Materials and Technology for Advanced Reactor Systems	80.00	60.00	20.00
XII-R&D-BAR-3.05-0200	Setting up Materials Processing Centre	87.00	44.00	43.00
XII-R&D-BAR-3.05-0300	Applied R&D on Rare-earth materials	70.00	40.00	30.00
XII-R&D-IPR-3.07-0100	Tokamak Research and Fundamental Plasma Studies	258.00	200.00	58.00
XII-R&D-IPR-3.07-0200	Development of Auxiliary Technologies for Fusion: Magnets, RF, NB an Plant Systems	251.00	185.00	66.00
XII-R&D-IPR-3.07-0300	Technologies for Fusion Reactor Materials, Blankets, Shields, Diverter & Fuel Cycle	230.00	165.00	65.00
	Total	1341.50	988.00	353.50

MAJOR PROGRAMME - 4A – ADVANCED TECHNOLOGIES AND THEIR APPLICATIONS

(₹ In Crore)

PIC No	Project Title	Estimated / Sanctioned Cost	XII Plan Outlay	Spill over
XII-R&D-BAR-4.01-0100	Research Reactor & Isotope Processing Laboratory Buildings	607.00	202.00	405.00
XII-R&D-BAR-4.01-0200	125 MW Thermal Research Reactor	850.00	180.00	670.00
XII-R&D-BAR-4.08-0100	Physics studies and enabling Technology development for Ion accelerators	140.00	100.00	40.00
XII-R&D-IOP-4.08-0100	Strengthening Low Energy Accelerator-based Research Activities	6.75	6.75	0.00
XII-R&D-CAT-4.08-0100	Performance Enhancement of Indus -2 with insertion devices and upgradation of various sub-systems	160.00	138.00	22.00
XII-R&D-CAT-4.08-0200	Infrared FEL based beam lines and their applications in Materials research	45.00	43.00	2.00
XII-R&D-CAT-4.08-0300	Enhancement of manufacturing and chemical treatment facilities for accelerator component	35.00	35.00	0.00
XII-R&D-CAT-4.08-0400	R&D activities for high energy proton LINAC based spallation neutron source	130.00	104.00	26.00
XII-R&D-VEC-4.08-0100	Superconducting Linacs for Electrons and Heavy-Ions	113.00	109.00	4.00
XII-R&D-VEC-4.08-0200	Development of Cyclotron Systems	29.00	29.00	0.00
XII-R&D-VEC-4.08-0300	Advanced Superconducting Magnet Development	42.70	39.00	3.70
XII-R&D-VEC-4.08-1300	ANURIB (Advanced National Facility for Unstable and Rare Isotope Beams)	*870.00	165.00	705.00
XII-R&D-CAT-4.09-0100	Development and applications of advanced lasers	72.00	72.00	0.00
XII-R&D-CAT-4.09-0200	High power lasers and laser-plasma interaction in high density and ultra high intensity regime	94.00	87.00	7.00
XII-R&D-CAT-4.09-0300	Development of Optical, Mechanical and Electronic Support Systems	40.00	40.00	0.00
XII-R&D-BAR-4.10-0100	R&D on Advanced Technologies for Special Material Programme	38.00	30.00	8.00

(₹ In Crore)

PIC No	Project Title	Estimated / Sanctioned Cost	XII Plan Outlay	Spill over
XII-R&D-BAR-4.10-0100	Research and Development of Special Materials	69.00	60.00	9.00
XII-R&D-BAR-4.10-0200	Technology Development related to Special Material Project	35.50	28.00	7.50
XII-R&D-BAR-4.10-0300	Creation of Infrastructure facilities for Special material at BARC, Mumbai	55.00	25.00	30.00
XII-R&D-BAR-4.10-0400	By-product Enrichment Facility and Storage	145.00	100.00	45.00
XII-R&D-IGC-4.10-0100	Advances in Materials and Manufacturing Technologies for Elevated Temperature Applications	220.00	220.00	0.00
XII-R&D-BAR-4.11-0100	Development of Cryogenic temperature process systems	46.50	41.50	5.00
XII-R&D-BAR-4.11-0200	Development of Integrated Test Station for Validation of C&I systems and Control Room operating interfaces of NPPs	45.00	45.00	0.00
XII-R&D-BAR-4.11-0300	Development of Advanced Radiation Detectors and Nuclear Instrumentation	104.50	104.50	0.00
XII-R&D-BAR-4.11-0400	Development of medical and Imaging instruments	13.50	13.50	0.00
XII-R&D-BAR-4.11-0500	Advanced Technologies for Control & Instrumentation	40.00	40.00	0.00
XII-R&D-BAR-4.11-0600	LIS Technologies	86.00	68.00	18.00
XII-R&D-BAR-4.11-0700	Establishing Technologies and Design for Electron Accelerators	120.00	80.00	40.00
XII-R&D-BAR-4.11-0800	Components & Systems Development for Lasers, Plasmas and Electron Beam Technologies	70.00	60.00	10.00
XII-R&D-BAR-4.11-0900	Upgradation of Manufacturing Facilities and Development of Special Purpose Hexapods	58.00	46.00	12.00
XII-R&D-BAR-4.11-1000	Advanced Rear End Development Facilities for Electronics and Instrumentation	259.00	259.00	0.00
XII-R&D-IGC-4.11-0100	Development of advanced digital instrumentation	15.00	15.00	0.00
XII-R&D-IGC-4.11-0200	Development of Computer based I&C systems for FBR and reprocessing plant	40.00	38.00	2.00
XII-R&D-VEC-4.11-0700	Development of He-liquefier of capacity 50 l/hr	14.50	14.50	0.00
XII-R&D-BAR-4.12-0100	Technology Development for Special Products	40.00	36.00	4.00
XII-R&D-BAR-4.12-0200	Special Facilities & Equipments	418.00	275.00	143.00
	Total	5166.95	2948.75	2218.20

MAJOR PROGRAMME - 4B - RADIATION TECHNOLOGIES AND THEIR APPLICATIONS

(₹ in Crore)

PIC No	Project Title	Estimated / Sanctioned Cost	XII Plan Outlay	Spill over
XII-R&D-BAR-4.02-0100	Technology Development and Applications of Isotopes	46.00	46.00	0.00
XII-R&D-BAR-4.03-0100	Nuclear agriculture for sustainability and societal benefits	25.00	25.00	0.00
XII-R&D-BAR-4.04-0100	Developing Novel Applications of Radiation Technology for Value Addition to Food & Agro Commodities	14.00	14.00	0.00
XII-R&D-BAR-4.05-0100	Expansion & Strengthening of Health Care Services in BARC & Nuclear Medicine Programme	153.00	80.00	73.00
XII-R&D-IGC-4.05-0100	Enhancement of medical facilities at Anupuram and Kalpakkam hospitals	40.00	40.00	0.00
XII-R&D-TMC-4.05.0100	Advanced Facilities for Diagnostics and Services	256.50	256.50	0.00
XII-R&D-TMC-4.05-0200	Establishment of Cancer Hospital at Vizag	400.93	400.93	0.00
XII-R&D-TMC-4.05-0300	Advanced Facilities for Cancer Research and Nuclear Medicine	246.60	246.60	0.00
XII-R&D-TMC-4.05-0400	National Cancer Grid - Upgradation of Major Nodes	112.00	112.00	0.00
XII-R&D-TMC-4.05-0500	National Facility for Hadron Beam Therapy	400.00	400.00	0.00
XII-R&D-TMC-4.05-0600	Women and Children Cancer Wing	38.00	38.00	0.00
XII-R&D-VEC-4.05-1100	Upgradation of RRMC facility and radiopharmaceutical research	4.50	4.50	0.00
XII-R&D-BAR-4.06-0100	Development & Application of Membrane Technology	24.00	24.00	0.00
XII-R&D-CAT-4.07-0100	Electron accelerator-based agricultural and industrial radiation processing facilities	28.00	26.00	2.00
	Total	1788.53	1713.53	75.00

MAJOR PROGRAMME - 5 – BASIC RESEARCH

(₹ In Crore)

