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A Civil Services Chronicle Initiative

SCIENCE & TECHNOLOGY

(PART – II)

Civil Services CHRONICLE

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CONTENTS

MANO TECHNOLOGY

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Where the 20th Century was the era of macro-science, characterized by gigantic Boeings, roaring Shuttles, draconian Dams, monstrous Refineries & Power plants, the 21st Century will be dominated by nano-science, featured with microscopic precision. Nano-technology is the design, characterization, production and application of structures, devices and systems by controlling shape and size at the nanoscale. Eight to ten atoms span one nanometer (nm). The human hair is approximately 70,000 to 80,000 nm thick. Nano-science is the world of atoms, molecules, macro-molecules, quantum dots, and macromolecular assemblies.

With the help of nanotechnology, a large set of materials with distinct properties (optical, electrical, or magnetic) can be fabricated. Nano-particles take advantage of their dramatically increased surface area to volume ratio. Their optical properties, e.g. fluorescence, become a function of the particle diameter. When brought into a bulk material, nano-particles can strongly influence the mechanical properties, such as the stiffness or elasticity. For example, traditional polymers can be reinforced by nano-particles resulting in novel materials e.g. as lightweight replacements for metals. In the coming days one can clearly visualise the huge applications of nano-science in different fields as follows:

NANO SCIENCE IN INDIA

Nano-tube Filter: The scientists from Banaras Hindu University have devised a simple method to produce carbon nanotube filters that efficiently remove micro to nano-scale contaminants from water and heavy hydrocarbons from petroleum. Made entirely of carbon nanotubes, the filters are easily manufactured. The nanotube composition makes the filters strong, reusable, and heat resistant, and they can be cleaned easily for reuse.

Typhoid Detection Kit: Using the nano-sensor, developed by Prof. A.K. Sood of IISc, Bangalore, a Typhoid Detection Kit has been developed by DRDE, Gwalior. Typhoid fever caused by Salmonella typhi is a major health problem and an important challenge to health authorities of third world countries due to unsatisfactory water supply, poor sanitary conditions, malnutrition, emergence of antibiotic resistant strains, etc.

Gas Flow Induced Generation of Voltage from Solids: Prof AK Sood, Professor of Physics at IISc and his student Shankar Ghosh have found that the liquid flow in carbon nano-tubes can generate electric current. One of the most exciting applications to emerge from the discovery is the possibility of a heart pacemaker - like device with nano-tubes, which will sit in the human body and generate power from blood. Instead of batteries, the device will generate power by itself to regulate defective heart rhythm.

Drug Delivery System: A research group headed by Professor A. N. Maitra of the University of Delhi has developed 11 patentable technologies for improved drug delivery systems using nanoparticles. Four of these processes have been granted U.S. patents. One of the important achievements at the initial stage of drug delivery research was development of a reverse micelles based process for the synthesis of hydrogel and 'smart' hydrogel nanoparticles for encapsulating water-soluble drugs. This method enabled one to synthesize hydrogel nanoparticles of size less than 100 nm diameter.

PROGRAMMES FOR DEVELOPMENT OF NANO TECHNOLOGIES IN INDIA

Support to Nanotechnology Business Incubator (NBI) at NCL, Pune continued during the year 2012-13. This NBI has nurtured activities by 7 start-up companies on items like-computational modelling of flow and chemical processes, therapeutic potential of biotechnologically engineered antibodies, ocular and maxillofacial implants, and 12 start-up companies are under incubation presently as Resident Incubates on items like maxillo-facial surgery, organic chemical synthesis etc. Support to other ongoing projects in this category continued during the year. Significant progress has been made in these projects.

Centre for Nano Science and Engineering (CeNSE)

The Centre for Nano Science and Engineering (CeNSE) was established in 2010 to pursue interdisciplinary research across several disciplines with a focus on nanoscale systems. Current research topics include, but are not limited to nanoelectronics, MEMS/NEMS, nanomaterials and devices, photonics, nano-biotechnology, solar cells and computational nano-engineering. Apart from the regular faculty members at CeNSE, almost 40 faculty members from different departments at IISc are associated in the academic and research activities at the centre. The centre offers PhD programmes in a wide range of areas, and has close interactions with the industry.

A state-of-the art nanofabrication facility with a clean room spanning 1400 square meters is located at the centre. In addition, there are several characterization labs that cater to material, electronic, mechanical, chemical and optical characterization.

Basic Research Promotion

25 new individual scientist-centric R&D projects were funded during the year 2012-13 which focused on fundamental scientific studies on nano-scale systems. Some of these projects were related to:

Study of catalytic activity of nano size metals and metal oxides prepared by novel or conventional routes; experimental and first-principles theoretical studies of metal oxide nanostructures for photoelectrochemical splitting of water; studies on magneto-transport in magnetic tunnel junctions; studies on bone targeted nano drug delivery systems for treatment of osteo-degenerative disease in improvement of women health; studies on superferromagnetism in magnetic nanoparticle systems; development of nano fibrous membrane polymer electrolytes and nano structured electrode materials for lithium rechargeable batteries; development of hybrid nanomaterials for energy production from renewable sources; development of titania aerogel photoanode for desensitized solar cell application; computational studies of bare and zeolite-supported metal nanoclusters and their application in catalysis; mechanistic studies on extra cellular biosynthesis of metal nanoparticles; development of protein nanoparticles delivery system for targeting anti-retroviral drugs to HIV infected cells; multifunctional materials for electrochemical energy conversion and storage devices; synthesis and characterization of novel nanoparticles and study of their interactions with stem cells; development of parenteral sustained release dosage forms and colon targeted drug delivery systems for low molecular weight heparin.

- Folic Acid Super Paramagnetic Iron Oxide Nanoparticles (FA-SPIONs) were developed which are highly stable, biocompatible, with prolong and better biodistribution profile as compared to commercially available SPIONs. It was also found out that developed FA-SPIONs have high selectivity and specificity to cancer cells. Also, Folic acid conjugated Quantum Dots were synthesized which are stable, biocompatible with good fluorescence properties. Preparation of bioceramics using synthesized mullite and colloidal silica together was done.

- Au-Ni, Cu-Co, Cu-Ni multilayer nanowires have been synthesized using potentiostatic electrodeposition. Nano-channels of anodic alumina membrane were used as template. Morphology of the wires has been studied, structural characterization has been done, Superconducting Quantum Interference Device (SQUID) was done to measure the magnetic properties. Impedance measurements were also made.

- Metal phosphide (MxPy) electrodes were prepared by direct electro-deposition, reporting the synthesis of high temperature materials at low temperature using aqueous electrolyte. The nanoarchi-tectured electrode assembly demonstrated high energy capacity as well as high power density as compared to traditional flat lithium battery electrode using any electroactive materials.

- Coiled carbon nanotubes (CCNT) have been synthesized on the carbon fibre substrate. The necessary conditions for coiled nanostructure growth have been investigated. Catalyst coated and CCNT coated substrates have been characterized. CCNTs, carbon microcoils (CMCs) and CNCs of varying length, diameter and coil pitch have been synthesized. Carbon nanocoil coated carbon fibre reinforced composites shall be useful for structural applications.

NANO MISSION OF INDIA

The Government of India, in May 2007, approved the launch of a Mission on Nano Science and Technology (Nano Mission) with an allocation of Rs. 1000 crore for 5 years. The Department of Science and Technology is the nodal agency for implementing the Nano Mission. Capacity-building in this upcoming area of research will be of utmost importance for the Nano Mission so that India emerges as a global knowledge-hub in this field. For this, research on fundamental aspects of Nano Science and training of large number of manpower will receive prime attention. In addition, the Nano Mission will strive for development of products and processes for national development, especially in areas of national relevance like safe drinking water, materials development, sensors development, drug delivery, etc. For this, it will forge linkages between educational and research institutions and industry and promote Public Private Partnerships.

The Nano Mission has been structured in a such fashion so as to achieve synergy between the national research efforts of various agencies in Nano Science and Technology and launch new programmes in a concerted fashion. International collaborative research efforts will also be made wherever required.

Objectives

The Nano Mission is an umbrella programme for capacity building which envisages the overall development of this field of research in the country and to tap some of its applied potential for nation's development. The main objectives of the Nano Mission are -basic research promotion, infrastructure development for carrying out front-ranking research, development of nano technologies and their applications, human resource development and international collaborations. During the year 2012-13, Nano Mission continued to record expansion in its activities and break new grounds in promotion of R&D and human resource development in the field of nanotechnology. In brief, the objectives of the Nano-Mission are:

- **Basic Research Promotion:** Funding of basic research by individual scientists and/or groups of scientists and creation of centres of excellence for pursuing studies leading to fundamental understanding of matter that enables control and manipulation at the nanoscale.

- **Infrastructure Development for Nano Science & Technology Research:** Investigations on the nano scale require expensive equipments like Optical Tweezer, Nano Indentor, Transmission Electron Microscope (TEM), Atomic Force Microscope (AFM), Scanning Tunneling Microscope (STM), Matrix Assisted Laser Desorption Time of Flight Mass Spectrometer (MALDI TOF MS), Microarray Spotter & Scanner etc. For optimal use of expensive and sophisticated facilities, it is proposed to establish a chain of shared facilities across the country.

- **Nano Applications and Technology Development Programmes:** To catalyze Applications and Technology Development Programmes leading to products and devices, the Mission proposes to promote application-oriented R&D Projects, establish Nano Applications and Technology Development Centres, Nano-Technology Business Incubators, etc. Special effort will be made to involve the industrial sector into nanotechnology R&D directly or through Public Private Partnership (PPP) ventures.

- **Human Resource Development:** The

Mission shall focus on providing effective education and training to researchers and professionals in diversified fields so that a genuine interdisciplinary culture for nanoscale science, engineering and technology can emerge. It is planned to launch M.Sc./M.Tech. programmes, create national and overseas post-doctoral fellowships, chairs in universities, etc.

- **International Collaborations:** Apart from exploratory visits of scientists, organization of joint workshops and conferences and joint research projects, it is also planned to facilitate access to sophisticated research facilities abroad, establish joint centres of excellence and forge academia-industry partnerships at the international level wherever required and desirable.

Organizational Structure

The Nano Mission is a Mission-Mode programme within DST. At the apex level, it is steered by a Nano Mission Council (NMC). It is currently being chaired by Professor CNR Rao. The technical programmes of the Nano Mission are also being guided by two advisory groups, viz. the Nano Science Advisory Group (NSAG) and the Nano Applications and Technology Advisory Group (NATAG).

DST Activities in Nano Science and Technology: The Nano Mission is the second phase of DST activities in Nano Science and Technology. DST, in October 2001, had launched a modest programme in Nano Science and Technology, called the Nano Science and Technology Initiative (NSTI), and the Nano Mission is the successor of this programme.

Under NSTI, and since May 2007 under the Nano Mission, DST has supported a number of activities in Nano Science and Technology. A brief resume of those programmes is being given below:

(i) Support for R & D Projects to Individual Scientists: Around 130 projects have been supported for individual scientists mainly working on fundamental scientific aspects of nanoscale systems. Investigations are aimed at looking into new and improved understanding of the relationship between structure of various nanoscale systems and their properties using sophisticated characterization facilities.

Significant results have been reported from these projects. Extensive studies on semiconductor nanocrystals have been undertaken in several projects. As semiconductor particles exhibit size-dependent properties like scaling of the energy gap and corresponding change in the optical properties, they are considered as technologically important materials. Several projects have looked into synthesis of important nanomaterials like CdSe, ZnO etc. Size-tunable, organic-soluble industrially important CdS, AlN, GaN and InN nanocrystals have been prepared by employing novel solvothermal techniques and some soft chemical routes. In another project, it has been reported that flow of various liquids and gases over a mat of single-walled carbon nanotube (SWNT) bundles generate electrical signals. This discovery has several important technological implications. It may have several applications in the fields of biotechnology, pharmaceutical industry, drug delivery, intelligent pneumatic systems, information technology etc.

(ii) Strengthening of Characterization Facilities: Research with nanoscale systems requires sophisticated characterization facilities which were not available in our institutions. Realizing this gap, DST has established an array of sophisticated equipments such as Optical Tweezer, Nano Indentor, Transmission Electron Microscope (TEM), Atomic Force Microscope (AFM), Scanning Tunneling Microscope (STM), Matrix Assisted Laser Desorption Time of Flight Mass Spectrometer (MALDI TOF MS), Microarray Spotter & Scanner etc. at various locations in the country.

(iii) Establishment of Centres of Excellence: Eleven Units/Core Groups on Nano Science have been sanctioned across the country. These centres of excellence house some of the more sophisticated facilities for sharing with other scientists in the region and would help in promoting scientific research on nanoscale systems in a decentralized fashion.

Seven Centres for Nano Technology focusing on development of specific applications have also been established. In addition, a centre of excellence on Computational Materials Science has also been established at JNCASR, Bangalore.

(iv) International Collaborative Programmes: As expected, Nano Science and Technology has prominently figured in all S&T cooperation agreements entered into in recent times. Joint R&D activities are already taking place with several countries. For example, with the US, several projects have been funded on CNTs in composites, nano-encapsulating materials, etc. under the DST-NSF programme. Several Indo-US Workshops have also been held. With Germany, a programme on engineered functional nano-composites has started which would focus on magnetic properties, magnetic interactions, gas-solid interactions including catalysis, etc. Programmes are also on with Italy, EU and developing with Taiwan. ARCI, Hyderabad, which is an autonomous institute of DST has active programme in nano-material with institutions in Russia, Ukraine, Japan, Germany and USA.

(v) Joint Institution-Industry Linked Projects and Public Private Partnership activities: In order to focus the existing expertise in research and educational institutions towards developing products and processes of direct interest to industries, DST, under the Nano Programme, has promoted Joint Institution-Industry Linked Projects and some other Public Private Partnership activities in recent times. In many of these activities, the industrial partners have also invested financially in the project. These activities will help us to simultaneously leverage the scientific knowledge-base existing in our research and educational institutions and the commercial vision of our industry to generate competitive technologies leading to products and devices. Six such projects have received financial support so far.

(vi) Human Resource Development in Nano Science & Technology: In order to train and nurture human resource in the area of Nano Science and Technology, a number of activities have already been undertaken; for example, organization of national and international conferences, national review meetings and advanced schools, support for post-doctoral fellowships through JNCASR, Bangalore, etc.

THE FUTURE SCOPE OF NANOTECHNOLOGY

1. **Creating better Computing Devices:** Perhaps more than anywhere else, the promise of nanotechnology is causing excitement in the computer chip and memory business for very good reasons: it would enable computer designers to break through the Moore's law. Intel co-founder Dr Gordon Moore predicted that technology that went into integrated circuits would roughly double in power every 12-18 months. That is why the latest Pentium 4 chip clocking 2.4 gigahertz, is about 25,000 times faster and packs 25,000 as many transistors on board as the first ever microchip, the Intel 4004 of 1971. Physicists say: it will take at least 10 years at the most before we are able to dream up a bigger, better, microchip on that slab of silicon. And that is where nano-technology comes in: the ability to fashion electronic circuits-entire computers-with atom-length nanowires or nanotubes, made from carbon rather than silicon, may allow computer hardware to progress beyond physical barriers of Moore's Law.

2. **Nano Biology:** The demand for environmentally sustainable industrial, agricultural, aquacultural, and silvi-cultural technologies is bringing about a shift from chemical-based solutions to biological based ones.

3. **Nano Medicine:** Nanotechnology would build fleets of computer- controlled molecular tools (called nanobots or cell machines) much smaller than a human cell and built with the accuracy and precision of drug molecules. If you get a cold or have contracted AIDS, you'd just drink a teaspoon of liquid that contained an army of molecule-sized nanobots programmed to enter your body's cells and fight viruses.

4. **Nanotechnology and Ecology:** Nanotechnology has the potential of

making our environment cleaner. For instance, if you make plastic with nanotechnology, you can feed stocks of pure elements like carbon, hydrogen, and oxygen and force individual atoms deliberately into chemical bonds without intermediate steps that produce all those environmentally unfriendly waste products.

5. **Nanotechnology in Agriculture:** With nanotechnology, growing food crops to feed the hungry and starving would no longer be a problem. Higher crop yields could be achieved by intensive greenhouse agriculture. Plants grown in controlled environments (with optimal temperature, CO2, water, nutrients, etc) can grow year round and produce an order of magnitude more food per acre than the existing methods.

6. **Nanotechnology and Use of Natural Resources:** Rather than felling forests to make paper, we'd have assemblers synthesizing paper. Rather than using oil for energy, we'd have molecule-sized solar cells mixed into road pavement. With such solar nanocells, a sunny patch of pavement of a few hundred square miles could generate enough energy for a country of the size of India.

7. **Nano Economy:** Nanotechnology will fundamentally revolutionize most industries. Assemblers will be able to build copies of themselves quickly, using inexpensive materials, little energy, and no human labour, a single assembler can be used to make billions.

8. **Nanoweapons**: The weapons of the nanogeneration will not only be much smaller than today's, but much deadlier. Distributed surveillance systems could quickly identify arms buildups and offensive weapons deployments, while lighter, stronger, and smarter materials controlled by powerful molecular computers would let us make radically improved versions of existing weapons.

9. **Nanotechnology in Space Science:** Space transportation costs could be reduced considerably with nanotechnology. Comparing structural components made from titanium versus a diamondoid composite material, it is estimated that single stage to orbit transportation costs would drop (in one scenario) from $16,000 / kg to $3.54 / kg.

NEW DEVELOPMENTS

Bio-Nanotechnology

The biological and medical research scientists have exploited the unique properties of nano-materials for various applications e.g., contrast agents for cell imaging and therapeutics for treating cancer. Biological tests measuring the presence or activity of selected substances become quicker, more sensitive and more flexible when certain nanoscale particles are put to work as tags or labels. Magnetic nano-particles, bound to a suitable antibody, are used to label specific molecules, structures or microorganisms. For example, gold nano-particles tagged with short segments of DNA can be used for detection of genetic sequence in a sample.

The overall drug consumption and side-effects can be lowered significantly by depositing the active agent in the morbid region only and in no higher dose than needed. This highly selective approach reduces costs and human sufferings. They could hold small drug molecules transporting them to the desired location. Some potentially important applications include cancer treatment with iron nano-particles or gold shells.

Nanotechnology can help to reproduce or to repair damaged tissue. This so called "tissue engineering" makes use of artificially stimulated cell proliferation by using suitable nanomaterial-based scaffolds and growth factors. Tissue engineering might replace today's conventional treatments, e.g. transplantation of organs or artificial implants.

Chemistry & Environment

Chemical catalysis and filtration techniques are two prominent examples where nanotechnology already plays a role. The synthesis provides novel materials with tailored features and chemical properties e.g. nano-particles with a distinct chemical surrounding or specific optical properties. Chemical catalysis benefits especially from nano-particles, due to the extremely large surface of volume ratio. The application potential of nano-particles in catalysis ranges from fuel cell to catalytic converters and photocatalytic devices. Catalysis is also important for the production of chemicals. A strong influence of nano-chemistry on waste-water treatment, air purification and energy storage devices is to be expected. Mechanical or chemical methods can be used for effective filtration techniques. Nano-porous membranes are suitable for a mechanical filtration with extremely small pores smaller than 10 nm. Nanofiltration is mainly used for the removal of ions or the separation of different fluids.

Energy

The most advanced nanotechnology projects related to energy are: storage, conversion, manufacturing improvements by reducing materials and process rates, energy saving e.g. by better thermal insulation, and enhanced renewable energy sources. Nanotechnology can help to increase the efficiency of Solar light conversion by specifically designed nanostructures. The degree of efficiency of combustion engines is not higher than 15-20 per cent at the moment. Nanotechnology can improve combustion by designing specific catalysts with maximized surface area.

The most prominent nanostructured material in fuel cells is the catalyst consisting of carbon supported noble metal particles with diameters of 1- 5 nm. Suitable materials for hydrogen storage contain a large number of small nanosized pores. Many nanostructured materials like nanotubes, zeolites or alanates are under investigation. Nanotechnology can contribute to the further reduction of combustion engine pollutants by nanoporous filters, which can clean the exhaust mechanically, by catalytic converters based on nanoscale noble metal particles or by catalytic coatings on cylinder walls and catalytic nano-particles as additives for fuels.

Information & Communication

Current high-technology production processes are based on traditional top down strategies, where nanotechnology has already been introduced silently. The critical length scale of integrated circuits is already at the nanoscale (50 nm and below) regarding the gate length of transistors in CPUs or DRAM devices. In the modern communication technology, traditional analog electrical devices are increasingly replaced by optical or optoelectronic devices due to their enormous bandwidth and capacity, respectively. Two promising examples are photonic crystals and quantum dots.

Consumer Goods

Nanotechnology is already impacting the field of consumer goods, providing products with novel functions ranging from easy-to-clean to scratch-resistant. Already in use are different nano-particle improved products. Nano-technology can be applied in the production, processing, safety and packaging of food. A nanocomposite coating process could improve food packaging by placing anti-microbial agents directly on the surface of the coated film. Nanocomposites could increase or decrease gas permeability of different fillers as is needed for different products. They can also improve the mechanical and heat-resistance properties and lower the oxygen transmission rate.

The first sunglasses using protective and antireflective ultrathin polymer coatings are in the market. For optics, nanotechnology also offers scratch resistant coatings based on nanocomposites. The use of nanofibres makes clothes water and stain-repellent or wrinkle-free. Textiles with a nanotechnological finish can be washed less frequently and at lower temperatures. Nanotechnology has been used to integrate tiny carbon particles membrane & guarantee full-surface protection from electrostatic charges for the wearer.

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be coal- or lignite-fired, and only 3.4 GWe nuclear, including two imported 1000 MWe units planned at one site and two indigenous 700 MWe units at another. By 2032 total installed capacity of 700 GWe is planned to meet 7-9 per cent GDP growth, and this was to include 63 GWe nuclear. The OECD's International Energy Agency predicts that India will need some $1600 billion investment in power generation, transmission and distribution to 2035.

India has a vision of becoming a world leader in nuclear technology due to its expertise in fast reactors and thorium fuel cycle. Per capita power consumption in India is around 400 Kwh/yr, which is much below the world average consumption of 2400 Kwh/yr. Thus, massive increase in the power generation to match the world average consumption is needed in the coming years to enhance the overall national growth rate. The estimated coal deposits in India is 206 billion tonnes (6% of the world coal reserves) and the distribution of conventional energy sources in India is:

Coal & Lignite – 68%

Natural gases - 12%

Petroleum – 12 %

This is far from adequate to meet the increasing future energy demands. Moreover the high sulphur and ash content in Indian coal creates environmental and ecological problems. Hydel power generation capacity is limited and depends on erratic monsoon.

India has consciously proceeded to explore the possibility of tapping nuclear energy for the purpose of power generation and the Atomic Energy Act was framed and implemented with the set objectives of using two naturally occurring elements Uranium and Thorium having good potential to be utilized as nuclear fuel in Indian Nuclear Power Reactors. The estimated natural deposits of these elements in India are:

- Natural Uranium deposits - 70,000 tonnes
- Thorium deposits - 3,60,000 tonnes

Nuclear Power Corporation of India Limited (NPCIL) is a Public Sector Enterprise under the administrative control of the Department of Atomic Energy (DAE), Government of India. The Company was registered as a Public Limited Company under the Companies Act, 1956 in September 1987 with the objective of operating the atomic power stations and implementing the atomic power projects for generation of electricity in pursuance of the schemes and programmes of the Government of India under the Atomic Energy Act, 1962.

NPCIL is a MOU signing Company with DAE. Presently NPCIL is operating twenty nuclear power plants with total installed capacity of 4780 MWe. NPCIL has achieved more than 379 reactor years of safe nuclear power plant operating experience. NPCIL operates plants with motto 'Safety first and Production next'. The reactor fleet comprises two Boiling Water Reactors (BWRs) and eighteen Pressurised Heavy Water Reactors (PHWRs) including one 100 MW PHWR at Rajasthan which is owned by DAE, Government of India. Currently it has six reactors under various stages of construction totaling 4800 MW capacity out of which one reactor of 1000 MW capacity at Kudankulam, Tamil Nadu, has attained criticality on July 13, 2013.

The target since about 2004 has been for nuclear power to provide 20 GWe by 2020, but in 2007 the Prime Minister referred to this as "modest" and capable of being doubled with the opening up of International cooperation. However, it is evident that even the 20 GWe target would require substantial uranium imports. In June 2009, NPCIL said it aimed for 60 GWe nuclear by 2032, including 40 GWe of PWR capacity and 7 GWe of new PHWR capacity, all fuelled by imported uranium. This 2032 target was reiterated late in 2010 and increased to 63 GWe in 2011. But in December 2011 Parliament was told that more realistic targets were 14,600 MWe by 2020-21 and 27,500 MWe by 2032, relative to present 4780 MWe and 10,080 MWe when reactors under construction were on line in 2017.

The XII Plan envisages start of work on eight indigenous 700 MW Pressurised Heavy Water Reactors (PHWRs), two 500 MW Fast Breeder Reactors (FBRs), one 300 MW Advanced Heavy Water Reactor (AHWR) and eight Light Water Reactors of 1000 MW or higher capacity with foreign technical cooperation. These nuclear power reactors are expected to be completed progressively in the XIII and XIV Plans. The power generation increased by 23 percent during the year 2011-12, 32455 Million KWh as against 26472 Million KWh during the year 2010-11. The net export increased by 24 percent during the year 2011-12, 29123 Million KWh as against 23533 Million KWh during the year 2010-11.

The Nuclear Power Corporation of India Ltd (NPCIL) is responsible for design, construction, commissioning and operation of thermal nuclear power plants. Its funding model is 70% equity and 30% debt financing. However, it is aiming to involve other public sector and private corporations in future nuclear power expansion, notably National Thermal Power Corporation (NTPC). NTPC is largely government-owned, and the 1962 Atomic Energy Act prohibits private control of nuclear power generation.

The two Tarapur 160 MWe Boiling Water Reactors (BWRs) built by GE on a turnkey contract before the advent of the Nuclear Non-Proliferation Treaty were originally 200 MWe. They were down-rated due to recurrent problems but have run well since. They have been using imported enriched uranium and are under International Atomic Energy Agency (IAEA) safeguards. However, late in 2004 Russia deferred to the Nuclear Suppliers' Group and declined to supply further uranium for them. They underwent six months refurbishment over 2005-06, and in March 2006 Russia agreed to resume fuel supply. In December 2008 a $700 million contract with Rosatom was announced for continued uranium supply to them.

The two small Canadian (Candu) PHWRs at Rajasthan nuclear power plant started up in 1972 and 1980, and are also under safeguards. Rajasthan-1 was down-rated early in its life and has operated very little since 2002 due to ongoing problems and has been shut down since 2004 as the government considers its future. Rajasthan-2 was restarted in September 2009 after major refurbishment, and running on imported uranium at full rated power.

The 220 MWe PHWRs (202 MWe net) were indigenously designed and constructed by NPCIL, based on a Canadian design. The Kalpakkam (MAPS) reactors were refurbished in 2002-03 and 2004-05 and their capacity restored to 220 MWe gross (from 170). Much of the core of each reactor was replaced, and the lifespans extended to 2033/36. Kakrapar unit 1 was repaired and upgraded in 2009, as was Narora-2.

Following the Fukushima accident in March 2011, four NPCIL taskforces evaluated the situation in India and in an interim report in July made recommendations for safety improvements of the Tarapur BWRs and each PHWR type. The report of a high-level committee appointed by the Atomic Energy Regulatory Board (AERB) was submitted at the end of August 2011, saying that the Tarapur and Madras plants needed some supplementary provisions to cope with major disasters. The two Tarapur BWRs have already been upgraded to ensure continuous cooling of the reactor during prolonged station blackouts and to provide nitrogen injection to containment structures, but further work is recommended. Madras needs enhanced flood defences in case of tsunamis higher than that in 2004. The prototype fast breeder reactor (PFR) under construction next door at Kalpakkam has defences which are already sufficiently high, following some flooding of the site in 2004.

NUCLEAR PROGRAMME

The Tata Institute of Fundamental Research (TIFR), which came up in 1945, provided the base and the structure for organising the early efforts for India's nuclear energy programme. Hence, it is also referred to as the 'cradle of Indian nuclear power programme.'

The horrors of the nuclear holocaust unleashed in Hiroshima and Nagasaki were followed by a new vista of atoms for peace, of nuclear power generation, transformations in agriculture and medical diagnostics and therapy for using atomic Science & Technology. It's in this context that in April 1948, the Atomic Energy Bill was enacted with the primary objective to develop, control and use atomic energy for peaceful purposes, a clear departure from the policy followed by the nuclear powers, often forgotten or ignored by the international community. India under the leadership of Jawaharlal Nehru was dedicated to the peaceful uses of atomic energy but it couldn't wish away the lurking threat posed by nuclear weapons, and so per force Indian option for nuclear weapons was kept open. For both areas peaceful applications and the weapon option, Dr. Homi

Bhabha, the architect of India's nuclear programme, had a clear strategic vision and priorities.

Subsequently, India's Atomic Energy Commission was set up on 10 August, 1948 under the Chairmanship of Dr. Bhabha with the sole objective of formulation and implementation of the governmental policy relating to the development of nuclear power in India. In fact, India was among the first eight countries of the world to have an Atomic Energy Commission. The next step was the establishment of the Department of Atomic Energy (DAE) with Bhabha as its Secretary in August 1954, the objectives of which, inter alia included:

(i) Proper use of the latest technologies for the development of nuclear power.