PIC No	Project Title	Estimated / Sanctioned Cost	XII Plan Outlay	Spill over
XII-R&D-BAR-5.01-0100	Development and Deployment of new Secure Computing, Communication and Information Systems	170.00	140.00	30.00
XII-R&D-HRI-5.01-0100	Special and Thematic Events in Mathematics	6.17	5.69	0.48
XII-R&D-IMS-5.01-0100	Thrust areas in pure and applied mathematics	18.76	18.76	0.00
XII-R&D-IMS-5.01-0200	Computational networking facilities and SETS-IMSc cryptology project	23.55	23.55	0.00
XII-R&D-IOP-5.01-0100	Development of Computing and Network Facilities	20.50	20.50	0.00
XII-R&D-NIS-5.01-0100	Centre for fundamental studies (CFS)	6.85	6.85	0.00
XII-R&D-CAT-5.01-0100	Development and deployment of computer, communication and information system	39.00	35.40	3.60
XII-R&D-SIN-5.01-0101	Centre for Computational Sciences (CCS)	33.00	33.00	0.00
XII-R&D-SIN-5.01-0102	SINP-IMSc & ISI - Econophysics Initiative	1.00	1.00	0.00
XII-R&D-TFR-5.01-0500	Mathematics and Computer Science	57.60	57.60	0.00
XII-R&D-BAR-5.02-0100	Astrophysics and Accelerator based Research in Physical Sciences	44.50	40.00	4.50
XII-R&D-BAR-5.02-0200	Physics of Materials	70.00	60.00	10.00
XII-R&D-BAR-5.02-0300	Physics with Neutrons and Neutron & X-Ray Based Techniques	51.50	41.50	10.00
XII-R&D-BAR-5.02-0400	Physics of Devices and Indigenous Development of Instrumentation	65.00	50.00	15.00
XII-R&D-HRI-5.02-0100	Advanced Research Facility for Theoretical Physics	41.96	38.03	3.93
XII-R&D-HRI-5.02-0200	RECAPP, Neutrino, Higher Energy Astro Physics and Cosmology	11.84	9.96	1.88
XII-R&D-IGC-5.02-0100	Exploration of novel material properties: Science and Applications	45.00	45.00	0.00
XII-R&D-IGC-5.02-0200	Utilization of physical, chemical and engineering facilities at UGC-DAE CSR, Kalpakkam	30.00	30.00	0.00
XII-R&D-IMS-5.02-0100	Thrust areas in theoretical physics	7.05	7.05	0.00
XII-R&D-IMS-5.02-0200	Science and Information: Interdisciplinary Approaches	18.51	18.51	0.00
XII-R&D-IOP-5.02-03	Development of Research in High Energy Physics	4.00	4.00	0.00
XII-R&D-IOP-5.02-01	Research programme in Theoretical Condensed Matter and Quantum Information	4.50	4.50	0.00
XII-R&D-IOP-5.02-04	Development of Research programme in Nuclear physics	1.52	1.52	0.00
XII-R&D-NIS-5.02-02	Experimental condensed matter ultra cold atoms and laser Physics	23.84	23.84	0.00
XII-R&D-NIS-5.02-01	Theoretical high energy and condensed matter Physics	7.95	7.95	0.00
XII-R&D-SIN-5.02-0101	Centre for Astroparticle Physics - II (CAPP-II)	9.00	8.00	1.00
XII-R&D-SIN-5.02-0102	Research In Atomic and Applied Nuclear Sciences (RAANS)	15.00	10.00	5.00
XII-R&D-SIN-5.02-0103	A Facility for Research in Experimental Nuclear Astrophysics (FRENA)	45.00	40.00	5.00
XII-R&D-SIN-5.02-0104	High Energy Nuclear and Particle Physics (HENPP)	50.00	40.00	10.00
XII-R&D-SIN-5.02-0105	Theoretical Physics Across energy Scales (TPAES)	18.00	18.00	0.00
XII-R&D-TFR-5.02-0200	Physics and Astronomy	153.30	146.00	7.30
XII-R&D-TFR-5.02-0300	Inter Institutional Programmes	216.00	214.00	2.00
XII-R&D-TFR-5.02-0700	Radio Astronomy	120.00	120.00	0.00

(₹ In crore)

PIC No	Project Title	Estimated / Sanctioned Cost	XII Plan Outlay	Spill over
XII-R&D-VEC-5.02-0500	Centre for nuclear theory	64.00	10.00	54.00
XII-R&D-VEC-5.02-0600	Detector development for Higher Energy Physics Research	40.71	30.71	10.00
XII-R&D-BAR-5.03-0100	Chemistry of materials for energy, environment and health	59.00	59.00	0.00
XII-R&D-BAR-5.03-0200	Basic and Applied Research in Chemistry	89.00	89.00	0.00
XII-R&D-DAE-5.03-0100	India based Neutrino Observatory (INO)	*1500.00	750.00	750.00
XII-R&D-IGC-5.03-0100	Augmentation of facilities for basic research and analytical services	6.50	6.50	0.00
XII-R&D-NIS-5.03-02	Novel organic compounds for biomedical and industrial applications	19.00	19.00	0.00
XII-R&D-NIS-5.03-01	Advance materials for different applications and theoretical studies	14.00	14.00	0.00
XII-R&D-SINP-5.03-0100	Trace, Ultratrace Analysis and Isotope Production (TULIP)	12.00	10.00	2.00
XII-R&D-BAR-5.04-0100	Molecular and Cellular Radiation Biology of Model Organisms and Human Population	72.50	60.00	12.50
XII-R&D-IOP-5.04-0100	Transport in Biological Membranes and Nanoscale Structures	3.80	3.80	0.00
XII-R&D-NIS-5.04-03	Outreach programmes in mathematics and systems biology	0.50	0.50	0.00
XII-R&D-NIS-5.04-02	Microbes Immunity and research biology	17.00	17.00	0.00
XII-R&D-NIS-5.04-01	Basic Research in cellular and molecular biology	18.00	18.00	0.00
XII-R&D-SIN-5.04-0101	Integrative Biology on Omics Platform (IBOP)	28.00	28.00	0.00
XII-R&D-SIN-5.04-0102	Molecular and Structural Aspects Cellular Regulatory Processes (MSACR)	22.00	22.00	0.00
XII-R&D-SIN-5.04-0103	Biomolecular Assembly, Recognition and Dynamics (BARD)	35.00	35.00	0.00
XII-R&D-TFR-5.04-0800	NCBS I: Understanding the Natural World	210.00	170.00	40.00
XII-R&D-TFR-5.04-0900	NCBS II:For the common Good (Infrastructure Services)	210.00	170.00	40.00
XII-R&D-BAR-5.06-0100	Synchrotron Radiation Based Physics Research	60.00	50.00	10.00
XII-R&D-CAT-5.06-0100	Enhancement of Indus synchrotron user facility	117.00	113.00	4.00
XII-R&D-VEC-5.07-0400	Advanced Experimental Nuclear Physics Research	56.00	51.00	5.00
XII-R&D-SIN-5.08-0101	Physics and Technology of Plasma (PTP)	11.00	11.00	0.00
XII-R&D-BAR-5.09-0100	Development of New Alloys	60.00	45.00	15.00
XII-R&D-IGC-5.09-0100	Advanced facilities for ferrofluids/ nanofluids development for fundamental understanding and applications	7.90	7.90	0.00
XII-R&D-IGC-5.09-0200	Materials research using ion beams and Computers	74.00	74.00	0.00
XII-R&D-IGC-5.09-0300	Nanomaterials to nanostructures for improved coatings and sensors	74.00	74.00	0.00
XII-R&D-IOP-5.09-0100	Study of Growth and Characterization of Advanced Materials	20.00	20.00	0.00
XII-R&D-CAT-5.09-0101	Research and development of laser materials, photonic nanomaterials and laser processing materials	55.00	55.00	0.00
XII-R&D-SIN-5.09-0101	Condensed Matter Physics: Interactions and Dynamics (CMPID)	40.00	40.00	0.00
XII-R&D-SIN-5.09-0102	Centre for Nanoscience and Surface Physics- Phase II (CENSUP-II)	45.00	45.00	0.00

(₹ In Crore)

PIC No	Project Title	Estimated / Sanctioned Cost	XII Plan Outlay	Spill over
XII-R&D-SIN-5.09-0103	Materials and Structures for Advanced Applications (MASTAAP)	15.00	15.00	0.00
XII-R&D-VEC-5.09-0800	Studies of multifunctional nanostructured materials	9.50	9.50	0.00
XII-R&D-NIS-5.10-0100	Centre for inter-disciplinary sciences (CIS)	35.50	35.50	0.00
XII-R&D-TFR-5.10-0100	Biology, Chemistry and Physics of Materials	234.40	234.40	0.00
XII-R&D-TFR-5.10-1100	Programmes in Theoretical and Mathematical Sciences	80.00	80.00	0.00
XII-R&D-TFR-5.10-1400	R&D Proposal for TIFR Hyderabad	600.00	547.00	53.00
XII-R&D-DAE-5.11-0100	Participation in International Collaborations	5.00	5.00	0.00
XII-R&D-IOP-5.11-0100	ALICE Utilization and CBM Participation	8.50	4.50	4.00
XII-R&D-IPR-5.11- 0100	Participation in Other Large Tokamak Experiments	145.00	145.00	0.00
XII-R&D-NIS-5.11-03	Study of standard and beyond standard model theories and detector R&D for the CMS experiment at LHC CERN	6.29	6.29	0.00
XII-R&D-CAT-5.10-0100	Biomedical and societal applications of lasers and laser based instruments	45.00	45.00	0.00
XII-R&D-CAT-5.11-0100	International collaboration in CERN accelerator projects	12.00	9.00	3.00
XII-R&D-TFR-5.11-0400	International Collaborations	52.40	45.90	6.50
XII-R&D-VEC-5.11-1000	ALICE upgrade, operation and utilization	23.00	19.00	4.00
	Total	5742.40	4619.71	1122.69