(ii) To ensure nuclear power generation against global economic competition by exploiting natural resources.

(iii) Establishment of nuclear power reactors and safe use of radioactive substances.

(iv) Production of nuclear power for meeting the defence requirements of India.

(v) To understand the role of nuclear power in economic development.

(vi) To carry out programmes on isotopes and radiation technology.

(vii) To support basic research in nuclear energy and other frontier areas of science.

Thus, India directed its nuclear power programme for attaining self -reliance on a broad front which comprised mineral exploration and mining, extraction of uranium and zirconium, designing and fabricating reactor control systems, production of heavy water, making radio isotopes and promoting their use in agriculture, medicine, etc., safety of nuclear power reactors and monitoring the radiation level for ensuring a safe limit.

Key milestones of Nuclear Programme:

- Tarapur units 3&4, at Tarapur in Maharashtra, are the largest in India with a capacity of 540 MW for each unit.
- Rajasthan Atomic Power Station, Rawatbhata in Rajasthan, is India's first nuclear park.
- Narora Atomic Power Station is Asia's first nuclear power plant to obtain ISO-14001 accreditation for its environment management system.
- Kakrapar Atomic Power Station was the first Indian nuclear power plant to undergo a peer review by an international team of experts from the World Association of Nuclear Operators (WANO). All other Indian nuclear power stations are also peer reviewed by WANO.

N-POWER POLICY OF INDIA

In the beginning of the Eighth Plan, it was aimed to produce 10,000 MW of power by 2000, to increase the nuclear power share in total power production. In order to achieve the above objective, the Central Government established Nuclear Power Corporation to coordinate various nuclear power organisations, in 1989. But, it was unlikely to achieve this objective, particularly after the disintegration of USSR, and then the target was reduced to 9000 MW. However, still it was not possible in the near future. Indian scientists have planned to achieve the above target in future through the development of three generations of nuclear reactors:

(a) **1st Generation Nuclear Reactors:** These are the pressurized Heavy Water reactors with the capacity of 235 HW each and use natural uranium as fuel. Plutonium is the by-product.

(b) **2nd Generation Nuclear Reactors:** These are planned to be the fast breeder reactors with the capacity of 500 HW each, and use Plutonium, a by-product of the first generation reactors, as the fuel.

(c) **3rd Generation Nuclear Reactors:** These are also planned to be the fast breeder reactors. This generation reactors will use fuel derived from second generation reactors and convert more Thorium into Uranium-233. So, the plan is to use vast Thorium deposits found in India.

India has established 1st generation nuclear reactors at Tarapur, Kalpakkam, Narora and Rawatbhata. Other two reactors of this grade are located at Kakrapar (Gujarat) and Kaiga (Karnataka). The first generation reactors have reached commercial stage. The generation of power from nuclear energy began in India in 1969 with the commissioning of first atomic power station at Tarapore (TAPS).

The second generation reactor has commenced with the successful operation of the Fast Breeder Test Reactor (FBTR) named KAMINI (Kalpakkam Mini Reactor) in 1985 at the Indira Gandhi Centre for Atomic Research (IGCAR) at Kalpakkam in Tamil Nadu.

The Kalpakkam reactor is the world's first fast-breeder reactor. The reactor has successfully used the mixed uranium - plutonium carbide fuel, hitherto untried elsewhere. Progress has also been made in the third generation reactor with the successful development of a U-233 based fuel. Work has commenced on the design of an Advanced Heavy Water Reactor which will make the use of thorium in power generation.

Chief Features of FBTR

(i) The nuclear chain reaction in the uranium fuel in a thermal reactor is sustained by slowing down the neutrons by a moderator. The chain reaction in FBTR is sustained by fast neutrons. The number of neutrons released per fission is more compared to that of thermal reactor. The extra neutrons are available for absorption in uranium-238 to transform it to fissile plutonium-239.

(ii) In a thermal reactor typically only about 1-2 per cent of the natural uranium is utilized whereas in FBTRs, the utilization is increased 60 to 70 times.

(iii) Considering the nuclear and heat transfer properties of various possible coolants, Sodium has been universally accepted as the coolant for FBTRs. In Thermal reactors water is used as a coolant.

(iv) The radioactivity released to the atmosphere and the radiation dose received by the operating personnel in FBTRs has been much less compared to the water control reactors.

(v) FBTR is based on the design of the Rhapsodic reactor, France.

(vi) The fuel used to FBTR is mixed carbide of plutonium and natural uranium. The carbide fuel has higher breeding ratio due to its higher density and thermal conductivity.

Why India Prefers Fast Breeders : A fast breeder reactor (FBR) breeds more fuel than it consumes that is it produces more plutonium than it consumes while generating power. For a uranium scarce country like India, it is an attractive technology. Plutonium produced in the thermal reactors as spent fuel is ideally suitable as the fuel material for use in the FBR due to its high fission neutron yield. Since the number of neutrons produced in plutonium fission is high, it helps to produce more plutonium from uranium (U-238) used as a blanket surrounding the fuel core of the FBR. FBR also consumes less uranium and that too very effectively. While the thermal reactors exploit only 0.6 per cent of uranium, a FBR utilises 70-75 per cent of it. Thus, it leaves less radioactive waste to dispose of. In fact, many scientists in India prefer FBRs for this reason.

RESEARCH AND DEVELOPMENT

The Atomic Energy Commission, set up in 1948, is responsible for formulating the policy for all atomic energy activities in the country. The Department of Atomic Energy (DAE) is the executive agency for implementing the atomic energy programme. There are three public sector undertakings under the administrative control of DAE:

1. Indian Rare Earth's Limited (IREL) which has set up the Orissa Sands Complex (OSCOM) at Chhattarpur for enhancing Rare Earth's production,
2. Uranium Corporation of India Limited (UCIL) with mines at Jaduguda in Jharkhand, and
3. Electronics Corporation of India Limited (ECIL) which manufactures electronic instruments and equipment for nuclear as well as non-nuclear users.

The Nuclear Power Corporation of DAE is responsible for design, construction and operation of nuclear power stations. Presently, Nuclear Power Corporation is operating 20 nuclear power reactors, including 18 PHWRs and 2 Boiling Water Reactors (BWR), with an installed capacity of 4,780 MW; six nuclear power reactors with an aggregate capacity of

4,800 MW are under different stages of construction. The Nuclear Fuel Complex (NFC) at Hyderabad fabricates nuclear fuel for the power reactors. NPCIL indigenously scaling up the capacity of PHWRs from 220 MW to 700 MW and attaining and sustaining over 90% availability factor. NPCIL Power Stations are:

- Tarapur Atomic Power Station (TAPS)
- Rajasthan Atomic Power Station (RAPS)
- Madras Atomic Power Station (MAPS)
- Kaiga Generating Station
- Narora Atomic Power Station (NAPS)
- Kakrapar Atomic Power Station (KAPS)

There are three research reactors in operation at the Bhabha Atomic Research Centre at Trombay. These are: APSARA (one MW swimming pool reactor), CIRUS (40 MW thermal reactor) and DHRUVA (100 MW thermal reactor). A mini pool 30 KW reactor KAMINI, containing Uranium -233 fuel is in an advanced stage of construction at Kalpakkam. Plutonium-fuelled fast reactor PURNIMA-I was built at Trombay in 1972. Later in 1984, it was modified as a homogenous reactor PURNIMA-II which uses Uranium-233 fuel in the form of a solution. PURNIMA-III is the modified form of PURNIMA-II to test the KAMINI core. PURNIMA-III is a zero-energy reactor and is the world's first experimental research reactor to use Uranium-233 as fuel.

The Indira Gandhi Centre for Atomic Research (IGCAR) at Kalpakkam carries out research and development pertaining to latest reactor technology. The major facility at the centre is the indigenously constructed 40 MW and 13 MW Fast Breeder Test Reactor (FBTR). The FBTR is a major step in the country's nuclear power programme. It has paved the way for using our vast thorium resources. The Centre for Advanced Technology was set up in 1984 at Indore to spearhead research in high technology fields such as fusion, lasers and accelerators. The country's first heavy ion accelerator of medium energy capacity called, 'Pelletron' has become fully operational at the TIFR. Pelletron is based on a tandem Van De Graff accelerator with 14 million volts terminal voltage.

The Atomic Energy Regulatory Board (AERB), set up in 1985, carries out regulatory and safety functions as envisaged under the Atomic Energy Act-1962. It lays down safety standards, and frames rules and regulations in regard to regulatory and safety requirements.

The Fast Breeder Test Reactor with a design capacity of 40 MW thermal and 13 MW electrical power, attained its first criticality on October 18, 1985 at the Indira Gandhi Centre for Atomic Research (IGCAR), Kalpakkam. The fuel used in FBTR is a mixed carbide of plutonium and natural uranium, the proportion of the latter being 30 per cent. Such a composition is being used for the first time in the world. The technology for the fabrication of the fuel was developed at the Radio-metallurgy Division of BARC. The next step after FBTR is to design and construct a Prototype Fast Breeder Reactor (PFBR) of 500 MW capacity. The 500 MW size of reactor has been selected to match the size of coal fired thermal power stations and PHWRs. The PFBR will be cooked by sodium as in the case of FBTR, but it will use the pool-type concept which is more favoured in recent times due to better safety and more operating experience.

RESEARCH CENTRES

Bhabha Atomic Research Centre (BARC), Trombay, Mumbai, is the country's premier nuclear research facility. BARC is a multi-disciplinary research centre with extensive infrastructure for advanced research and development covering the entire spectrum of nuclear science, engineering and related areas. BARC's core mandate is to sustain peaceful applications of nuclear energy, primarily for power generation.

Tata Institute of Fundamental Research (TIFR), Mumbai, is a national centre for advanced research in nuclear physics, mathematics and high - energy physics and astrophysics.

Indira Gandhi Centre for Atomic Research (IGCAR) is a multi-disciplinary R & D centre mainly concerned with FBR technology and associated fuel cycle, material sciences, fuel reprocessing and sodium technology. IGCAR has developed several relatively cheap and highly sensitive electrochemical sensors to continuously monitor the purity of liquid sodium used as coolant in FBR. As a next step, design of 500 MWe proto-type has been completed and the same is undergoing review.

Centre for Advanced Technology (CAT), established in Indore in 1984, focuses its research on lasers, accelerators, high vacuum technology and cryogenics. It has set up two synchrotron Radiation Sources (INDUS - 1 & INDUS -2) and developed versatile lasers such as 70 W and 400 W carbon dioxide lasers for industrial, medical and research applications. The Variable Energy Cyclotron Centre (VECC) at Kolkata is a national facility for advanced research in nuclear physics, nuclear chemistry, production of novel medical isotopes and study of radiation damage in reactor materials. The Seismic Activity Monitoring Station at Gauribidanur near Bengaluru helps in detection and identification of underground nuclear explosions anywhere in the world.

Raja Ramanna Centre for Advanced Technology (RRCAT) was established in May, 1984 by the Department of Atomic Energy, India to expand the activities carried out at Bhabha Atomic Research Centre (BARC), Mumbai, in two frontline areas of science and technology namely Lasers and Accelerators. Since then, the centre has rapidly grown into a premier institute for research and development in lasers, accelerators and their applications.

Variable Energy Cyclotron Centre (VECC) is a premier R & D unit of the Department of Atomic Energy, Government of India and one of the constituent institutions of Homi Bhabha National Institute. This Centre is dedicated to carry out frontier research and development in the fields of Accelerator Science & Technology, Nuclear Science (Theoretical and Experimental), Material Science, Computer Science & Technology and in other relevant areas.

Atomic Minerals Directorate for Exploration and Research's prime mandate is to identify and evaluate uranium resources required for the successful implementation of Atomic Energy programme of the country. For implementing this important task investigations are taken up across the length and breadth of the country from Regional Exploration & Research Centres located at New Delhi , Bengaluru, Jamshedpur, Shillong, Jaipur, Nagpur and Hyderabad (Headquarter & South Central Region).

INDIAN RESEARCH REACTORS

There are seven Research Reactors working in the country named as: Apsara, Cirus, Kamini, Purnima I, Purnima II, Purnima III and Zerlina. India's first research reactor, APSARA, a 1 MWe 'swimming pool' type, built indigenously, became operational at Trombay in 1956, heralding a novel nuclear age in Asia. ZERLINA, a zero energy tank type research reactor was built indigenously in 1961. CIRUS, a tank type reactor of 40 MWe was commissioned at Tarapur in 1960 with the assistance of Canada, for engineering experimental work with facilities for materials testing and radioisotope production. Moreover, with the commissioning of PURNIMA I & PURNIMA II respectively in 1972 and 1984, India achieved an important milestone in its 'fast reactor' programme. DHRUVA, an indigenous tank type 100 MWe reactor went into operation in 1985 for research in advanced nuclear physics and for isotope production. PURNIMA III, also a tank type reactor of 1 MWe attained criticality on 9 November, 1990. The sole objective of this reactor is to conduct mock up studies for Kamini reactor.

The construction of KAMINI (Kalpakkam Mini Reactor) in 1996 marks an important land mark in India's endeavour at mastering uranium -233-based nuclear fuel. Designed on the basis of Rapsody reactor of France, it is the only reactor in the world which uses U-233 as fuel. It will be mainly used to study the highly radioactive fuel elements which are discharged from FBTR at Kalpakkam. This will help in the development of high performance plutonium fuel elements for the proto-type FBR to be built in the next century. It is also called the 'Zero - Power' reactor as the amount of electricity produced (40 MWe) is consumed by the reactor itself for research purposes. The design for India's next generation of reactors, called Advanced Heavy Water Reactors (AHWRs), which will employ thorium-based fuel, has already been prepared.

BARC has developed comprehensive technology for industrial operations in fuel reprocessing and waste management. Reprocessing plants are operational in Trombay and Tarapur. The first fuel reprocessing plant at Trombay is based on hot - cell technology. A comprehensive waste management technology for handling and safe disposal of all types of waste, generated in nuclear industries, has been perfected by the centre. It has also undertaken the recent studies of high-energy-density systems.

BARC has been able to develop a plasma - based aerosol generator and also achieved plasma coatings of alumina on carbon steel moulds. Moreover, BARC has also been working on the pulsed electron beam system and has developed Kilo Ampere Linear Injector (KALI - 5000) which finds applications in high power microwave generation and pulsed intense neutron source.

BARC has undertaken an extensive programme on laser cooling and trapping of atoms. Very recently, it has been able to develop the atom laser, which uses coherent beam of massive bosons. The objectives of this programme are two-fold: first, to study the ultra-high resolution spectrospectry for fundamental physics experiments and second, experiments leading to Bose - Einstein condensation. Following the global interest in fabricating high temperature superconducting materials, BARC has succeeded in synthesising a single phase superconducting compound of bismuth-lead-calcium-strontium and copper oxide with a temperature equivalent to 120K.

India's tokamak, Aditya, was installed in 1989 at the Institute of Plasma Research in Gandhinagar, Ahmedabad. It is an indigenous effort, which can generate plasma at 5 million degree Celsius. The discoveries made by Aditya in plasma research and edge turbulence have had an impact on the world fusion research programme.

BHAVINI

The Department of Atomic Energy (DAE) in its Golden Jubilee Year has set up its fifth public sector unit -Bharatiya Nabhikiya Vidyut Nigam Limited (BHAVINI). BHAVINI is a wholly owned Enterprise of Government of India under the administrative control of the Department of Atomic Energy (DAE) incorporated on 22nd October 2003 as Public Limited Company. It was incorporated under the Companies Act 1956, with an authorized share capital of Rs. 5000 crore, BHAVINI is responsible for the construction and commissioning of the country's first 500 MWe Fast Breeder Reactor (FBR) project at Kalpakkam, Tamil Nadu and to pursue construction, commissioning, operation and maintenance of subsequent Fast Breeder Reactors for generation of electricity in pursuance of the schemes and programmes of Government of India under the provisions of the Atomic Energy Act,1962. It is a forerunner of commercial fast breeder power reactors in the country and in this regard, it marks a major step in the country's efforts to ensuring energy security through the use of atomic energy.

BHAVINI is currently constructing a 500MWe Prototype Fast Breeder Reactor (PFBR) at Kalpakkam. The PFBR is the forerunner of the future Fast Breeder Reactors and is expected to provide energy security to the country. The PFBR is being built with the design and technology developed at the Indira Gandhi Centre for Atomic Research (IGCAR) located at Kalpakkam. The four other PSUs under the Department are Nuclear Power Corporation of India Ltd. (NPCIL), Electronics Corporation of India Ltd. (ECIL), Indian Rare Earths Ltd. (IREL) and Uranium Corporation of India Ltd. (UCIL).

The engineering design and technical expertise for BHAVINI will be drawn from the Indira Gandhi Centre for Atomic Research (IGCAR), which has accumulated over two decades of experience in fast breeder reactor technology. NPCIL, which will take 5% of the equity in the new company, will provide the expertise for project management to enable timely construction and commissioning of the project. NPCIL is at present operating 20 nuclear power reactors and setting up 3 more at different locations in the country.

When completed, PFBR would produce electricity through recycle of plutonium and depleted uranium recovered from the spent fuel of Pressurized Heavy Water Reactors being operated by NPCIL.

URANIUM FUEL CYCLE

DAE's Nuclear Fuel Complex at Hyderabad undertakes refining and conversion of uranium, which is received as magnesium diuranate (yellow cake) and refined. The main 400 t/yr plant fabricates PHWR fuel (which is unenriched). A small (25 t/yr) fabrication plant makes fuel for the Tarapur BWRs from imported enriched (2.66% U-235) uranium. Depleted uranium oxide fuel pellets (from reprocessed uranium) and thorium oxide pellets are also made for PHWR fuel bundles. Mixed carbide fuel for FBTR was first fabricated by Bhabha Atomic Research Centre (BARC) in 1979.

Heavy water is supplied by DAE's Heavy Water Board, and the seven plants are working at capacity due to the current building programme.

A very small enrichment plant - insufficient even for the Tarapur reactors - is operated by DAE's Rare Materials Plant at Ratnahalli near Mysore. Some centrifuge R&D is undertaken by BARC.

Fuel fabrication is by the Nuclear Fuel Complex in Hyderabad, which is setting up a new 500 t/yr PHWR fuel plant at Rawatbhata in Rajasthan, to serve the larger new reactors. Each 700 MWe reactor is said to need 125 t/yr of fuel. The company is proposing joint ventures with US, French and Russian companies to produce fuel for these reactors.

Reprocessing: Used fuel from the civil PHWRs is reprocessed by Bhabha Atomic Research Centre (BARC) at Trombay, Tarapur and Kalpakkam to extract reactor-grade plutonium for use in the fast breeder reactors. Small plants at each site were supplemented by a new Kalpakkam plant of some 100 t/yr commissioned in 1998, and this is being extended to reprocess FBTR carbide fuel. Apart from this all reprocessing uses the Purex process. Further capacity is being built at Tarapur and Kalpakkam, to come on line by 2010. India will reprocess the used fuel from the Kudankulam reactors and will keep the plutonium.

In 2003, a facility was commissioned at Kalpakkam to reprocess mixed carbide fuel using an advanced Purex process. Future FBRs will also have these facilities co-located.

The PFBR and the next four FBRs to be commissioned by 2020 will use oxide fuel. After that it is expected that metal fuel with higher breeding capability will be introduced and burn-up is intended to increase from 100 to 200 GWd/t.

Under plans for the India-specific safeguards to be administered by the IAEA in relation to the civil-military separation plan several fuel fabrication facilities will come under safeguards.

Uranium Resources in India

India's uranium resources are modest, with 102,600 tonnes U as reasonably assured resources (RAR) and 37,200 tonnes as inferred resources in situ (to $260/kgU) at January 2011. In February 2012, 152,000 tU was claimed by DAE. Accordingly, India expects to import an increasing proportion of its uranium fuel needs. In 2013 it was importing about 40% of uranium requirements.

Mining and processing of uranium is carried out by Uranium Corporation of India Ltd (UCIL), a subsidiary of the Department of Atomic Energy (DAE). The Company is having its mining operations at Bagjata, Jaduguda, Bhatin, Narwapahar, Turamdih underground mines and Banduhurang opencast mines and upcoming mining projects at Mohuldih in East Singhbhum district of Jharkhand and at Tummalapalle mining project in Andhra Pradesh and Gogi mining project at Karnataka. It has two processing plants at Jaduguda and Turamdih and an upcoming milling project at Tummalepalle in Andra Pradesh. KPM opencast mining and milling project at Meghalaya is in the pipeline.

Plans were announced to invest almost US$ 700 million to open further mines in Jharkhand at Banduhurang, Bagjata and Mohuldih; in Meghalaya at Domiasiat-Mawthabah (with a mill) and in Andhra Pradesh at Lambapur-Peddagattu (with mill 50km away at Seripally), both in Nalgonda district.

In Jharkhand, Banduhurang is India's first open cut mine and was commissioned in 2007. Bagjata is underground and was opened in December 2008, though there had been earlier small operations 1986-91. A new mill at Turamdih in Jharkhand, with 3000 t/day capacity, was commissioned in 2008. The Mohuldih underground mine of Jharkhand has been developed as a modern underground mine and was commissioned by Chairman & Managing Director, UCIL on 17th April 2012. UCIL now operates six underground mines and one openpit mine in the state of Jharkhand in addition to an underground mine in Andhra Pradesh.

In Andhra Pradesh there are three kinds of uranium mineralisation in the Cuddapah Basin, including unconformity-related deposits in the north of it. The northern Lambapur-Peddagattu project in Nalgonda district 110 km southeast of Hyderabad has environmental clearance for one open cut and three small underground mines (based on some 6000 tU resources at about

0.1%U) but faces local opposition. In August 2007 the government approved a new US$ 270 million underground mine and mill at Tummalapalle near Pulivendula in Kadapa district, at the south end of the Basin and 300 km south of Hyderabad, for commissioning has been initiated. A further northern deposit near Lambapur-Peddagattu is Koppunuru, in Guntur district.

In Meghalaya, close to the Bangladesh border in the West Khasi Hills, the Domiasiat-Mawthabah mine project (near Nongbah-Jynrin) is in a high rainfall area and has also faced longstanding local opposition partly related to land acquisition issues but also fanned by a campaign of fear mongering. For this reason, and despite clear state government support in principle, UCIL does not yet have approval from the state government for the open cut mine at Kylleng-Pyndeng-Shahiong (also known as Kylleng-Pyndengshohiong-Mawthabah and formerly as Domiasiat) though pre-project development has been authorised on 422 ha.

India's Forest and Environment Ministry has given clearance to the UCIL to start uranium mining in Meghalaya. UCIL has earmarked an investment of $229-million to develop the uranium reserves in Meghalaya. However, the environmental approval in December 2007 for a proposed uranium mine and processing plant here and for the Nongstin mine has been reported. There is sometimes violent opposition by NGOs to uranium mine development in the West Khasi Hills, including at Domiasiat and Wakhyn, which have estimated resources of 9500 tU and 4000 tU respectively. Tyrnai is a smaller deposit in the area. The status and geography of all these is not known. The clearance comes despite decades of opposition to uranium exploration and mining in the province by locals claiming to be victims of radiation and toxic waste resulting from exploratory drillings by UCIL. However, plans for an opencast mine to extract the mineral from the West Khasi Hills have been hanging fire since 1992 on fears of radiation and environmental hazards.

However, India has reserves of 290,000 tonnes of thorium - about one quarter of the world total, and these are intended to fuel its nuclear power programme for a longer-term.

In September 2009 state-owned oil company ONGC proposed to form a joint venture with UCIL to explore for uranium in Assam.

Uranium Imports

By December 2008, Russia's Rosatom and Areva from France had contracted to supply uranium for power generation, while Kazakhstan, Brazil and South Africa were preparing to do so. The Russian agreement was to provide fuel for PHWRs as well as the two small Tarapur reactors, the Areva agreement was to supply 300 tU.

In February 2009 the actual Russian contract was signed with TVEL to supply 2000 tonnes of natural uranium fuel pellets for PHWRs over ten years, costing $780 million, and 58 tonnes of low-enriched fuel pellets for the Tarapur reactors. The Areva shipment arrived in June 2009. RAPS-2 became the first PHWR to be fuelled with imported uranium, followed by units 5 & 6 there.

In January 2009 NPCIL signed a memorandum of understanding with Kazatomprom for supply of 2100 tonnes of uranium concentrate over six years and a feasibility study on building Indian PHWR reactors in Kazakhstan. Under this agreement, 300 tonnes of natural uranium was to come from Kazakhstan in the 2010-11 year. Another 210 t would come from Russia. A further agreement in April 2011 covered 2100 tonnes by 2014. In March 2013 both countries agreed to extend the civil nuclear cooperation agreement past 2014.

In September 2009 India signed uranium supply and nuclear cooperation agreements with Namibia and Mongolia. In March 2010 Russia offered India a stake in the Elkon uranium mining development in its Sakha Republic, and agreed on a joint venture with ARMZ Uranium Holding Co. In 2013 negotiations for a bilateral supply treaty with Australia were to commence.

In July 2010 the Minister for S&T reported that India had received 868 tU from France, Russia & Kazakhstan in the year to date: 300 tU natural uranium concentrate from Areva, 58 tU as enriched UO_2 pellets from Areva, 210 tU as natural uranium oxide pellets from TVEL and 300 tU as natural uranium from Kazatomprom.

As of August 2010 the DAE said that seven reactors (1400 MWe) were using imported fuel and working at full power, nine reactors (2630 MWe) used domestic uranium.

THORIUM FUEL CYCLE DEVELOPMENT IN INDIA

The long-term goal of India's nuclear programme has been to develop an advanced heavy-water thorium cycle. The first stage of this employs the PHWRs fuelled by natural uranium, and light water reactors, to produce plutonium.

Stage 2 uses fast neutron reactors burning the plutonium to breed U-233 from thorium. The blanket around the core will have uranium as well as thorium, so that further plutonium (ideally high-fissile Pu) is produced as well as the U-233.

Then in Stage 3, Advanced Heavy Water Reactors (AHWRs) burn the U-233 from stage 2 and this plutonium with thorium, getting about two thirds of their power from thorium.

In 2002 the regulatory authority issued approval to start construction of a 500 MWe prototype fast breeder reactor at Kalpakkam and is in an advanced stage of completion, construction by BHAVINI. The unit is expected to be operational in 2013, fuelled with uranium-plutonium oxide (the reactor-grade Pu being from its existing PHWRs). It will have a blanket with thorium and uranium to breed fissile U-233 and plutonium respectively. This will take India's ambitious thorium programme to stage 2, and set the scene for eventual full utilisation of the country's abundant thorium to fuel reactors. Six more such 500 MWe fast reactors have been announced for construction, four of them by 2020.

So far about one tonne of thorium oxide fuel has been irradiated experimentally in PHWR reactors and has reprocessed and some of this has been reprocessed, according to BARC. A reprocessing centre for thorium fuels is being set up at Kalpakkam.

Design is largely complete for the first 300 MWe AHWR, though no site has yet been announced. It will have vertical pressure tubes in which the light water coolant under high pressure will boil, circulation being by convection. A large heat sink - "Gravity-driven water pool" - with 7000 cubic metres of water is near the top of the reactor building. In April 2008 an AHWR critical facility was commissioned at BARC "to conduct a wide range of experiments, to help validate the reactor physics of the AHWR through computer codes and in generating nuclear data about materials, such as thorium-uranium 233 based fuel, which have not been extensively used in the past." It has all the components of the AHWR's core including fuel and moderator, and can be operated in different modes with various kinds of fuel in different configurations.

In 2009 the AEC announced some features of the 300 MWe AHWR – It is mainly a thorium-fuelled reactor with several advanced passive safety features to enable meeting next generation safety requirements such as three days grace period for operator response, elimination of the need for exclusion zone beyond the plant boundary, 100-year design life, and high level of fault tolerance. The advanced safety characteristics have been verified in a series of experiments carried out in full-scale test facilities. Also, per unit of energy produced, the amount of long-lived minor actinides generated is nearly half of that produced in current generation Light Water Reactors. Importantly, a high level of radioactivity in the fissile and fertile materials recovered from the used fuel of AHWR, and their isotopic composition, preclude the use of these materials for nuclear weapons.

At the same time the AEC announced an LEU version of the AHWR. This will use low-enriched uranium plus thorium as a fuel, dispensing with the plutonium input. About 39% of the power will come from thorium (via in situ conversion to U-233, of two thirds in AHWR), and burn-up will be 64 GWd/t. Uranium enrichment level will be 19.75%, giving 4.21% average fissile content of the U-Th fuel. Plutonium production will be less than in light water reactors, and the fissile proportion will be less and the Pu-238 portion three times as high, giving inherent proliferation resistance. The design is intended for overseas sales, and the AEC says that "the reactor is manageable with modest industrial infrastructure within the reach of developing countries".