MAJOR PROGRAMME - 6 : RESEARCH EDUCATION LINKAGE

(₹ In Crore)

PIC No	Project Title	Estimated / Sanctioned Cost	XII Plan Outlay	Spill over
XII-R&D-AEE-6.01-0101	Excellence in Education and Societal Outcomes	25.00	25.00	0.00
XII-R&D-AEE-6.01-0102	Providing Laboratory Items and Furniture and Upgradation	20.00	20.00	0.00
XII-R&D-BAR-6.01-0100	Enhancement of Digital Knowledge Resources and Human Resource Development	69.00	64.00	5.00
XII-R&D-DAE-6.01-0100	Expansion of DAE Outreach and perception management	160.00	160.00	0.00
XII-R&D-DAE-6.01-0200	Development of GCNEP	494.00	382.00	112.00
XII-R&D-GIA-6.01-0100	Exhibitions	10.00	10.00	0.00
XII-R&D-GIA-6.01-0200	NBHM	250.00	250.00	0.00
XII-R&D-GIA-6.01-0300	Fellowships / Scholarships	58.00	58.00	0.00
XII-R&D-GIA-6.01-0400	Symposia	20.00	20.00	0.00
XII-R&D-GIA-6.01-0500	Public Awareness and Neighbourhood Welfare Programme	5.00	5.00	0.00
XII-R&D-GIA-6.01-0600	ER Programmes	0.50	0.50	0.00
XII-R&D-GIA-6.01-0700	Management Development	1.00	1.00	0.00
XII-R&D-GIA-6.01-0800	HBNI	32.00	32.00	0.00
XII-R&D-GIA-6.01-0900	Collaboration with Academic Institutions	180.00	180.00	0.00
XII-R&D-HRI-6.01-0100	Scientific information retrieval development	6.18	5.74	0.44
XII-R&D-NIS-6.01-0100	AEES school at NISER campus	1.58	1.58	0.00
XII-R&D-NIS-6.01-0100	Expansion of academic facility in NISER (library teaching lab instruments)	21.00	21.00	0.00
XII-R&D-SIN-6.01-0101	Centre for Advanced Research and Education - Phase III (CARE-III)	9.00	9.00	0.00
XII-R&D-SIN-6.01-0102	Library Digitization and Resource Management (LDRM)	9.00	9.00	0.00
XII-R&D-GIA-6.02-0100	BRNS	450.00	450.00	0.00
XII-R&D-GIA-6.02-0200	Misc. R&D Schemes	10.00	10.00	0.00
XII-R&D-GIA-6.02-0300	Assistance to RMC and Cancer Hospitals	60.00	60.00	0.00
XII-R&D-GIA-6.03-0100	Prospective Research Funding	50.00	50.00	0.00
XII-R&D-TFR-6.04-0600	Science Education Programme	26.00	26.00	0.00
XII-R&D-DAE-6.05.0100	DAE Integrated Information Systems Applications	50.00	50.00	0.00
XII-R&D-DAE-6.05.0200	Multi tier ultra high speed Anunet Network	30.00	25.00	5.00
XII-R&D-DAE-6.05.0300	Upgradation of WLCG System	30.00	30.00	0.00
XII-R&D-IGC-6.05-0100	Semantic digital library	19.30	19.30	0.00
	Total	2096.56	1974.12	122.44

MAJOR PROGRAMME - 7A: INFRASTRUCTURE

(₹ In Crore)

PIC No	Project Title	Estimated / Sanctioned Cost	XII Plan Outlay	Spill over
XII-R&D-AEE-7.01-0101	Strengthening and Renovating the Existing Infrastructure	55.00	55.00	0.00
XII-R&D-AEE-7.01-0102	Strengthening and Renovating the Existing sports Infrastructure	50.00	50.00	0.00
XII-R&D-AMD-7.01-0100	Construction of office complex (phase-II) at southern region, B'lore	6.50	6.50	0.00
XII-R&D-AMD-7.01-0200	Upgradation of infrastructural facilities, renovation of office cum laboratory complexes and residential quarters at AMD...	20.00	20.00	0.00
XII-R&D-BAR-7.01-0100	Infrastructure / Upgradation of civil engineering services	185.00	140.00	45.00
XII-R&D-BAR-7.01-0200	Upgradation of Electrical Utility Services in BARC	106.00	70.00	36.00
XII-R&D-BAR-7.01-0300	Upgradation of Mechanical & Other Utility Services in BARC	125.00	87.00	38.00
XII-R&D-BAR-7.01-0400	Construction of Engineering Halls, Field lab and Security Infrastructure at BARC, Visakhapatnam	212.00	212.00	0.00
XII-R&D-BAR-7.01-0500	Construction of Computer Centre building and other Infrastructure facilities at BARC, Visakhapatnam	280.00	100.00	180.00
XII-R&D-BAR-7.01-0600	Construction of Township at BARC, Visakhapatnam	205.00	205.00	0.00
XII-R&D-DAE-7.01-0100	Development of an Inter-University Science Centre in A'nagar	17.00	17.00	0.00
XII-R&D-DEM-7.01-0100	Upgradaton of Water Supply & Sewage System of DAE Colony Under DCSE	37.91	37.91	0.00
XII-R&D-DEM-7.01-0200	Upgradation of External Engineering Services in DAE Colony Under DCSE	36.25	36.25	0.00
XII-R&D-DEM-7.01-0300	New Infrastructure Development at Anushaktinagar	55.00	15.00	40.00
XII-R&D-DEM-7.01-0400	Restoration / Renovation of Old Houses More than 20 Years Phase-II	280.00	180.00	100.00
XII-R&D-DEM-7.01-0500	Infrastructure for Improvement of Security System of DAE Premises under DCSE	15.00	15.00	0.00
XII-R&D-GSO-7.01-0100	Construction of Public Buildings, other Infrastructure, Augmentation of Existing Infrastructure at Anupuram	55.00	24.50	30.50
XII-R&D-GSO-7.01-0200	Construction of Buildings and Augmentation of Infrastructure at Kalpakkam	101.50	33.50	68.00
XII-R&D-GSO-7.01-0300	Infrastructure of Electrical and Mechanical System at Kalpakkam and Anupuram	34.00	27.90	6.10
XII-R&D-HRI-7.01-0100	Expansion of HRI campus - purchase of additional land	3.00	3.00	0.00
XII-R&D-HRI-7.01-0200	Infrastructure development	4.56	4.56	0.00
XII-R&D-IGC-7.01-0100	Refurbishment and establishment of Air-conditioning and ventilation infrastructure at IGCAR	20.00	15.00	5.00
XII-R&D-IGC-7.01-0200	Refurbishment and infrastructure development of electrical and communication system at IGCAR	64.50	25.00	39.50
XII-R&D-IGC-7.01-0300	Development of Infrastructure and improvement to facilities within IGCAR, on the western side of DAE Plant site and Edaiyur area	60.67	55.67	5.00
XII-R&D-IMS-7.01-0100	Augmentation of Infrastructural facility	65.00	65.00	0.00
XII-R&D-IMS-7.01-0200	Library facilities Upgradation & Procurement of Online Archives	4.00	4.00	0.00
XII-R&D-IPR-7.01-0100	DPR for New Campus & Site Infrastructure	25.00	25.00	0.00
XII-R&D-IPR-7.01-0200	Infrastructure for IPR & CPP-IPR	120.00	100.00	20.00
XII-R&D-NIS-7.01-0100	NISER infrastructure	125.75	125.75	0.00
XII-R&D-CAT-7.01-0100	Infrastructure development-Phase VI	60.00	60.00	0.00
XII-R&D-CAT-7.01-0200	Technical Infrastructure	30.00	30.00	0.00
XII-R&D-TFR-7.01-0100	Civil Projects in TIFR Hyderabad Campus	1560.00	523.40	1036.6
XII-R&D-TFR-7.01-0200	Upgradation of Common Facilities	215.00	195.00	20.00
XII-R&D-VEC-7.01-1200	Infrastructure development at various campus of VECC	110.00	110.00	0.00
	Total	4343.64	2673.94	1669.7

MAJOR PROGRAMME - 7B: HOUSING

(₹ In Crore)

PIC No	Project Title	Estimated / Sanctioned Cost	XII Plan Outlay	Spill over
XII-R&D-DEM-7.02-0100	Construction of 500 Flats of Type-V(E)	282.40	200.00	82.40
XII-R&D-GSO-7.02-0100	Construction of Housing for IGCAR at Anupuram	202.10	57.40	144.70
XII-R&D-GSO-7.02-0200	Construction of Housing for BARCF at Anupuram	249.40	170.70	78.70
XII-R&D-HRI-7.01-0100	Infrastructure (housing)	3.85	3.85	0.00
XII-R&D-IOP-7.02-0100	Construction of Additional Housing, Hostels & related infrastructure at IOP campus, Bhubaneswar.	17.70	17.70	0.00
XII-R&D-CAT-7.02-0100	Housing	13.00	13.00	0.00
XII-R&D-TFR-7.02-1300	Housing	100.00	50.00	50.00
XII-R&D-TMC-7.02.0100	Housing for Patients and Residents Compliance	80.00	80.00	0.00
	Total	948.45	592.65	355.80
	Grand Total of New Schemes	24212.45	17713.72	6498.73

*Mega Science Project (Cost to be shared by DAE and DST)

CHAPTER 5
IMPLEMENTATION ASPECTS OF THE DAE'S XII PLAN PROPOSALS

5.1 General Guidelines

As part of XII Plan, a large number of activities are being pursued in DAE and through an approach based on multi-disciplinary task force, may disciplines in a given activity have been successfully integrated. DAE units are moving towards realizing most of the goals set for the XI plan and the Department is on the steep take-off. The share of electricity from the nuclear power programme is set to increase to 10 GWe by the end of XII-plan period, from the existing 4.78 GWe installed capacity which is nearly a two-fold increase. This puts a tall demand on the various aspects of fuel cycle. While formulating the XII plan, efforts have been made to take up projects within the mandate of the Department. The thrust is on development of domestic technologies, identify and bridge all the gap areas in technologies required for sustaining the nuclear power programme and work for accelerated growth of the programme. .

As started in the XI-plan, activities of the Department have been grouped into twenty themes. Specialist Groups have been formed for each of these themes. These specialist groups reviewed proposals from across the units in terms of scientific content of the proposal, identified overlap and suggested filling the gaps in the programmes etc. Every scheme has been examined for relevance, technical feasibility, economic viability and the availability of additional space for setting up of new facilities, including analysis on the principles of Zero Based Budgeting. When finally sanctioned, every proposal would have been examined at the level of Governing Councils of the various Units, in their respective specialist groups, IWG for R&D Sector of DAE, and finally at the level of Atomic Energy Commission. Continuing schemes have been periodically assessed for their progress by the specialist groups in accordance with the guidelines set for project monitoring, and also by the respective Units based on the report of the SGs. It was decided to foreclose some of the delayed projects.

In addition to the guidelines provided by the Planning Commission, the following general points have been kept in perspective by the Department while formulating the plan proposals.

(a) The three stage power programme formulated by the Department has stood the test of time. DAE has built up a formidable base in the past and general expectation for the Department to deliver 20,000 (MWe), to speed up further development of fast reactor programme in the industrial domain and take up suitable measures to ensure efficient thorium utilization programme.

(b) Extramural funding through BRNS and NBHM has been very successful. This has helped in utilization of expertise available outside the Department and in development of scientific manpower for the country. To move further, the upcoming campus at Visakhapatnam will be pursuing the activities of HBNI increasing intake of Ph.D. students by increasing number of DAE fellowships is planned. HBNI has signed MoUs with several Indian academic institutes and with some institutes abroad for academic collaboration. The Global Centre for Nuclear Energy Partnership coming up in Haryana is another important initiative of DAE to strengthen research-education linkage.

(c) Prospective Research Funds created for Departmental personnel for research complementary to the major projects, has proved to be quite successful, it is proposed to continue this scheme in the XII-plan. This would be available

on competitive basis and would be operated on lines similar to BRNS.

(d) Duplication of research work by different groups within the Department is avoided as they get referred to the same specialist group by design. However, parallel pursuit of same goal using different approaches is encouraged as it is recognized that not all the laboratory-scale technologies may be adaptable for industrial scale applications, and it is important to have alternate technologies available in hand.

(e) Meticulous project planning, including phasing of the technical milestones and utilization of funds, planning manpower during project execution and O&M stage etc. is ensured by way of taking the Detailed Project Report (DPR) from every project coordinator. Provision for midcourse correction is provided particularly to incorporate new ideas, new developments in science and technology and participation of newer groups.

(f) Estimates of the budget and time schedule should take into account realistic implementation rate consistent with the available infrastructural resources. For manpower, by and large rely mainly on redeployment for new programmes.

(g) In case of International collaborations elaborate MoUs or / and agreements covering roles, responsibilities, financial commitments as well as share of intellectual property rights resulting from collaborative research are formulated before the release of grant.

5.2 Monitoring and Follow-up

The SGs and the Internal Working Group formed for the formulation of XII Plan proposal, is also responsible for review and monitoring of these projects throughout the XII plan period. The SGs will hold periodic review to ensure that objectives of every project are realized in the time frame envisaged in the plan documents.

Monitoring of the projects would be done at three levels. First two levels would be done within the concerned unit itself at the Group / faculty level, followed by the next higher level of managements that is by respective councils. The third level would be at the DAE-level, in which the review will be carried out by the specialist group along with IWG R&D sector.

For the purpose of monitoring, projects would be classified into three groups based on the cost as 1) Less than ₹75 Crore, 2) ₹75-300 Crores and 3) More than ₹300 Crores. In case of projects that are of value above ₹75 crores, the progress is reviewed at least once in a year by the specialist group, while those that are of value less than ₹75 crores could be reviewed once in two years, and the report is communicated to IWG.

The SGs will also examine the requirement of any midcourse corrections in the scientific contents of the programmes and attempt to integrate the activities of a given programme across various units of the DAE. Wherever possible, the groups will b interacting with other institutions and national laboratories in the country for the implementation of the XII plan projects.

CHAPTER 6
FINANCIAL OUTLAY OF XII PLAN PROPOSALS

The total outlay provided for XI Plan after the Mid Term Appraisal is ₹10128.69 crore (original outlay during the XI Five Year Plan was (₹11000 Crore). As against this, the actual expenditure up to March 2011 is ₹5719.09 and the estimated expenditure up to the end of XI Plan (March 2012) is ₹8446.09 crore.

For the XII Plan, outlay of ₹23902.69 crore is proposed, which includes a provision of ₹6188.97 crore for the continuing schemes. It may be noted that of the 138 continuing schemes, 96 schemes are expected to be completed in the first two years of the XII plan period, amounting to ₹1917.17 crore. The New Schemes proposed for DAE during XII Plan cost ₹24212.45 crore of which outlay under XII Plan would be ₹17713.72 crore with a spill over component of ₹6498.73 crore. These requirements have been projected after a critical review by the Specialist Groups / Internal Working Group constituted in the Department.

Unit wise distribution of proposed outlay is given in the Table-1. Table-2 and Fig-1 show the unit-wise outlay for XI and XII Plan. Fig-2 shows the unit-wise distribution of XII plan outlay for continuing and new schemes, which includes the funding through Grant-in-aid mechanism. Major Programme wise outlay is shown in Fig-2.

Table-1 Unit wise Outlay

XII PLAN OUTLAY (₹ in Crores)

Sl. No.	Unit	Continuing Schemes	New Schemes	Total	Spill over
1	AEES	0.00	150.00	150.00	0.00
2	AMD	162.71	439.17	601.88	21.30
3	BARC	2725.00	4733.00	7458.00	2584.00
4	RRCAT	232.74	905.40	1138.14	69.60
5	DAE	167.78	1425.00	1592.78	867.00
6	DCS&EM	416.38	484.16	900.54	222.40
7	Grant in Aid	49.00	1126.50	1175.5	0.00
8	GSO	0	314.00	314.00	328.00
9	HRI	31.10	70.83	101.93	6.73
10	IGCAR	312.48	1632.72	1945.20	122.60
11	IMSc	8.70	136.87	145.57	0.00
12	IoP	0.00	83.27	83.27	4.00
13	IPR + ITER	1167.00	820.00	1987.00	209.00
14	NISER	425.31	297.26	722.57	0.00
15	SINP	63.45	374.00	437.45	23.00
16	TIFR	161.60	2579.30	2740.90	1255.40
17	TMC	26.98	1534.03	1561.01	0.00
18	VECC	238.74	608.21	846.95	785.70
	Total	6188.97	17713.72	23902.69	6498.73

Table -2 : Unit wise Outlay (XI & XII Plan)

₹ in Crores

No.	Unit	XI Plan (MTA)	XII Plan Outlay
1	AEES	103.10	150.00
2	AMD	442.82	601.88
3	BARC	3300.00	7458.00
4	RRCAT	506.86	1138.14
5	DAE	47.71	1592.78
6	DCS&EM	281.32	900.54
7	Grant in Aid	710.98	1175.5
8	GSO	0.00	314.00
9	HRI	58.26	101.93
10	IGCAR	829.43	1945.20
11	IMSc	66.23	145.57
12	IoP	55.80	83.27
13	IPR + ITER	1259.64	1987.00
14	NISER	350.00	722.57
15	SINP	332.52	437.45
16	TIFR	1035.35	2740.90
17	TMC	351.86	1561.01
18	VECC	396.81	846.95
	Total	10128.69	23902.69

Fig-1 : Unit wise Outlay (XI & XII Plan)