NUCLEAR ENERGY PARKS IN INDIA

In line with past practice such as at the eight-unit Rajasthan nuclear plant, NPCIL intends to set up five more "Nuclear Energy Parks", each with a capacity for up to eight new-generation reactors of 1,000 MWe, six reactors of 1600 MWe or simply 10,000 MWe at a single location. By 2032, 40-45 GWe would be provided from these five. NPCIL says it is confident of being able to start work by 2012 on at least four new reactors at all four sites designated for imported plants. The new energy parks are to be:

Kudankulam in Tamil Nadu: Three more pairs of Russian VVER units, making 9200 MWe. Environmental approval has been given for the first four. A general framework agreement for construction of units 3 & 4 was planned to be signed in mid 2010, with equipment supply and service contracts soon after, but these were delayed on account of supplier liability questions, with India wanting the units to come under its 2010 vendor liability law. In July 2012 Russia agreed to $3.5 billion in export financing for units 3 & 4, to cover 85% of their cost. A further credit line of $800 million is available to cover fuel supplies. The credit lines carry interest at 4% pa and would be repayable over 14 years and 4 years respectively, from one year after the start of power generation. The Indian government said it expected to take up the credit offers to the value of $3.06 billion, about 53% of the $5.78 billion estimated total project cost. In March 2013 cabinet approved construction of units 3 & 4, and site work began.

Jaitapur in Maharashtra: An EUR 7 billion framework agreement with Areva was signed in December 2010 for the first two EPR reactors, along with 25 years supply of fuel. Environmental approval has been given for these, and site work was planned to start in 2011 with a view to 2013 for construction. In July 2009 Areva submitted a bid to NPCIL to build the first two EPR units, which will have Alstom turbine-generators, accounting for about 30% of the total EUR 7 billion plant cost. The site will host six units, providing 9600 MWe. Areva now hopes to obtain export credit financing and sign a contract which would put the first two units on line in 2020 and 2021. In 2013 negotiations continued and the government said it expected the cost of the first two units to be 1,20,000 crore ($21 billion).

Mithi Virdi in Gujarat will host up to six Westinghouse AP1000 units built in three satages. NPCIL says it has initiated pre-project activities here, with groundbreaking in 2012. A preliminary environmental assessment for the whole project was completed in January 2013. Westinghouse signed an agreement with NPCIL in June 2012 to launch negotiations for an early works agreement which was expected in a few months. The first stage of two units is due on line in 2019-20, the others to 2024.

Kovvada in Andhra Pradesh will host six GE Hitachi ESBWR units. GE Hitachi said in June 2012 that it expected soon to complete an early works agreement with NPCIL to set terms for obtaining approval from the Government for the project. Site preparation is under way, and a preliminary environmental assessment is being prepared.

Haripur in West Bengal to host four or six further Russian VVER-1200 units, making 4800 MWe. NPCIL says it has initiated pre-project activities here, with groundbreaking planned for 2012. However, strong local opposition led the West Bengal government to reject the proposal in August 2011, and change of site to Orissa state has been suggested

Kumharia and Gorakhpur in the Fatehabad district in Haryana is earmarked for four indigenous 700 MWe PHWR units and the AEC had approved the state's proposal for a 2800 MWe nuclear power plant.

Bargi or Chuttka in Madhya Pradesh is also designated for two indigenous 700 MWe PHWR units.

At Markandi (Pati Sonapur) in Orissa there are plans for up to 6000 MWe of PWR capacity.

NUKE COMMAND

Formalizing the country's nuclear command and control structure, India's cabinet on January 4, 2003 decided to place ultimate control of the country's nuclear forces in the hands of a political council chaired by then Prime Minister Atal Behari Vajpayee. It took more than four and a half years after declaring itself a nuclear weapon power, to make public a set of political principles and administrative arrangement to manage its arsenal of atomic weapons. The Cabinet Committee on Security (CCS) met to review progress in implementing India's nuclear doctrine, the state of readiness of its strategic forces and the procedures for their command and control.

Through the CCS statement the government has tried to share information on some key aspects of its nuclear weapons management with the Indian public and the world. Although the broad outline of India's nuclear doctrine was known for a while, the nature of its command and control over the atomic arsenal had remained unclear.

N-Command Structure: The government accounted the formation of "Nuclear Command Authority" (NCA) which will be solely responsible for ordering a nuclear strike. The NCA will have two bodies: Political council and Executive council.

Political Council: Political council is the sole body, which can authorize the use of nuclear weapon. It represents the civilian leadership. As the first among equal, the Prime Minister will symbolically have his finger on the nuclear button. An alternative chain of command has also been approved to take charge in case the command chain is disturbed in any way. It has not been made public besides the Prime Minister, as the chairperson, the political council will also be represented by the Home Minister, the Defence Minister, the Foreign Minister and the Finance Minister.

Executive Council: The executive council chaired by the National Security Advisor to the Prime Minister, will provide inputs for decision making by the National command Authority and execute the directives given to it by the Political council. The real strength of the council has not been announced by the Cabinet Committee on Security.

The cabinet committee also approved the appointment of a "Commander-in-chief, strategic forces command" who would be responsible for the administration of the nuclear force. It will be the custodian of all nuclear weapons and delivery systems. It will also formulate the strategy for retaliation and advise the chiefs of staff committee and actually fire the nukes. A senior officer of the Indian Air Force is expected to be nominated to the post. Once the "chief of staff committee" receives inputs from the strategic forces command, it will provide military advice to the political council of the nuclear command authority through the executive council. The final decision has to be made by the leader (Prime Minister) in his individual capacity based on military advice, especially when one is going to act only in retaliation.

The security committee expressed satisfaction with the overall preparedness of its arsenal and reiterated the decision to limit India's capability to a "credible minimum deterrent" and the commitment to use nuclear weapons only in retaliation. India also reaffirmed that it would not use the weapons against non-nuclear weapon powers. Against nuclear weapon powers, its strategy would remain on the policy of "No-first use". India is committed not to use nuclear arms first in any conflict, but only in retaliation for a nuclear attack against it or its forces. But in the event of a major attack involving chemical or biological weapons, India reserves the right to use nuclear weapons.

The nuclear draft doctrine was released by the National Security Advisory Board set up after May 1998 tests, in August 1999. The announcement has confirmed the essence of that draft as official policy. The only new element in the doctrine is the interesting caveat it has introduced to its No-first use posture. The United States has retained a similar option to prevent nations with chemical and biological weapons from assuming that the use of these weapons of mass destruction will not invite a nuclear response. While India has consciously chosen not to use nuclear weapons first, it warned potential adversaries that the nuclear retaliation to a first strike will be massive and designed to inflict unacceptable damage.

Alternative N-Command: India has more than one alternative nuclear command structure in place. In the event of a surprise attack, these alternative command authorities will be in position to take retaliatory action. An alternative command puts the final touch to India's nuclear deterrent. If an enemy knows that such a command exists, but does not know where they are; this will deter a surprise attack.

India may have two or three alternative command structures. Both the location and nature of the command will remain a secret. This will never be disclosed. The succession ladder of various officials had also been worked out. During the Kargil war and mobilization crisis, India had made adequate preparation on the nuclear front and could have retaliated if there had been any need.

The civil chain of command has also not been made public. In a setting in which the Prime Minister who has been vested with the sole authority over the nuclear button, is unable to function, conventional nuclear command and control hierarchy demands that the next in the line of succession be identified. In the US, for instance, where the President has authority over the nuclear button, the structure identifies 16 others in the line of succession.

India has also full-fledged delivery system. There are multiple agencies tasked with responsibility on nuclear issues. Some of these, like the Department of Atomic Energy are Civil and some, like the Army's 333 Missiles Group, are military. India's Prithvi and Agni missiles and its Mi ranges and Sukoi-30 fighter bombers are nuclear capable. A sea based nuclear deterrent will be ready once India has submarine-launched cruise missile.

INDIAN NUCLEAR DRAFT

The acquisition of an advanced nuclear weapon capability also necessitated the formulation of a nuclear draft. It was in this context that the Indian Nuclear Draft was released by National Security Advisory Board of India on 17 Aug. 1999. This document prepared on India's nuclear doctrine was designed for informal public debate, details regarding the configuration of nuclear forces and targeting schemes flowing from the broad framework.

The prime objective of India is to achieve economic, political, social, scientific and technological developments within a peaceful and democratic framework. It considers India's security as an integral component of its development process. The notion adheres firmly to its continued commitment to certain principles - (a) to restrict the purpose of nuclear weapons to credible minimum deterrence against nuclear weapons only and not visualizing use of these weapons in nuclear scenario and (b) to have commitment to a policy of 'no first use'.

The draft earnestly seeks to enhance the credibility of India's nuclear deterrence and acquire adequate retaliatory capability. Deterrence requires that India maintains: (a) sufficient survivable and prepared nuclear force; (b) robust communication & control system; (c) effective intelligence; (d) comprehensive planning and training for operations; (e) the will to employ nuclear forces and weapons. Special focus is to be given to ensure nuclear safety and improvement in R&D programmes to sustain technological advancements. India will focus on developing a strong disaster control system and continue to strive for making a nuclear-free world. In a nutshell, India's nuclear doctrine firmly adheres to a tolerant defensive policy as well as explicitly reflects its nuclear prowess. The doctrine is indicative of the endurance, tolerance, strength and greatness of a nuclear India.

NUCLEAR POWER VISION

The vision 2020 document of 2000 and the Tenth Five-Year Plan (2002-2007) say nuclear power is India's insurance for energy security. "Aggressively build capabilities and capacity in nuclear power to progressively raise its share in India's fuel mix," according to the Tenth Five Year Plan that advocated for more nuclear energy. To achieve this, it suggested partial privatisation of nuclear power generation and market financing for projects.

India would need 500,000 MW of power by 2050. It has a vast coal reserve, but there are doubts whether all of it can be mined. The country's hydrocarbon resources won't last long and it will become even more dependent on imports. India would have harnessed all its hydroelectricity resources by 2050, and non-conventional energy is unlikely to be cost-effective. A mix of all these resources could help but DAE feels that nuclear energy is the only solution, which can fill the gap between demands and supply. The government agrees and has decided to cut the estimated 70 per cent contribution of coal-based power to 62 per cent by 2020 and compensate the shortfall through nuclear stations. The government wants that by 2050 nuclear reactors supply 25 per cent of India's total power production. The DAE is sure that it can generate 10,000 MW of nuclear power by 2010 and 20,000 MW by 2020. Its confidence is based on an indigenous technology, which recycles spent fuel of thermal nuclear reactors to get plutonium for FBRs. The Nuclear Power Corporation says it will generate 1,300 MW during the Tenth Five Year Plan and 4,660 MW during Eleventh Plan to make up for the first 10,000 MW target within the next six years.

Three-stage nuclear energy programme aims at generating 20,000 MW of electricity by 2020. The programme will begin by using scarce uranium in the first stage to thorium in the third stage by 2020.

Stage-I: Twenty-one pressurized heavy water reactors using natural uranium to generate 10,000 MW of power by 2010.

Stage-II: Fast breeder reactors (FBRs) will use plutonium extracted from spent uranium fuel of Stage-I to generate 10,000 MW by 2020, which means 12.5 per cent of India's electricity need.

Stage III: Advanced heavy water reactors to use plutonium and new fuel of thorium. India's 3,00,000 tonnes of thorium supposed to produce electricity for 400 years.

NUCLEAR PROLIFERATION

As per the current definition, Nuclear proliferation includes, apart from acquisition of nuclear weapons, the acquisition of fissionable materials like plutonium and enriched uranium and also the ability to produce them.

Nuclear proliferation can be accomplished in two ways, horizontal and vertical. If non-nuclear regions or states become nuclear powers, it is the case of horizontal proliferation. A nuclear power state when goes on adding to its nuclear arsenal, the case is of vertical proliferation. The emphasis on horizontal proliferation totally ignoring vertical proliferation has been the real cause of confrontation between the nuclear haves and have-nots.

In order to check the horizontal proliferation nuclear haves devised various inspection and control mechanisms based on bilateral accord. But this was not enough as the fear that nations may strop around and buy their materials from states that imposed the least control and even no controls prompted them to establish International Atomic Energy Agency (IAEA) to preserve the "long term and safe" foreign markets for its nuclear materials and technology and international system of safeguards.

This control system consists of five basic elements:

1. An agreement between the agency and the recipient country regarding control provisions.
2. A design of the nuclear facilities under control.
3. Provision of records.
4. Reports to the agency based upon the records.
5. Onsite inspection by the agency.

Structural weaknesses of the NPT

(a) The imbalance in the distribution of obligations and benefits between the nuclear weapon powers and the non nuclear weapon states.

(b) The omission of any reference to the vertical proliferation in the treaty.

(c) The technological denials embodied in the discriminatory provisions regarding safeguards (Art. III), right to peaceful uses of nuclear energy (Art. IV) and right to peaceful nuclear explosives PNEs (Art. V).

(d) The omission of nuclear security guarantees to non-nuclear weapon states in the Treaty.

(e) The fragile UN resolution 225 on nuclear security guarantee in 1968.

Political Instrument Devised by the Super Powers

(a) To perpetuate the status quo and the hierarchical character of the international system.

(b) To restrict the nuclear club membership only to five nuclear weapon powers.

(c) To establish a clientele relationship between the nuclear powers and the non-nuclear powers.

(d) To sharply divide nations into the nuclear haves and nuclear have nots.

(e) To establish technological hegemony over the developing nations.

N-safety & Regulation

The nuclear safety in India is regulated by an autonomous body, the Atomic Energy Regulatory Board (AERB) established under section 27 of the Atomic Energy Act, 1962 on 15 Nov. 1983. Moreover, in recent times, environmental issues have assumed significance mainly for ensuring sustainable development in all spheres. The AERB has issued the guidelines fixing the upper limit for radiation annually which is 30 mSv. Besides, the BARC has set up a Health Safety and Environmental Group in the premises of every nuclear power plant to monitor radiation.

In fact, the AERB together with the Safety Review Committee for Operating Plants (SARCOP) is responsible for regulating the safety standards. In order to deal with nuclear emergencies, a Crisis Management Group (CMG) was constituted in 1987, which comprises members from organisations like NPCIL, BARC, AERB, HWB (Heavy Water Board) etc. With a view to managing the crises situation, the DAE has identified an Exclusion Zone of 1.6 km surrounding the power station where habitation has been prohibited. Besides, an area of 16 km radius around the plant has been identified as the EPZ.

INDIA AND NPT

After the end of the Second World War, the world which had experienced the catastrophic effect of atom bomb embarked on the path not to have a repetition of nuclear history. After eighteen years of futile discussions a series of substantial developments got its origin and its manifestation came in the form of Partial Test Ban Treaty, 1963. The process yielded a very important and relevant treaty in 1968 known as Non proliferation Treaty or NTP. This treaty prohibits further spread of nuclear weapons. The decade of 1970, which was declared as Disarmament Decade by U.N. had an auspicious starting by having 43 countries ratifying the treaty. Thus the treaty came into force on 5 March, 1970. A total of 190 parties joined the Treaty, with five states being recognized as nuclear-weapon states: the United States, Russia, the United Kingdom, France, and China.

The Indian stand is that it has refused to sign the treaty on the ground that it is discriminatory and unequal. The official stand of India over the treaty was in crystal clear manner aircasted by Mr. K. P. Unnikrishnan in U. N. General Assembly that India would not subscribe to a treaty of an attitude that divides the world into haves and have-nots.