Fig-2 : Unit wise Outlay

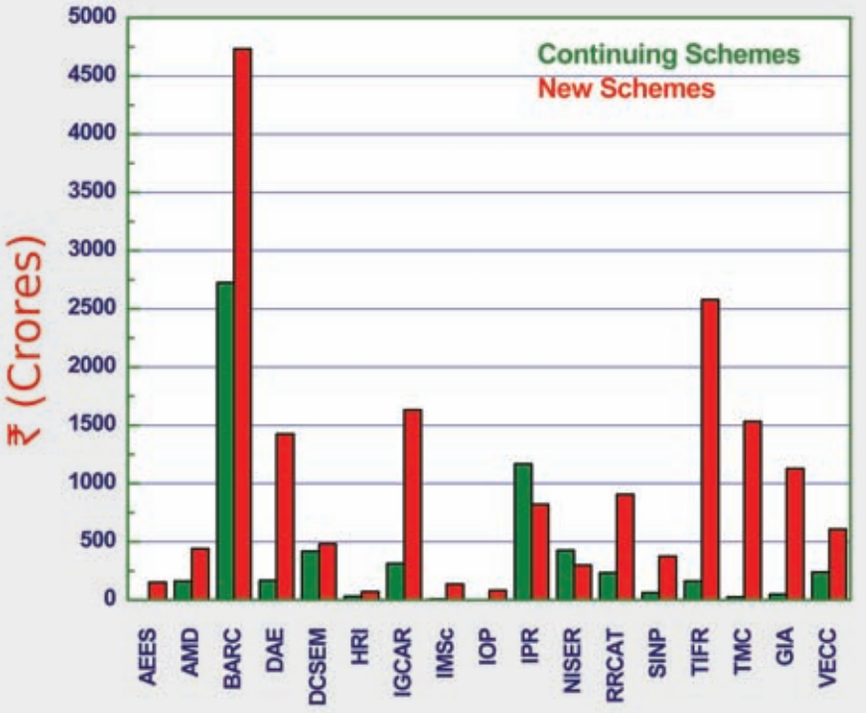
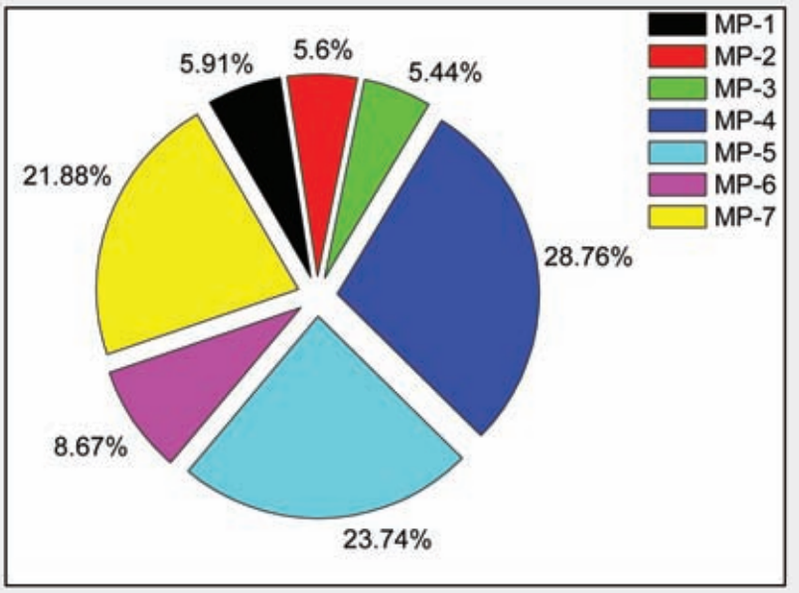
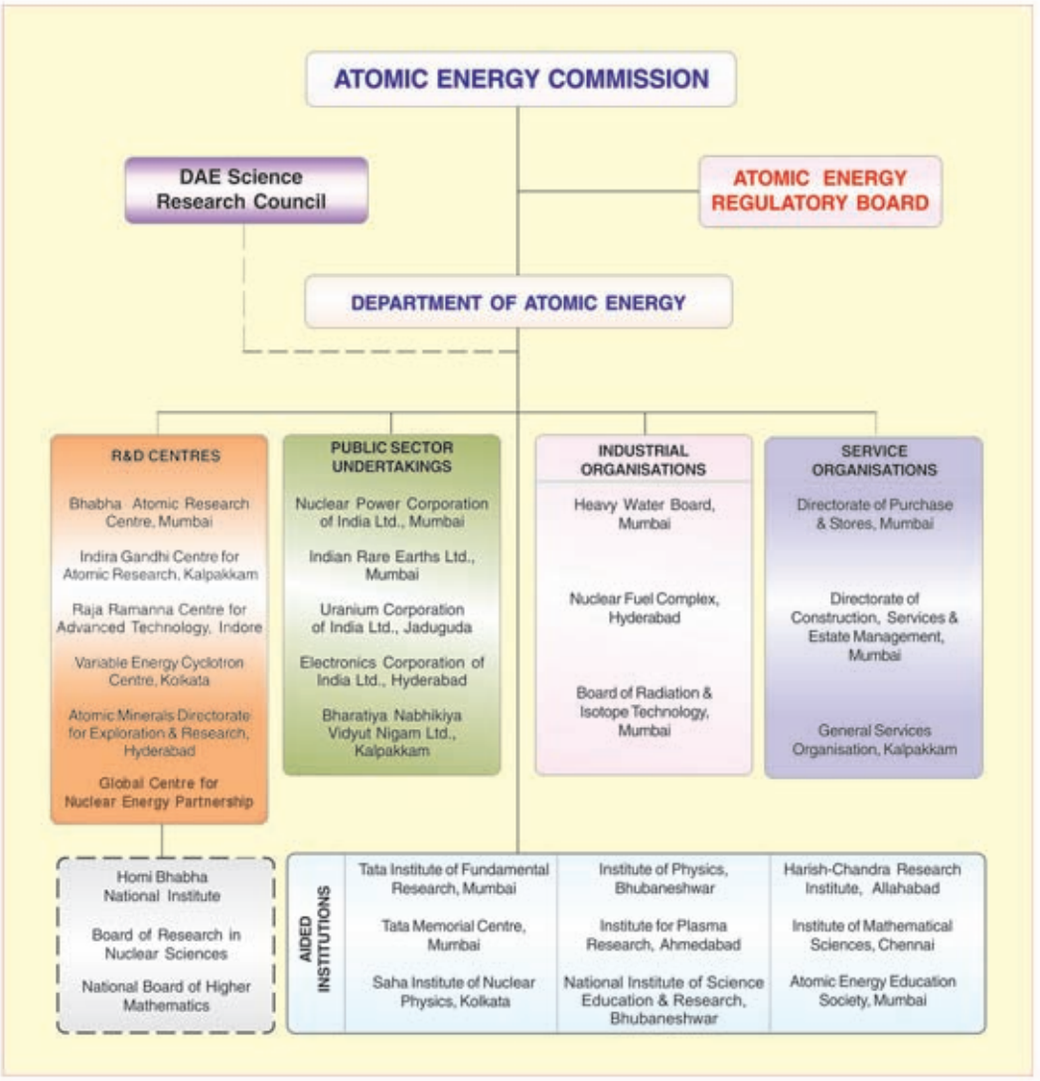


Fig-3 Major Programme Wise Break-up



ANNEXURES

ANNEXURE - 1
ORGANISATIONAL STRUCTURE OF DAE



ANNEXURE - 2
CONSTITUTION OF WORKING GROUP

R.K. Gupta
Joint Adviser (S&T),
Telefax: 011-23096528
Email: rkgupta-pc@nic.in

भारत सरकार
योजना आयोग
योजना भवन
नई दिल्ली–११०००१

GOVERNMENT OF INDIA
PLANNING COMMISSION
YOJANA BHAWAN
NEW DELHI-110001

DO No. 12016/3/2011-S&T

Dated 20.04.2011

Respected Sir,

The Steering Committee on Science and Technology for the formulation of Eleventh Five Year Plan in its first meeting held on 5th April, 2011 decided to constitute a number of Working Groups and Task Forces to comprehensively address various tasks assigned to the Steering Committee. It has been decided to constitute a **'Working Group of the Department of Atomic Energy (R&D Sector)'** under your Chairmanship with Shri S. Gangotra, Member, SPG, DAE as Member Secretary. A copy of the Office Memorandum in this regard is enclosed.

Keeping in view that the task before the Steering Committee is very vast, which needs to be completed in a limited time frame, it has been decided that the Working Groups may submit their report to the Steering Committee by 15th July, 2011. Planning Commission therefore solicits your active support and leadership in ensuring that the task is accomplished in the stipulated time frame.

With kind regards.

Yours sincerely,

(R.K. Gupta)

To

Dr. Sri Kumar Banerjee,
Secretary,
Department of Atomic Energy,
Anushakti Bhawan,
CSM Marg,
Mumbai-400001

Copy to:

Shri S. Gangotra, Member, Strategic Planning Group, Department of Atomic Energy, Anushakti Bhawan, CSM Marg, Mumbai-400001.

You are requested to kindly inform all the Members of the Working Group and take necessary follow up action in consultation with the Chairman.

(R.K. Gupta)

No. 12016/3/2011-S&T
Government of India
Planning Commission
Science and Technology Division

Yojana Bhawan,
Sanasd Marg,
New Delhi-110001

Dated 18.04.2011

OFFICE MEMORANDUM

Subject: WG-13: Constitution of Working Group of the Department of Atomic Energy (R&D Sector)

The Steering Committee on Science and Technology for the formulation of Twelfth Five Year Plan, during its first meeting held on 5th April, 2011 under the Chairmanship of Dr. K. Kasturirangan, Member (Science). Planning Commission has decided to constitute a Working Group for the Department of Atomic Energy (R&D Sector). The composition and Terms of Reference of the Working group are as under:

COMPOSITION

S.No.	Name & Designation	
1.	Dr. Srikumar Banerjee, Secretary, Dept. of Atomic Energy, Mumbai	**Chairman**
2.	Dr. R.K. Sinha, Director, Bhabha Atomic Research Centre, Mumbai	Member
3.	Shri S.S. Bajaj, Chairman, Atomic Energy Regulatory Board, Niyamak Bhavan, Mumbai	Member
4.	Chairman, Board of Research in Nuclear Sciences, Dept.of Atomic Energy, Mumbai	Member
5.	Director UGC – DAE Consortium for Scientific Research, University Branch, Indore	Member
6.	Prof. M.S. Ananth, Director, Indian Institute of Technology, Madras, Chennai	Member
7.	Dr R.B. Grover, Principal Adviser, Department of Atomic Energy, Mumbai	Member
8.	Prof. Devang Khakhar, Director, Indian Institute of Technology, Bombay, Mumbai	Member
9.	Prof. G.D. Yadav, Director, Institute of Chemical Technology, Bombay, Mumbai	Member
10.	Director, Indira Gandhi Centre for Atomic Research, Kalpakkam	Member
11.	Director, Tata Memorial Centre, Mumbai	Member
12.	Director, Tata Institute of Fundamental Research, Mumbai	Member
13.	Director, Raja Ramanna Centre for Advanced Technology, Indore	Member

14.	Director, Variable Energy Cyclotron Centre (VECC), Kolkata	Member
15.	Joint Secretary (R&D), Department of Atomic Energy, Mumbai	Member
16	Shri A.K. Verma, Adviser (S&T), Planning Commission or his Nominee	Member
17.	Representative, Dept. of Science & Technology	Member
18.	Representative, Min. of Information & Technology	Member
19.	Representative of ICMR	Member
20.	Representative of CSIR	Member
21.	Representative of UGC	Member
22.	Shri S. Gangotra, Member, Strategic Planning Group, Department of Atomic Energy, Mumbai	**Member Secretary**

Terms of Reference

1. To review and assess the performance and role of the Department at the end of the Eleventh Five Year Plan. Identify priorities of the Department for the Twelfth Five Year Plan and suggest measures including policy initiatives for enabling India to emerge as a major global technological power by 2025
2. To suggest plan programmes for the Department (R&D Sector) by adopting a ZBB approach and keeping in view the priorities and goals for the Twelfth Five Year Plan as well as the agenda for the Decade of Innovations during 2010-20.
3. To define deliverables as well as goals for the Department for the Twelfth Five Year Plan period as well as Annual Plans, both in terms of tangible and non-tangible outputs and formulate guidelines for deployment of resources for relating inputs to the specified goals
4. To suggest an optimum outlay for the Department, comprising of the on-going commitment and new programmes proposed to be undertaken.
5. The Chairman may co-opt any other member.
6. The expenditure towards TA/DA in connection with the meetings of this Working Group in respect of Official Members would be borne by their respective Ministries/Departments. In respect of Non-Official Members, the expenditure would be met by the Department of Atomic Energy, as admissible to class-I officers of the Government of India. .
7. The report of the Working Group would be submitted to the Steering Committee on the S&T for the formulation of Twelfth Five Year Plan by 15th July, 2011

18/4/11

(R.K. Gupta)
Joint Adviser (S&T)

Copy forwarded to:

1. Secretary, Department of Atomic Energy
2. Chairman, all Members and Member-Secretary of the Working Group

3. PS to Deputy Chairman, Planning Commission
4. PS to Adviser to PM on PI[3]
5. PS to Minister of State (Planning)
6. PS to all Members, Planning Commission
7. PS to Member-Secretary, Planning Commission
8. All Principal Advisers/Sr. Advisers/Advisers/HODs, Planning Commission
9. Director(PC), Planning Commission
10. Information Officer, Planning Commission
11. Library, Planning Commission

8/4/11

(R.K. Gupta)
Joint Adviser (S&T)

ANNEXURE - 3
CONSTITUTION OF INTERNAL WORKING GROUP

Government of India
Department of Atomic Energy
Office of Principal Adviser

2nd Floor, O.Y.C. Building,
CSM Marg
Mumbai 400001

No. DAE/OPA/B-14.1/ 2011/ 34 March, 16 2011

ORDER

Sub:- Re-Constitution of Internal Working Group for Department of Atomic Energy (R&D Sector).

Internal Working Group (IWG) for R&D Sector (IWG R&D Sector) is reconstituted as follows:

1. Director BARC	- Chairman
2. Director, IGCAR	- Member
3. Director, RRCAT	- Member
4. Director, VECC	- Member
5. Director, TIFR	- Member
6. Director, IPR	- Member
7. Director, IMSc	- Member
8. Director, E&I Group, BARC	- Member
9. Director, NISER	- Member
10. Director, Nuclear Fuels Group, BARC	- Member
11. Director, Reactor Projects Group, BARC	- Member
12. Director, Reactor Design & Development Group, BARC	- Member
13. Director, Physics Group, BARC	- Member
14. Director, Health, Safety & Environment Group, BARC	- Member
15. Director, Bio-Medical Group, BARC	- Member
16. Director, Chemistry Group, IGCAR	- Member
17. Director, Reactor Engineering Group, IGCAR	- Member
18. Director, Radiochemistry & Isotope Group, BARC	- Member
19. Joint Secretary (R&D), DAE	- Member
20. Shri Suresh Gangotra, SPG, DAE	- Member
21. Dr T. Sakuntala, SPG, DAE	- Member Secretary

2. The terms of reference of the Internal Working Group are given in the Annexe-1. The IWG will get inputs from the Specialist Groups (SGs) working on various themes. The list of themes and the composition of SGs are given in Annexe-2, while the guidelines for review of ongoing Plan projects and

submission of new Plan project proposals in R&D sector are given in Annexe-3. SGs will continue to monitor the progress of ongoing and new projects. Some more details are given in the following Annexes: Annex-4 – Outline for the new Plan project for R&D Sector; Annex-5 - Numbering system; Annex-6 – Major programmes and sub-programmes.

3. 'Prospective Research Fund (PRF)' will continue to be operated on lines similar to BRNS. Project proposals will be invited from units within the Department. The proposals covering the following areas will be considered for funding.

- Research complimentary to the major projects proposed to be taken up during XII plan.
- Filling up of critical gaps, which might be identified during XII Plan.
- Enrichment of scientific knowledge and stimulating futuristic research.

4. While proposing major projects, complimentary research areas and funds needed for such research may be indicated in the outline of the proposals submitted for XII Plan. Funds for the same will then be estimated. All such requirements will be consolidated and funds will be requested under the head, PRF. Individual needing funding for curiosity driven research on areas of relevance may send their proposals to DAE and these will be examined by SGs on the same pattern as advisory committees of BRNS examine proposals for funding from BRNS. Funding will be on a competitive basis and it is possible that research complimentary to a major project might get done in a unit different from where the major project is being done.

5. The Internal Working Group may start preparatory work for the XII Plan and coordinate its activities with the main Working Group when set up in such a way that the main Working Group will be able to submit the proposals to the Planning Commission within the stipulated time.

This order supersedes the order constituting IWG R& D Sector issued vide letter No. DAE/DSPG/B-14.1/2006/85 dt. May 01, 2006 and is issued with the approval of Secretary, DAE.

(R.B.Grover)
Principal Advisor

Chairman & Members of the IWG
Heads of Constituent Units & Aided Institutions
Copy to: Secretary, DAE
Convenors of Specialist Groups

Annex-1

Internal Working Group on R&D Sector

Terms of Reference

1. To review various schemes/projects undertaken by the Department of Atomic Energy during the XI Plan period (both ongoing and new) in the R&D Sector and to suggest specific projects for the next Plan period along with the Plan outlay required, keeping in view the mandate of the Department.

2. To review the XII Plan proposals submitted under R&D sector by different DAE units (R&D centers, Industrial Units and Autonomous Institutions) and vetted by Specialist Groups (SG) identified for different R&D themes, as indicated in the Annexure.

3. To identify the technologies developed by DAE which have potential for commercial exploitation and suggest the manner in which these potential capabilities can be utillised for societal developments in cooperation with other agencies including Central and State Governments, cooperative bodies and NGOs.

4. To indicate year-wise phasing of R&D activities and the budgetary allocation and other inputs required.

5. To periodically review and monitor the progress made by the projects in such a way that all projects are reviewed at least once in a year.