The NPT professes for a world where five countries would have nuclear weapons and rest of the countries would be devoid of it as the proliferations of nuclear weapon is prohibited under the treaty. It tantamounts to nuclear hegemony creating an inequality in the world order. India says that it can become a part of treaty, but first there should be complete disarmament. Despite several resolutions and treaties, no substantial development has been done by NWS (Nuclear Weapon States). It is a matter of great concern to India's security, as we have China and Pakistan as nuclear states. The government of India is in favour of expansion of exclusive club of nuclear power by induction of it. So, NPT has to be genuine to its goal, either we have a range of states having nuclear war heads to balance global power or all the countries of the world adopt a totally nuclear weapons free world. However, in the light of recent tests of China and France and proposed NMD of US and its withdrawal from ABM 1972, there is not much light of hope.

INDIA AND CTBT

The another very substantial step, to get a world in which there would be supremacy of five countries rather than a world free from nuclear weapon, was taken in June 1995 in Geneva to adopt the Comprehensive Test Ban Treaty (CTBT). The treaty contains a comprehensive plan to prohibit nuclear tests. The treaty comprised 154 countries and verified by 51 countries before a review conference was held in Vienna in October 1999. The ratification of America and China is required to get the treaty into force. But these countries have not yet ratified it and one of the bizarre points is that America, that preaches other countries to sign it, didn't get it approved by its Senate as they treated it as against the interest of US security. Russia signed the treaty on Sep 24, 1996 and ratified it on Jun 30, 2000.

The 44 countries, including five nuclear powers are considered as having nuclear capability. Out of 44, 41 countries have signed it, while 26 countries have ratified it. As of June 2013, 159 states had ratified the CTBT and another 24 states signed it but not ratified it. There are 183 signatories of CTBT.

India opposes the treaty on the ground that it doesn't speak about destruction of existing nuclear stockpiles. The treaty doesn't contain any time bound destruction programme. So according to the treaty, disarmament of the weapons would solely depend on the attitude of NWS. The recent tests of China, France and

US, underground subcritical tests of Nevada put a huge question mark on their intention. The recent development in US Congress and withdrawal from ABM clearly shows that future is by no way going to be nuclear free world.

In such a condition India says that her security concerns demand nuclear power, as we have in our surrounding nuclear China and Pakistan. India is willing to have a consensus over CTBT in country only if some of her demands are conceded. It demands that India should be included in the club of NWS and countries having nuclear arms should go for a comprehensive programme for disarmament with specific time bound resolution.

But no proper attention is given to our demands and India has refused to become a party of the treaty. The self moratorium imposed by India is an example of our stand that, our nuclear programme is only for alternate purpose. The commitment becomes more authentic with our proposal of 'no first use' which was rejected by Pakistan.

India has been voicing since 1960 in favour of disarmament and has actively participated in it. But it is against a global order where some countries have weapons of mass destruction and the rest are at their mercy. We aspire for a world based on equality and respect for each other. India believes in peace based on cooperation, and not under the cover of fear.

India's Objections

- No time frame to denuclearize the five (US, UK, France, Russia, China) nuclear weapon States.
- Treaty allows withdrawal without sanction of signatories.
- The entry into force clause is unacceptable.
- The Treaty is not comprehensive; it bans nuclear tests but allows computer "simulations.

INDO-US NUCLEAR DEAL

In the current scenario, the then President George W. Bush called India a natural partner of the United States and his Administration sought to assist India's rise as a major power. In July 2005, President Bush and Indian Prime Minister Manmohan Singh issued a Joint Statement resolving to establish a global partnership between their two countries through increased cooperation on numerous economic, security, and global issues. In this Joint Statement, the Bush Administration dubbed India a responsible state with advanced nuclear technology and vowed to achieve full civilian nuclear energy cooperation with India.

The Joint Statement acknowledged that India's nuclear programme has both a military and a civilian component. Both sides agreed that the purpose was not to constrain India's strategic programme but to enable resumption of full civil nuclear energy cooperation in order to enhance global energy and environmental security. Such cooperation was predicated on the assumption that any international civil nuclear energy cooperation (including by the US) offered to India in the civilian sector should, firstly, not be diverted away from civilian purposes, and secondly, should not be transferred from India to third countries without safeguards. These concepts will be reflected in the Safeguards Agreement to be negotiated by India with International Atomic Energy Agency (IAEA).

Principles which Guided India

- Credible, feasible, and implementable in a transparent manner;
- Consistent with India's national security and R&D requirements as well as not prejudicial to the three-stage nuclear programme in India;
- Must be cost effective in its implementation; and
- Must be acceptable to Parliament and public opinion.

Based on these principles, India will:

Include in the civilian list only those facilities offered for safeguards that, after separation, will no longer be engaged in activities of strategic significance.

The overarching criterion would be a judgement whether subjecting a facility to IAEA safeguards would impact adversely on India's national security.

However, a facility will be excluded from the civilian list if it is located in a larger hub of strategic significance, notwithstanding the fact that it may not be normally engaged in activities of strategic significance.

A civilian facility would therefore, be one that India has determined not to be relevant to its strategic programme.

Taking the above into account, India, on the basis of reciprocal action by the US, would like to adopt the following approach:

Thermal Power Reactors: India will identify and offer for safeguards 14 thermal power reactors between 2006 and 2014. This will include the 4 presently safeguarded reactors (TAPS 1&2, RAPS 1&2) and in addition KK 1&2 that are under construction and other PHWRs, each of a capacity of 220MW, will also be offered.

Phasing of specific thermal power reactors, being offered for safeguards would be indicated separately by India. Such an offer would, in effect, cover 14 out of the 22 thermal power reactors in operation or currently under construction to be placed under safeguards, and would raise the total installed Thermal Power capacity by MWs under safeguards from the present 19% to 65% by 2014.

Fast Breeder Reactors: India is not in a position to accept safeguards on the Prototype Fast Breeder Reactors (PFBR) and the Fast Breeder Test Reactor (FBTR), both located at Kalpakkam. The Fast Breeder Programme is at the R&D stage and its technology will take time to mature and reach an advanced stage of development.

Future Reactors: India has decided to place under safeguards all future civilian thermal power reactors and civilian breeder reactors, and the Government of India retains the sole right to determine such reactors as civilian.

Research Reactors: India will permanently shut down the CIRUS reactor. It will also be prepared to shift the fuel core of the APSARA reactor that was purchased from France outside BARC and make the fuel core available to be placed under safeguards.

Upstream facilities:

The following upstream facilities would be identified and separated as civilian:

- List of those specific facilities in the nuclear fuel complex, which will be offered for safeguards.
- The heavy water production plants at Thal, Tuticorin and Hazira are proposed to be designated for civilian use. We do not consider these plants as relevant for safeguards purposes.

Downstream facilities:

The following downstream facilities would be identified and separated as civilian.

- India is willing to accept safeguards in the 'campaign' mode in respect of the Tarapur power reactor fuel reprocessing plant.
- The Tarapur and Rajasthan away from reactors' spent fuel storage pools would be made available for safeguards with appropriate phasing.

Research Facilities: India will declare the following facilities as civilian:

(a) Tata Institute of Fundamental Research

(b) Variable Energy Cyclotron Centre

(c) Saha Institute of Nuclear Physics

(d) Institute for Plasma Research

(e) Institute of Mathematics Science

(f) Institute of Physics

(g) Tata Memorial Centre

(h) Board of Radiation and Isotope Technology

(i) Harish Chandra Research Institute

These facilities are safeguards-irrelevant. It is our expectation that they will play a prominent role in international cooperation.

Safeguards

The United States has conveyed its commitment to the reliable supply of fuel to India. Consistent with the July 18, 2005, Joint Statement, the United States has also reaffirmed its assurance to create the necessary conditions for India to have assured and full access to fuel for its reactors.

To further guard against any disruption of fuel supplies, the United States is prepared to take the following additional steps:

(i) The United States is willing to incorporate assurances regarding fuel supply in the bilateral U.S.-India agreement on peaceful uses of nuclear energy under Section 123 of the U.S. Atomic Energy Act, which would be submitted to the U.S. Congress.

(ii) The United States will join India in seeking to negotiate with the IAEA an India-specific fuel supply agreement.

(iii) The United States will support an Indian effort to develop a strategic reserve of nuclear fuel to guard against any disruption of supply over the lifetime of India's reactors.

(iv) If despite these arrangements, a disruption of fuel supplies to India occurs, the United States and India would jointly convene a group of friendly supplier countries like Russia, France and the United Kingdom to pursue such measures as would restore fuel supply to India.

In the light of the above understanding with the United States, an India-specific safeguards agreement will be negotiated between India and the IAEA providing for safeguards to guard against withdrawal of safeguarded nuclear material from civilian use at any time as well as providing for corrective measures that India may take to ensure uninterrupted operation of its civilian nuclear reactors in the event of disruption of foreign fuel supplies. Taking this into account, India will place its civilian nuclear facilities under India-specific safeguards in perpetuity and negotiate an appropriate safeguards agreement to this end with the IAEA. This plan is in conformity with the commitments made to Parliament.

NUCLEAR POLLUTION

It is not only the use of fossil fuels that pollutes our surroundings; even the use of nuclear energy gives rise to pollutants and, hence, pollutes our environment. In fact, the pollution caused by the use of nuclear energy from fission process is much more damaging than the pollution caused by burning fossil fuels. The fuels like U-235 are radio-active substances, which keep on emitting some nuclear radiations all the time.

The dangerous nuclear radiations can enter into the environment by leakage from nuclear reactors where fission of U-235 is going on. These nuclear radiations can damage and cause irreparable damage to cells and in some cases even lead to death.

The waste material produced during the various steps of the nuclear energy production is collectively known as nuclear wastes. These are harmful nuclear radiations. If these radioactive wastes are dumped in garbage bins, they will emit nuclear radiations, and pose a threat to the life of humans and animals. Also if they are dumped in rivers or sea, they will contaminate water and damage aquatic life. So, there is a great problem of disposal of nuclear waste.

NUCLEAR WASTE MANAGEMENT

No discussion on nuclear power is complete without consideration of safety and environmental factors. These are issues of legitimate concern to the public in the aftermath of the Chernobyl accident and because of the alarming scenarios of nuclear power appearing in the media. More than 99 per cent of the total radioactivity in the entire nuclear fuel cycle is generated from the fuel processing plants. To ensure that this highly radioactive waste stream does not pose any hazards to the environment, a three-stage approach has been adopted. First, the waste will be incorporated in stable and inert solid matrices. The conditioned waste will then be placed in canisters and kept in a retrievable store under cooling and constant surveillance. Ultimately, the canisters will be stored in suitable geological media.

A waste immobilization plant for incorporating the high level radioactive wastes generated from the fuel processing plants is set up along with the solid storage surveillance facility of Tarapur. Immobilization involves verification of radioactive waste, which is coded at underground disposal. The canisters in storage will be air-cooked by natural convection and when the heat and the radioactivity in canisters decay to desired level, they will be transported to a suitable geological formation for ultimate storage. The work on identifying suitable geological formations for ultimate disposal has been completed and a graveyard for storage of nuclear wastes has been established in Trombay.

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DEFENCE

The Supreme Command of the Armed Forces vests with the President of India. The responsibility for national defence rests with the Cabinet. This is discharged through the Ministry of Defence, which provides the policy framework and wherewithal to the Armed Forces to discharge their responsibilities in the context of the defence of the country. The Defence Minister is the head of the Ministry of Defence. The principal task of the Defence Ministry is to obtain policy directions of the Government on all defence and security related matters and communicate them for implementation to the Services Headquarters, Inter-Services Organizations, Production Establishments and Research and Development Organisations. It is also required to ensure effective implementation of the Government•fs policy directions and the execution of approved programmes within the allocated resources. Ministry of Defence comprises four Departments viz.

- Department of Defence (DOD)
- Department of Defence Production (DDP)
- Department of Ex-Servicemen Welfare (DESW)
- Department of Defence Research & Development (DDR&D)

Principal functions of all the Departments are as follows:

- The Department of Defence (DOD) deals with the Integrated Defence Staff (IDS) and three Services and various Inter-Service Organisations. It is also responsible for the defence budget, establishment matters, defence policy, matters relating to Parliament, defence co-operation with foreign countries and co-ordination of all activities.
- The Department of Defence Production (DDP) is headed by a Secretary and deals with matters pertaining to defence production, indigenisation of imported stores, equipment and spares, planning and control of departmental production units of the Ordnance Factory Board and for Defence Public Sector Undertakings (DPSUs).
- The Department of Defence Research and Development (DDR&D) is headed by a Secretary, who is also the Scientific Adviser to the Raksha Mantri. Its function is to advise the Government on scientific aspects of military equipment and logistics and the formulation of research, design and development plans for equipment used by the Services.
- The Department of Ex-Servicemen Welfare (DESW) is headed by an Additional Secretary and deals with all re-settlement, welfare and pensionary matters of Ex-Servicemen.

DEPARTMENT OF DEFENCE RESEARCH AND DEVELOPMENT

The Indian Security is based on armed forces. The arms and ammunitions for these forces are provided by the Department of Defence Research and Development. The department is dedicatedly working towards enhancing self-reliance in Defence Systems. The Department undertakes design & development leading to production of world class weapon systems and equipment in accordance with the expressed needs and the qualitative requirements laid down by the three services. The Department is working in various areas of military technology which include aeronautics, armaments, combat vehicles, electronics, instrumentation engineering systems, missiles, materials, naval systems, advanced computing, simulation and life sciences.

Defence Research & Development Organisation (DRDO) works under Department of Defence Research and Development of

Ministry of Defence. DRDO is dedicatedly working towards enhancing self-reliance in Defence Systems and undertakes design & development leading to production of world class weapon systems and equipment in accordance with the expressed needs and the qualitative requirements laid down by the three services. DRDO is working in various areas of military technology which include aeronautics, armaments, combat vehicles, electronics, instrumentation engineering systems, missiles, materials, naval systems, advanced computing, simulation and life sciences.

Department of Defence Production

The Department of Defence Production was set up in 1962, in the aftermath of the Chinese aggression to create a self-reliant and self-sufficient indigenous defence production base. In November, 1965, Department of Defence Supplies was created to forge linkages between the civil industries and defence production units. The two departments were merged in December, 1984 into the Department of Defence Production and Supplies. The Department of Defence Production and Supplies has been renamed as Department of Defence Production w.e.f. January, 2004.