6. To submit the report of the review to the Secretary, DAE.

Members of the reconstituted Internal Working Group (IWG) for R&D Sector (IWG R&D Sector) – revised as on April 13, 2011

1.	Director BARC	- Chairman
2.	Director, IGCAR	- Member
3.	Director, RRCAT	- Member
4.	Director, VECC	- Member
5.	Director, TIFR	- Member
6.	Director, IPR	- Member
7.	Director, IMSc	- Member
8.	Director, E&I Group, BARC	- Member
9.	Director, NISER	- Member
10.	Director, Nuclear Fuels Group, BARC	- Member
11.	Director, Reactor Projects Group, BARC	- Member
12.	Director, Reactor Design & Development Group, BARC	- Member
13.	Director, Physics Group, BARC	- Member
14.	Director, Health, Safety & Environment Group, BARC	- Member
15.	Director, Bio-Medical Group, BARC	- Member
16.	Director, Chemistry Group, IGCAR	- Member
17.	Director, Reactor Engineering Group, IGCAR	- Member
18.	Director, Radiochemistry & Isotope Group, BARC	- Member
19.	Chief Executive, NFC	- Member
20.	Chief Executive, HWB	- Member
21.	Chief Executive, BRIT	- Member
22.	Dr. N. Ramamoorthy, Sr. Adv. to Director, BARC	- Member
23.	Shri. S.F. Vhora, AD (TDG), NPCIL	- Member
24.	Director, SINP	- Member
25.	Joint Secretary (R&D), DAE	- Member
26.	Shri Suresh Gangotra, SPG, DAE	- Member
27.	Dr. T. Sakuntala, SPG, DAE	- Member Secretary

ANNEXURE - 4
MAJOR PROGRAMMES AND SUB-PROGRAMMES

MP-1 Nuclear Power Programme – Stage -1

1.01 PHWR (Pressurised Heavy Water Reactor)
1.02 LWR (Light Water Reactor)
1.03 Front End Fuel Cycle – Exploration, Mining & Ore Processing, Fuel Fabrication, Heavy Water Production
1.04 Back End Fuel Cycle- Reprocessing
1.05 Health, Safety & Environment
1.06 Waste Management

MP-2 Nuclear Power Programme – Stage -2

2.01 Fast Reactors
2.02 Materials
2.03 FBR-Front End Fuel Cycle (including Fuel Selection, Chemistry, Fabrication, Sodium and its related activities, Boron etc)
2.04 FBR-Back End Fuel Cycle
2.05 Repair and Inspection Technologies
2.06 FBR-Health, Safety & Environment

MP-3 Nuclear Power Programme – Stage -3 and beyond

3.01 AHWR (Advanced Heavy Water Reactor)
3.02 Thorium Fuel Cycle
3.03 Other Thorium Reactor Systems
3.04 Accelerator Driven Sub-critical System
3.05 Materials
3.06 Hydrogen Energy
3.07 Fusion Reactor

MP-4 Advanced Technologies and Radiation Technologies and their Applications

4A Advanced Technologies and their Applications

4.01 Research Reactors
4.08 Accelerators
4.09 Lasers
4.10 Special Materials
4.11 Advanced Technologies
4.12 Special Programmes

4B Radiation Technologies and their Applications

4.02 Isotope Processing
4.03 Agriculture
4.04 Food Processing
4.05 Health
4.06 Water
4.07 Industrial Applications

MP-5 Basic Research

5.01 Mathematics and Computational Sciences
5.02 Physics
5.03 Chemistry
5.04 Biology
5.05 Cancer
5.06 Synchrotrons & their Utilisation
5.07 Cyclotrons & their Utilisation
5.08 Fusion & Other Plasma Technologies
5.09 Materials Science
5.10 Interdisciplinary Areas
5.11 International Research Collaboration

MP-6 Research Education Linkages

6.01 Human Resource Development
6.02 Sponsored Research
6.03 Prospective Research Fund
6.04 HBCSE
6.05 Information Technology Applications Development

MP-7 Infrastructure & Housing

7.01 Infrastructure
7.02 Housing

ANNEXURE - 5

SPECIALIST GROUPS FOR REVIEWING PLAN PROJECTS UNDER R&D SECTOR

Theme No.	Theme	Sub-Prog. Nos.	Specialist Group
1.	Front End Fuel Cycle	1.03, 3.02., 3.05	Dr. A.K. Suri, BARC - **Convenor** Shri P.B. Maithani, AMD Shri R.N. Jayaraj, NFC Shri S.A.V. Satya Murty, IGCAR Shri D. Acharya, UCIL
2.	Back End Fuel Cycle	1.04, 1.06, 2.04	Dr. P.R. Vasudeva Rao, IGCAR - **Convenor** Shri R. Natarajan, IGCAR Shri P.K. Wattal, BARC Shri P. Janardan, BARC Dr. G. Sugilal, BARC Shri G. Srikumar, BARC Dr. K. Nagarajan, IGCAR Dr. U. Kamachi Mudali, IGCAR
3.	Research Reactors	4.01	Shri V.K. Raina, BARC - **Convenor** Dr. P.D. Krishnani, BARC Shri P.K. Nema, BARC Shri G. Srinivasan, IGCAR
4.	Advanced Reactor Technology	1.01, 3.01, 3.03, 3.04, 3.05	Shri Manjit Singh, BARC - **Convenor** Shri K.B. Dixit, NPCIL Shri R.R.S. Yadav, BARC Dr. J.K. Chakravartty, BARC Shri K.K. Rajan, IGCAR
5.	Light Water Reactors & Manufacturing	1.02, 4.11, 7.01	Shri V.K. Mehra, BARC - **Convenor** Dr. A.K. Das, BARC Shri R.L. Suthar, BARC Shri U. Mahapatra, BARC
6.	Fast Reactor Technology	2.01, 2.02, 2.03, 2.05, 2.06	Shri S.C. Chetal, IGCAR - **Convenor** Shri Prabhat Kumar, Bhavini Dr. T.K. Mitra, Bhavini Shri Arun Kumar, BARC

Theme No.	Theme	Sub-Prog. Nos.	Specialist Group
7.	Safety Related Research	1.05, 2.06	Dr. A.K. Ghosh, BARC - **Convenor** Dr. D.N. Sharma, BARC Shri S. Anantharaman, BARC Dr. P. Chellapandi, IGCAR Prof U.N. Gaitonde, IIT, Mumbai
8.	Isotope & Radiation Technology	4.02, 4.03, 4.04	Dr. K.L. Ramkumar, BARC - **Convenor** Dr. A.K. Kohli, BRIT Dr. M.R.A. Pillai, BARC Dr. A.K. Sharma, BARC Dr. N. Ramamoorthy, BARC
9.	Astro, Nuclear & High Energy Physics	5.02, 5.11	Dr. S. Kailas, BARC – **Convenor** Prof. Kajari Mazumdar, TIFR Dr. D.K. Srivastava, VECC Prof. Naba Mandal, TIFR Prof. Rohini Godbole, IISc, Bangalore Prof. Ajit Kembhavi, IUCAA
10.	Advanced Physical Sciences	5.02	Dr. S.L. Chaplot, BARC - **Convenor** Dr. P.K. Gupta, RRCAT Dr. C.S. Sundar, IGCAR Prof. Avinash Khare, IISER, Pune Prof. Shiva Prasad, IIT Bombay Prof. S. Ramkrishnan, TIFR
11.	Laser & Accelerator Technology	3.04, 4.05, 4.07, 4.08, 4.09, 4.10, 4.11, 5.02, 5.06, 5.07, 5.10, 5.11	Dr. R.K. Bhandari, VECC - **Convenor** Dr. P.D. Gupta, RRCAT Dr. Pitamber Singh, BARC Shri Gurnam Singh, RRCAT Dr. Amit Roy, IUAC, Delhi Prof. G. Ravindra Kumar, TIFR Dr. B.K. Panigrahi, IGCAR Prof. D.P. Mahapatra, IOP Prof. R.G. Pillay, TIFR Dr. L.M. Ganatyet, BARC

Theme No.	Theme	Sub-Prog. Nos.	Specialist Group
12.	Mathematics, Computer Science & Technology	2.01, 5.01, 6.05, 7.01	Prof. R. Balasubramanian, IMS- **Convenor** Shri A.G. Apte, BARC Prof. S.V. Raghavan, IITM, Chennai Shri S.A.V. Satya Murty, IGCAR Prof. Shivkumar, IIT, Mumbai Prof. V. Srinivas, TIFR Prof. R.V. Gavai, TIFR
13.	Advanced Chemical Sciences	3.06, 4.06, 4.10, 5.03	Shri S.K. Ghosh, BARC- **Convenor** Dr. T. Gnanasekharan, IGCAR Dr. S.K. Sarkar, BARC Dr. A.V.R. Reddy, BARC Prof. G. Krishnamurthy, TIFR Prof. S. Wategaonkar, TIFR
14.	Materials Science & Technology	5.09	Prof. Milan Sanyal, SINP - **Convenor** Prof. Pushan Ayyub, TIFR Dr. T. Jayakumar, IGCAR Dr. G.K. Dey, BARC Dr. S.B. Roy, RRCAT Prof. D. Bahadur, IIT, Mumbai
15.	Electronics & Instrumentation	4.11, 4.12, 6.01	Shri G.P. Srivastava, BARC- **Convenor** Shri B.B. Biswas, BARC Shri N. Murali, IGCAR Shri P.R. Hannurkar, RRCAT Shri V.M. Joshi, BARC Prof. U.B. Desai, IITB, Mumbai
16.	Biology and Medicine	4.05, 5.04, 5.05	Dr. K.B. Sainis, BARC- **Convenor** Dr. Rajiv Sarin, ACTREC Dr. M.G.R. Rajan, RMC Dr. S.K. Apte, BARC Prof. B.J. Rao, TIFR Prof. Vijay Raghavan, NCBS, Bengaluru

Theme No.	Theme	Sub-Prog. Nos.	Specialist Group
17.	Advanced Technologies	4.11	Dr. L.M. Gantayet, BARC- **Convenor** Shri S. Bhattacharya, BARC Dr. S.M. Oak, RRCAT Dr B. Sarkar, ITER-India, IPR Dr. Amar Sinha, LNPS, BARC Prof. A.K. Nath, IIT, Kharagpur
18.	Fusion & Plasma Research	3.07, 5.08, 5.11	Prof. P.K. Kaw, IPR- **Convenor** Prof. Abhijit Sen, IPR Prof. Y.C. Saxena, IPR Dr. A.K. Das, BARC
19.	HRD	4.12, 6.01 to 6.05	Dr. R.R. Puri, BARC- **Convenor** Dr. M. Saibaba, IGCAR Shri S.B. Agarkar, NPCIL Prof. S.L. Bapat, IITB, Mumbai Dr. P. Barat, VECC
20.	Infrastructure & Housing	7.01, 7.02	Shri N. S. Gabhane, - **Convenor** Shri Y.C. Manjunatha, IGCAR Shri K. Srinivas, BARC Shri A.K. Jana, DCSEM

ANNEXURE - 6
ABBREVIATIONS

ACTREC	Advanced Centre for Treatment, Research and Education in Cancer
ADS	Accelerator Driven System
AEES	Atomic Energy Education Society
AERB	Atomic Energy Regulatory Board
AHWR	Advanced Heavy Water Reactor
ALICE	A Large Ion Collider Experiment
AMD	Atomic Minerals Directorate for Exploration & Research
ATF	AHWR Test Facility
BARC	Bhabha Atomic Research Centre
BRIT	Board of Radiation and Isotope Technology
BRNS	Board for Research in Nuclear Sciences
CERN	European Organisation for Nuclear Research (English name)
CFBR	Commercial Fast Breeder Reactor
CGCRI	Central Glass and Ceramic Research Institute
CHTR	Compact High Temperature Reactor
CICC	Cable in Conduit Conductor
CMS	Compact Muon Solenoid
CORAL	Compact Reprocessing Facility for Advanced Fuels in Lead Cells
DAE	Department of Atomic Energy
DNA	Deoxyribo Nucleic Acid
DSC&EM	Directorate for Construction, Services & Estate Management
ECCS	Emergency Core Cooling System
ECR	Electron Resonance Source
EMCCR	En-Masse Coolant Channel Replacement
FAC	Flow Assisted Corrosion
FAIR	Facility for Antiproton and Ion Research
FBR	Fast Breeder Reactor
FM	Fuelling Machine
FMITF	Fuelling Machine Integrated Test Facility
GCNEP	Global Centre for Nuclear Energy Partnership
GMRT	Giant Metrewave Radio Telescope
HBCSE	Homi Bhabha Centre for Science Education
HBNI	Homi Bhabha National Institute
HLNRA	High Level Natural Radiation Area
HRD	Human Resource Development
HRI	Harish-Chandra Research Institute
HRTF	Hydrogen Recombiner Test Facility
HTR	High Temperature Reactor
IERMON	Indian Environmental Radiation Monitoring Network
IGCAR	Indira Gandhi Centre for Atomic Research
INO	Indian Neutrino Observatory
IOP	Institute of Physics
IPR	Institute for Plasma Research
IRFEL	Infra red Free Electron Laser
ITER	International Thermonuclear Experimental Reactor
ITFT	Integrated Test Facility
IWG	Internal Working Group
LHC	Large Hadron Collider
LINAC	Linear Accelerator
LLCB	Lead Lithium Cooled Ceramic Breeder
LLNRA	Low Level Natural Radiation Area
LOCA	Loss of Coolant Accident
LWR	Light Water Reactor
MEMS	Micro Electro Mechanical Systems
MOU	Memorandum of Understanding
MOX	Mixed Oxide
MP	Major Programme
NBHM	National Board for Higher Mathematics
NISER	National Institute of Science Education and Research
NPCIL	Nuclear Power Corporation of India Limited

NSSS	Nuclear Steam Supply System
NTHTF	NPCIL Thermal Hydraulic Test Facility
ODS	Oxide Dispersion Strengthened
OSL	Optically Simulate Luminescence
OSLD	Optically Simulated Luminescence Dosimeter
OWRD	One Way Rupture Discs
PCCS	Primary Containment Clean-up System
PET	Positron Emission Tomography
PFBR	Prototype Fast Breeder Reactor
PIC	Project Identification Code
PHWR	Pressurised Heavy Water Reactor
PRTRF	Power Reactor Thoria Reprocessing Facility
R&D	Research & Development
RAFM	Reduced Activation Ferritic Martensitic
RDDD	Research, Development, Demonstration and Deployment
RDTF	Reactivity Devices Test Facility
RFQ	Radio Frequency Quadrapole
RIB	Radioactive Ion Beam
RO	Reverse Osmosis
RRCAT	Raja Ramanna Centre for Advanced Technology
SG	Specialists Group
SOTEF	Solar Test Facility
SNM	Special Nuclear Material
SPECT	Single Photon Emission Tomography
SPND	Self Powered Neutron Detector
SRC	Science Research Council
SST	Steady State Superconducting Tokamak
TBM	Test Blanket Module
TIFR	Tata Institute of Fundamental Research
TIG	Tungsten Inert Gas
TMC	Tata Memorial Centre
TRISO	Tristructural Isotropic
UGC	University Grants Commission
VECC	Variable Energy Cyclotron Centre
VSRP	Visiting Student's Research Programme
WG	Working Group

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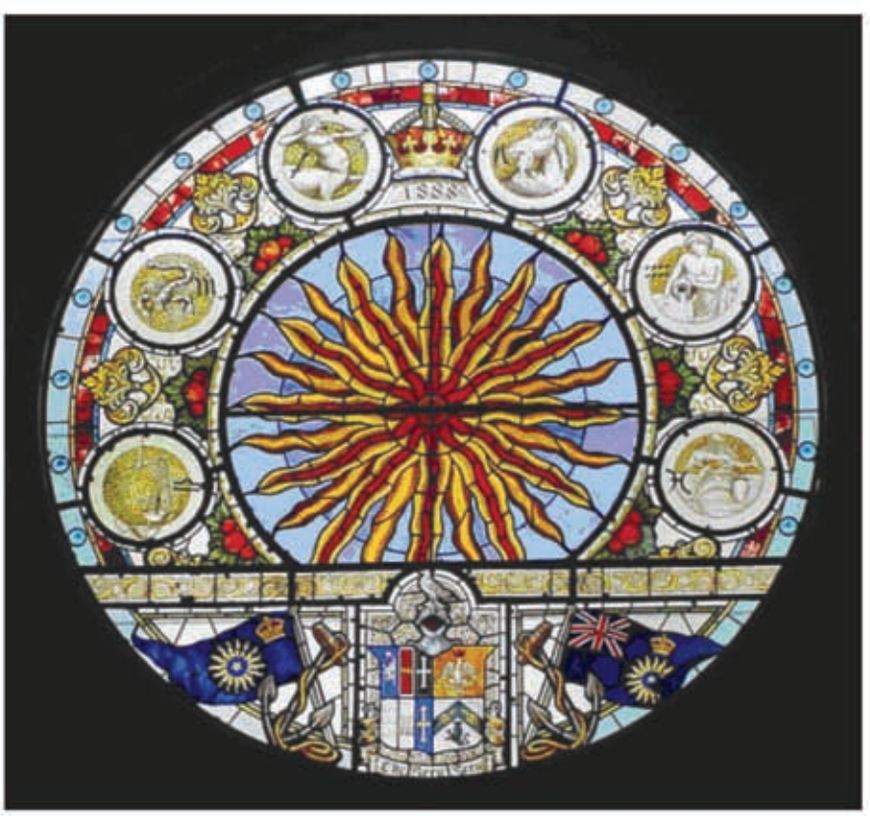

Stained Glass Rosette Windows on the Walls of
the Commission Room in the Old Yacht Club Building.
Each Windows, 8 feet in Diameter, Depict Sun at the Centre and
Six Zodiac Signs. The Building was Renovated during XI Plan Period.