Since 1962, 39 Ordnance factories have been set up and two projects, coming up at Nalanda in Bihar and Korwa in U.P. Their capacities have been augmented and modernised selectively keeping in mind the emerging requirements of the Armed Forces. All the Ordnance Factories and Defence Public Sector Undertaking (DPSUs) are engaged in the task of manufacture of equipment and stores for Defence Services. The products manufactured include arms and ammunition, tanks, armoured vehicles, heavy vehicles, fighter aircraft and helicopters, warships, submarines, missiles, ammunition, electronic equipment, earth moving equipment, special alloys and special purpose steels. In addition, capacities of civil sectors are also utilised for the purpose. The following DPSUs are functioning under the administrative control of the Department:-

- Hindustan Aeronautics Limited (HAL)
- Bharat Electronics Limited (BEL)
- Bharat Earth Movers Limited (BEML)
- Mazagon Dock Ltd (MDL)
- Goa Shipyard Limited (GSL)
- Hindustan Shipyard Limited (HSL)
- Garden Reach Shipbuilders and Engineers Limited (GRSE)
- Bharat Dynamics Limited (BDL)
- Ordinance Factory Board (OFB)
- Mishra Dhatu Nigam Limited (MIDHANI)

In addition, the following organisations are also associated with the Department of Defence Production for the technical support:-

- Directorate General of Quality Assurance (DGQA)
- Directorate of Standardisation (DOS)
- Directorate General of Aeronautical Quality Assurance (DGAQA)
- Directorate of Planning & Coordination (Dte. of P&C)
- Defence Exhibition Organisation (DEO)
- ?National Institute for Research & Development in Defence Shipbuilding (NIRDESH)

These Defence Production Units have become self reliant, progressively. Additional capacities have been built up and new items have been productionised. These include the main battle tank Arjun, the Advanced Light Helicopter (ALH) and a range of 155 mm ammunition.

Defence Research and Development Organisation (DRDO)

Providing a solid base to the national security system, Defence Research and Development Organisation (DRDO) was formed in 1958 by amalgamating Defence Science Organisation and some of the technical development establishments. A separate department of Defence Research and Development was formed in 1980 which now administers DRDO and its 48 laboratories and establishments. The Department of Defence Research and Development formulates and executes programmes of scientific research, design and development in the fields of relevance to national security, leading to the induction of new weapons, platforms and other equipments required by the Armed Forces. It also functions as the nodal agency for the execution of major development programmes of relevance to defence through integration of research, development, testing and production facilities with the national scientific institutions, public sector undertakings and other agencies. It functions under the control of scientific advisor to Defence Minister who is also Secretary, Defence Research and Development.

Contribution of DRDO: DRDO has made great strides since 1980 towards making our armed forces self reliant. On the one hand this has enabled our Armed Forces to face the arms export control regimes of advanced countries, whereas on the other hand, DRDO has progressively enhanced their combat effectiveness through development of state-of-the-art indigenous defence systems. During last few years, a number of defence systems and equipments have been productionised. These include:

1. **Lakshya:** Pilotless target aircraft (aerial target practice system)
2. **Nishant:** Remotely piloted vehicle (for aerial surveillance)
3. **Prithvi:** Surface -to-surface tactical battlefield missile.
4. **Agni-I, Agni-II, Agni-III, Agni-IV, Agni-V & Agni-VI:** Surface to surface missile.
5. **BrahMos:** Supersonic cruise missile
6. **Trishul:** Short range surface-to-air missile
7. **Akash:** Medium-range mobile surface-to-air missile
8. **Arjun:** Main Battle Tank
9. **Sangraha:** Integrated Electronic warfare (EW) System for Navy
10. **Samyukta:** Integrated Electronic warfare (EW) System for Army
11. **Mihir:** Helicopter based dunking sonar
12. **Nag:** Third generation “Fire-and-forget” anti-tank missile
13. **AERV:** Armoured Engineer Reconnaissance Vehicle for crossing water obstacles.
14. **Ajeya:** Combat improved T-72 tank.
15. **Sarvatra:** Assault Bridge mechanically launched.
16. **Safari [MK1]:** Muting systems for deactivating remotely- controlled explosive device.
17. **Pinaka:** Multibarrel rocket system.
18. **INSAS:** 5.56 mm. Indian small arms system.
19. **Tranquil:** Radar warning receiver for MIG 23 aircraft
20. **Tempest:** Radar warning receiver and self protection jammer for MIG aircraft.
21. **Catch:** Airborne signal intelligence systems.
22. **Sansar:** Bulk secrecy equipment with high grade digital secrecy.
23. **Samvahak:** Artillery combat command and control system.
24. **Bhima:** Aircraft weapon trolley
25. **Humsa:** Hull mounted sonar system
26. **Kaveri Engine:** Technologically complex and vital system for the LCA as well as its future variants.
27. **Rajendra:** Passive phased array radar

INDIA'S DEFENCE POLICY

The main objectives of India•fs defence policy are to (a) promote and sustain durable peace in the subcontinent and (b) equip the defence forces adequately to safeguard the territorial integrity of the country against foreign aggression. In the field of defence research, India has achieved great success and owing to defence scientists, India, today is in the short list of some developed nations of the world who have capabilities to produce modern defence arsenals. India is the third largest importer of arms and equipment in the world.

Integrated Guided Missile Programme

The Integrated Guided Missile Development Program (IGMDP) was formed in 1983 with the aim of achieving self-sufficiency in missile development & production and today comprises of five core missile programs •\the strategic Agni ballistic missile, the tactical Prithvi ballistic missile, the Akash and Trishul surface-to-air missiles and the Nag anti-tank guided missile. The program has given India the capability to produce indigenous missiles in other key areas. By enforcing the Missile Technology Control Regime (MTCR) to stop supplies of all kinds of missile material, Western nations are trying to prevent India from developing these strategic and tactical missiles. Undaunted by this high-level conspiracy, hats off to all the brilliant Indian scientists who have toiled so hard, in their dedicated efforts, that they managed to develop these missiles.

In India IGMDP comprises of following missiles developed by DRDO:

(i) Surface to surface missile: Prithvi

(ii) Surface to air medium range missile: Akash

(iii) Anti-tank missile: Nag

(iv) Surface-to-air short range missile: Trishul

(v) Intermediate range ballistic missile (IRBM): Agni

Difference between Cruise Missile and Inter-Ballistic Missile

Cruise missile is an unmanned self-propelled guided vehicle that sustains flight through aerodynamic lift for most of its flight path and whose primary mission is to place a payload on a target. They fly within the earth•fs atmosphere and use jet engine technology. These vehicles vary greatly in their speed and ability to penetrate defences. These can be classified as:

a) Subsonic cruise missile

b) Supersonic cruise missile

c) Hypersonic cruise missiles

Ballistic missiles follow ballistic trajectory i.e. first moves to outer space and then enters earth atmosphere and strike the target. Ballistic missiles are categorized according to their range, the maximum distance measured along the surface of the earth•fs ellipsoid from the point of launch of a ballistic missile to the point of impact of the last element of its payload. These can be classified as:

a) Intercontinental Ballistic Missile

b) Intermediate-Range Ballistic Missile

c) Medium-Range Ballistic Missile

d) Short-Range Ballistic missile

Brief introduction of important missiles

- **Prithvi**

Type: Short range, surface-to-surface battlefield tactical missile.

Range: 150 km with 1000 kg warhead and 250 km with 500 kg warhead (minimum 40 km)

Payload: 500-1000 kg

Warhead: Both conventional and nuclear, pre-fragmented and bomblets

Propulsion: Single stage, liquid propellant

Description: The use of Prithvi is visualized as phases of preparatory and subsequent phases of the battle to destroy enemy concentration of tanks and troops, logistic installations, airfields and communication facilities. It is difficult to spot the Prithvi or trace its trajectory and target because of its supersonic speed and limited flight time. The missile is extremely accurate (its circular error probability- CEP- is lower than most missile of its class) - with a circular accuracy of 10m. The short-range version is for the Indian Army and long-range for IAF.

The Air Force version, designated as the SS-250 had a range of 250 km and could carry up to a maximum of a 500 kg as its payload. By using boosted liquid propellant to generate more thrust-to-weight ratio, DRDO has increased the payload of the SS-250 to 1000 kg. The Prithvi reportedly has the highest warhead-weight to overall-weight of any missile in its class.

- A**gni**

Type: Surface-to-surface, Intermediate Range Ballistic Missile (IRBM)

Range: 700 km - 5000 km

Payload: 500 kg - 1000 kg; Multipurpose.

Propulsion: Two stage, first stage uses solid propellant while second stage uses twin liquid propellant engines.

Description: Agni is a re-entry technology demonstrator. It is capable of carrying a multipurpose payload. One of its unique features is the heat shield of the re-entry vehicle.

Tested: First successful test of Agni took place on 22nd May, 1989. After this test, India became sixth nation-along with USA, Russia, France, China and Israel who have tested IRBM. In April 1999 India tested its Agni-II missile at Balasore (Odisha) successfully. Range of Agni-

II is more than 2500 km. A shorter variant of Agni- Agni-1 was successfully test-fired in January 2002. Its range is about 700 km.

Agni-III Missile:

On September 21, 2012 India test-fired the 3000 km range surface-to-surface nuclear capable Agni-III missile from the Wheelers•f Island off Odisha coast. Agni-3 is the country•fs first solid fuel missile that is compact and small enough for easy mobility and can be easily packaged for deployment on a variety of surface and sub-surface platform. Agni-III is an intermediate-range ballistic missile with a range of 3,500 km- 5,000 km. The missile•fs Circular Error Probable (CEP) is within 40 meters range, which makes it the most sophisticated and accurate ballistic missile of its range class in the world. In June 2011, Agni-III has been inducted into the armed forces and is under-production.

Though the first development trial of Agni-III carried out on July 9, 2006 could not achieve the desired result, subsequent tests conducted on April 12, 2007, May 7, 2008 and February 7, 2010 from the same base were all successful.

Agni-IV Missile:

India test-fired nuclear-capable strategic missile Agni-IV with a strike range of about 4000 km from a test range off Odisha coast. Agni-IV missile is one of its kind and represents a quantum leap in terms of missile technology. The missile is lighter in weight and has two stages of solid propulsion and a payload with re-entry heat shield. The missile, is undergoing developmental trials by country•fs premier Defence Research and Development Organisation.

Agni-V Missile:

India successfully test-fired Agni-V missile, a nuclear-capable missile, with a range of more than 5,000 km. Agni-V is an intercontinental ballistic missile developed by the DRDO. Agni-V missile will be tested twice before end of year 2013 to ensure it is ready for full-scale induction in the armed forces towards end-2015.

With the launch of Agni-V, India has joined a small group of countries - up to now only the nuclear-armed superpowers - with inter-continental range ballistic missiles. The Agni-V is capable of delivering a single 1.5-ton warhead deep inside nuclear rival China's territory. It is 17.5m-tall, solid-fuelled, has three stages and a launch weight of 50 tons.

Agni VI Missile:

DRDO announced the next version of Agni missile, Agni VI. The new version will be capable of carrying multiple warheads besides having a longer range. Agni VI is likely to propel India into the club of countries having inter-continental ballistic missiles (ICBMs). The missile, having a strike range of 8,000-10,000 km, will also have the facility of a road launcher. While Agni-V can carry up to three nuclear warheads, the number could be double or more than that in case of Agni VI. It is likely to be a three-stage missile. The trial may come in mid-2014.

- **Akash**

Type: Medium range, surface-to-air missile.

Range: 25 km

Warhead: Pre-fragmented warhead activated by proximity fuse.

Tested: First time on 14th August, 1990 at Chandipur (Odisha)

Description: It is totally indigenous missile. The nodal agency which designed the Akash is Defence Research and Development Laboratory, Hyderabad. The weight of Akash is about 700 kg and its length is 5.6 meters. This missile had better features than its U.S. counterpart 'Patriot. It is totally mobile and it can be launched from a battle tank. The Patriot has thrust only for 12 seconds and then the coasting begins. But Akash has thrust for 35 seconds.

It is a multi-target missile - can target four to five enemy aircrafts and missiles at a time. Integrated with the indigenously produced phased array radar called Rajendra. It is capable of tracking many targets simultaneously. The Akash system is comparable to the Patriot system of the USA. India on May 24, 2012 successfully test fired its two indigenously-developed surface-to-air •eAkash•f missiles of Air Force version with a strike range of 25 km from the Integrated Test Range at Chandipur, Odisha.

- **Nag**

Type: Third generation, 'fire and forget, anti-tank guided missile.

Range: 4 km

Warhead: Tandem shaped charges

Propulsion: Solid propellant motor

Tested: First time on Nov. 24, 1990

Description: The missile is being developed to counter contemporary advances in tank armour especially the very hard or the reactive types of armour. The missile is mounted on a tracked vehicle equipped with Line of Sight (LOS) radar. The radar detects the target, passes the information (image coordinates) to the missile. The missile then aligns its sight with that of the LOS radar and blasts off.

Aerial Version of Nag: DRDO, in collaboration with HAL has developed an aerial version of land based anti-tank Nag missile. Nag, an all weather, fire-and-forget anti-tank missile is one of the five developed by the DRDO under the Integrated Guided Missile Development Programme (IGMDP). The others are Akash, Trishul, Prithvi, and Agni, Nag which has been successfully test-fired is the only of its kind having the range in line of sight-up to four km. It can cover the 4 km. distance in 20 seconds, travelling at a speed of 900 km an hour.

- **Avatar:**

Indian scientists have designed a reusable space plane called 'Avatar. This space plane can launch satellites at extremely low cost. Besides, it can also take tourists on a ride to space. The man behind this low profile project is air commander Raghavan Gopalswami; former Chairman of Hyderabad based Bharat Dynamics Limited and a pioneer in liquid propulsion technology. The project team which designed this plane included Defence Research Development Organisation (DRDO) and Cim Technologies. The unique design of Avatar enables it to be launched again and again upto 100 times. Besides, it produces its own fuel during the flight. Judging its popularity, applications have been filed in patent offices in the United States, Germany, China and Russia.

- **Trishul**

Type: Short range, surface-to-air missile

Range: 300 m to 9 km

Warhead: A pre-fragmented warhead with a strike radius of 20m.

Propulsion: Single, solid composite propellant

Tested: The short-range missile, Trishul, was first tested on 5th June, 1989. The supersonic surface-to-air missile could hit targets both in the air and on land within a distance of 300 meters to 9 km. The solid fuel propelled Trishul has a capacity to carry 15 kg of warhead and has been developed to cater to the needs of all the three defence services. The three meter long missile, having a diameter of 200 cm, is part of the country's Integrated Guided Missile Development Programme.

Description: It is being developed for all the three services. The IAF will use it against low flying aircraft while the Navy will use a modified version against sea-skimming missiles like the American Harpoon. The moment the enemy aircraft is within range, the missile will be launched, maneuvered into the line of the tracking beam and guided all the way to the target. The Air Force version will be simple except that the version designed for the Navy will contain an accurate altimeter in its sensor unit which will enable the missile to skim above the waves and intercept enemy missiles. The Trishul has high manoeuvrability and is powered by a two-stage solid propellant system, with a highly powered HTBP-type propellant similar to the ones used in the Patriot.

- **Astra missile**

Type: Air-to-air missile, beyond visual range (BVR) missile

Length: 3570 m

Body Diameter: 178 mm

Launch Weight: 154 kg.

Warhead: 15 kg pre-fragmented directional

Range: 80 km head on, 15 km tail chase

India on December 21, 2012 successfully test fired its indigenously developed Astra air-to-air interceptor missile from a defence base in Odisha. The beyond-visual-range missile was tested from the Integrated Test Range (ITR) at Chandipur, Odisha.

The Astra missile uses a terminal active radar-seeker to find targets and a mid-course internal guidance system with updates, to track targets. The on-board ECCM capability allows it to jam radar signals from an enemy surface-to-air battery, ensuring that the missile is not tracked or shot down. This indigenous missile is intended to have performance characteristics similar to the R-77RVV-AE (AA-12), which currently forms part of the IAF•fs missile armoury. The missile is 3.8 metres long and is said to be configured like a longer version of the Super 530D, narrower in front of the wings. Astra uses a HTPB solid-fuel propellant and a 15 kg HE (high-explosive) warhead, activated by a proximity fuse. The missile has a maximum speed of Mach 4+ and a maximum altitude of 20 km.

OTHER MISSILE PROJECTS

Surya: Inter- Continental missile with range of 5000 km is in process of development.

Sagarika: Cruise missile to be launched from sea. Its range will be some 100 km.

- **Light Combat Aircraft**

The Government of India in 1984 decided to establish the Aeronautical Development Agency (ADA) to manage the Light Combat Aircraft (LCA) programme. Hindustan Aeronautics Limited (HAL) was the principal partner with participation of various DRDO & CSIR Laboratories.

On 22nd January 2009 Light Combat Aircraft Tejas completed 1000 flights. On 29th April, 2012, the Naval version of the Light Combat Aircraft Tejas, made its maiden flight from the HAL airport in Bangalore. This was a significant milestone in the history of Indian Aviation in designing a naval variant of a fighter aircraft. On 22nd February, 2013, the LCA took part in the Iron Fist Exercise in Pokhran, Jaisalmer and on 31st March, 2013, the Tejas Light Combat Aircraft, LSP-8 accomplished its maiden flight from HAL airport.

LSP 8: After having received the Flight Readiness Review Board's (FRRB) clearance for the flight, the most advanced edition of India's Light Combat Aircraft's (LCA)—Tejas—limited series production-8 (LSP-8) completed its maiden flight on 31st March 2013. The LSP-8, along with LSP-7 are the configurations marked for the Initial Operational Clearance-2 (IOC-2). LSP-8 is the last aircraft in the Limited Series Production programme.

Planned Product Variants

Tejas Trainer : Two-seat operational conversion trainer for the Indian Air Force.

Tejas Navy : Twin- and single-seat carrier-capable variants for the Indian Navy. The LCA's naval variant is to be ready for carrier trials by 2013 and is slated for deployment on the INS Vikramaditya as well as the Vikrant class aircraft carrier.

Future Development

Tejas Mark 2 - Featuring more powerful General Electric F414-GE-INS6 engine with 98Kn thrust and refined aerodynamics. The Mark 2 is being developed to meet the Indian Air Staff requirements.

Other Achievements in Defence Production

- **MBT-Arjun:**

India's Main Battle Tank (MBT), Arjun, indigenously designed and developed by DRDO and Combat Vehicle Research Development Establishment (CVRDE), Avadi was dedicated to the nation in January 1996.

Arjun weighs 58 tonnes and hence falls in the main battle tank category (above 50 tonnes). Medium battle tanks are in the weight range of 35 to 40 tonnes. The Russian T-72 M-1 (42 tonnes) and Vijayanta (38 tonnes) come under this category. The 58.5 tonnes Arjun with state-of-the art technology, superior fire power, mobility and high speed (72 kmph on roads and 40 kmph on rocky terrain), and weapon system has been designed to meet Indian Army•fs most stringent specifications. It is rated among top MBTs in the world. The satellite based Global Positioning System (GPS) can facilitate the Arjun to find its geographical grid in barren areas and in the dark.

- **Bhishma:**

The T-90S, named 'Bhishma' is highly versatile and state-of-the-art tank and assembled from important semi-knocked down units at the Heavy Vehicles Factory, Avadi. The features of this tank are the following:

1. Its mobility, lethal fire power, surprise hit-at-first sight and self-protection.

2. Its enhanced mobility, ballistic computers for sight and accuracy and capability to fire all types of ammunition in addition to firing guided missiles.
3. The tank has superior armour protection with its explosive reactor armour panel and also has protection against nuclear, biological and chemical weapons.

- **Lakshya:**

'Lakshya' the Pilotless Target Aircraft (PTA), is a sophisticated unmanned aircraft. It has been designed and developed to simulate realistic air threats and to mimic the radars and infra-red signals. It will be used to impart training for surface-to-air, air-to-air missiles and gun firing. This aircraft can be launched either from ground or a ship using a rocket and is powered during flight by a turbo jet engine.

Lakshya, with a sub-sonic speed of 0.7 Mach in clean configuration and 0.54 mach in 'one stow one tow' configuration could climb upto 9 km. in clean configuration and 6 km with two bodies at a rate of 35 m/s at sea level. It has a fuel capacity of 190 kg and can tolerate a weight upto 630 kg. It can float above sea for 3 to 4 hours on a parachute until it is retrieved by a helicopter and minimum altitude possible is 300 m.

- **Nishant:**

India's indigenous Remotely Piloted Vehicle (RPV) 'Nishant', is intended for battlefield surveillance and reconnaissance roles and incorporates advanced designed feature comparable or superior to those developed elsewhere in the world. It can carry a 45 kg payload, travel at a speed of 150 kmph and fly more than five hours. It can be controlled from the ground for distances upto 160 km and can also be programmed for an autonomous flight. Its detection on radar is difficult as it is made entirely of fibre reinforced glass.

- **Pinaka:**

To build up ground support for Indian army, DRDO has developed lethal ground based multibarrel rocket launcher weapon system, 'Pinaka'. Pinaka is a mobile weapon system characterized by capability to deliver saturation fire over targets not engageable by artillery guns. It has a range of 39 km and has a capability of fire upto 12 rockets within seconds. It can launch a variety of warheads. The system has a quick reaction time, high accuracy and excellent mobile characteristics. It consists of a launcher rocket, replenishment-cum loader vehicle and a command post vehicle. Pinaka is said to be contemporary with other systems of its class that have been developed or are being developed anywhere in the world.

- **Dhanush:**

On October 5, 2012 India successfully test-fired nuclear capable Dhanush, the naval version of Prithvi short-range ballistic missile, from a warship off Odisha coast. The indigenously developed Prithvi missile has a strike range of up to 350 km and can carry 500kg of conventional or nuclear warhead. Developed by the DRDO, the missile is about 8.53 metre in length and 0.9 metre in diameter. This single stage missile uses liquid propellant. The Dhanush missile can be used as an anti-ship weapon as well as for destroying land targets depending on the range. The naval variant was first tested on 11 April 2000 from one of the Indian Navy's Sukanya Class vessels. Inter-Continental missile was designed and formulated by Indian Scientist under the guidance of Dr. Abdul Kalam.

Advanced Light Helicopter (ALH):

ALH is a twin engined cost effective, multi-purpose and multi-role helicopter with rugged design to meet the stringent requirements of the armed forces. It has been designed and developed by the HAL, Bangalore. It incorporates state of the art technology to meet the diverse operational requirements of the Air Force, Navy and the Army. It has a maximum continuous speed of 290 kmph and a cruise speed of 245 kmph. It has a range of 800 km and an endurance of four hours with a 20 minute reserve.

- **Hans-3:**

Training aircraft is developed by scientists of National Aerospace Laboratories, Bangalore on 11 May, 1998. This aircraft is made of light and strong Fibre Glass with a total weight of 750 kg.

- **Sukhoi-30:**

It is a fighter aircraft produced by Russia. Recently India and Russia signed a pact, in which Russia will give 30 Sukhoi-30 MKI aircraft and its technology to India. Its minimum flying range is 3000 km. It is one of the world's most modern fighter aircraft.

- **Saina:**

This is a modern Torpedo developed by Naval Science and Technology laboratory, Vishakhapatnam. This Torpedo has capability to be launched from both Helicopter and Ship. With 35 kmph and 200 kg weight, can attack on a 2.7 m long and on 6 km away target.

- **Pichora:**

Surface to air missile is in process of development. This missile technology is imported from Russia.

- **Sarath:**

Sarath is the Infantry Combat Vehicle (ICV) which has been developed by the Indian scientists to carry and launch Trishul, Akash and Nag missiles.

Brahmos Missile

It is a cruise missile, jointly developed by India and Russia under an agreement signed in 1998. It has a range of 290 km and can deliver payload of 300 kg over 3 times the speed of sound. It can effectively engage targets from an altitude as low as 10 metres and has a top speed of Mach 2.8, which is about three times faster than the US-made subsonic Tomahawk cruise missile.

The name Brahmos has been derived from Brahmaputra and Moskva river of Russia. The company has established with an authorized capital of $250 million with 50.5 per cent from Indian side and 49.5 per cent from Russian side. BrahMos Aerospace was formed as a joint venture between DRDO and Military Industrial Consortium NPO Mashinostroeyenia of Russia. The missile can be installed on ships, submarines, aircraft and ground vehicles. BrahMos missiles are inducted in to the armed forces of India and Russia and can also be exported to friendly nations.

Sea and ground-launched versions have been successfully tested and put into service with the Indian Army and Navy. The flight tests of the airborne version will be completed by the end of 2012.

Propulsion: BrahMos is powered by a two-stage propulsion system. Initial acceleration is provided by a solid-propellant booster and supersonic cruise speed is provided by a liquid-fuelled ramjet system. The air-breathing ramjet propulsion is more fuel-efficient in comparison with conventional rocket propulsion. It provides the BrahMos with a longer range over similar missiles powered by rocket propulsion.

Two advantages of missile:

1. It is highly accurate and can be guided to the target with the help of on-board computers.
2. It travels at supersonic speed in a sea-skimming profile.

Supersonic BrahMos

India on May 21, 2013 successfully test-fired the 290-km range BrahMos supersonic cruise missile from the Navy's latest guided missile frigate INS Tarkash off the Goa coast. The missile performed the high-level 'C' manoeuvre in the pre-determined flight path and successfully hit the target. The launch was carried out by the Navy as part of Acceptance Test Firing (ATF) of the ship. The vertical launch configuration of the supersonic missile enhances the stealth capabilities of the ship as the missiles are under the deck and not exposed.

Brahmos-II

A hypersonic version of the missile namely BrahMos-II is also presently under development with speed of Mach 5 to Mach 7 to boost aerial fast strike capability. It is expected to be ready for testing by 2017. During the cruise stage of flight the missile will be propelled by a scramjet airbreathing jet engine.

Stealth Technology: It is a technology that makes an aircraft invisible or less visible to the radars. It involves superior design of aircraft and use of advanced materials that makes the surface of aircraft less reflective and absorbs the electromagnetic waves produced by Radar.

Indigenous Air Defence System: An indigenous DRDO-developed air defence system with a centralized command, control and communication structure and linked to several mission (control) units throughout the country to detect all incoming missile and enemy aircraft.

'Silent' Radar

India has developed low-probability intercept radar that cannot be detected by an incoming aircraft and can escape from an anti-radiation missile attack. The radar for naval applications has been developed by Bharat Electronics Limited (BEL).

This is different in the sense that a normal radar sends out a warning to incoming air craft that is being tracked. "The low probability intercept radar developed by BEL does the radiation in a special way at a very low level of power." Dubbed as "Silent radar", it can be saved from anti-radiation missile attack by the aircraft since it cannot be detected by the aircraft. The main features of the new radar are: nil personal hazard, high resolution, fully solid state and low power consumption.

SUPERSONIC INTERCEPTOR MISSILE OF INDIA

India rides new high with successfully conducting a test of new supersonic interceptor missile off the Orissa coast, on 22nd November, 2012. India successfully test-fired an indigenously developed supersonic interceptor missile, capable of destroying a hostile ballistic missile, from a test range off the Odisha coast. India is working towards development of a multi-layer Ballistic Missile Defence system. The 'hostile' ballistic missile, a modified surface- to-surface 'Prithvi', mimicking an incoming enemy weapon, first lifted off from a mobile launcher from the launch complex-3 of integrated test range (ITR) at Chandipur-on-Sea, about 15 km from Balasore.

Within about four minutes, the interceptor, Advanced Air Defence (AAD) missile positioned at Wheeler Island, about 70 km from Chandipur, after getting signals from tracking radars, roared through its trajectory to destroy the incoming missile mid-air, in an "endo-atmospheric" altitude. The interceptor is a 7.5-metre-long single-stage solid rocket propelled guided missile equipped with a navigation system, a hi-tech computer and an electro-mechanical activator. The interceptor missile had its own mobile launcher, secure data link for interception, independent tracking and homing capabilities, besides sophisticated radars.

The system is in fact slightly better than Patriot Advanced Capability - (PAC-3) of the US in terms of interception, altitude and range against incoming ballistic missiles. The aim and objective of the exercise was to test the missile's ability to provide an air-shield (cover) to important Indian metros against hostile attacks. Besides, the missile would be moved closer to the Indio-Pak and Sino-Indian borders during crisis or wartime.

Missile Technology Control Regime

The MTCR (Missile Technology Control Regime) grew out of arrangements entered into in the East-West conventional arms talks of the 1970s. It became a formal but non-treaty arrangement in 1987 and currently has about 34 members/adherents. Its purpose is to control the technology and export of items that could be used to produce a missile capable of carrying a nuclear warhead. MTCR guidelines apply to missiles with ranges longer than 300 km. and payloads greater than 500 kg. The guidelines incorporate a list of items to be controlled. However, national export decisions are not subject to group review or sanctions. Export of munitions items are denied to non-members with appropriate assurances from the government of the importing country. The MTCR originally formulated by the G-7 nations for restricting transfer of critical technology classified as category I (greatest sensitivity) and category II (least sensitivity). The cryogenic engine technology falls under category I of the MTCR list of controlled technologies and the transfer therefore goes against what the guidelines seek to prevent and 'curb', in the language of MTCR guidelines, "the dangerous proliferation of missile technology by non-members". India is neither member nor adherent of the MTCR.

SUBMARINES & SHIPS

- **INS Chakra:**

With the induction of Nerpa, rechristened INS Chakra, into the Indian Navy in April 2012, India is back in the elite club of nations having nuclear-powered submarines. INS Chakra is a Russia-made, nuclear-propelled, hunter-killer submarine. The Akula Class submarine will carry conventional weapons. The vessel is armed with four 533 mm torpedo tubes and four

650mm torpedo tubes. It will be used to hunt and kill enemy ships. The INS Chakra displaces about 10,000 tons. It can do over 30 knots - more than twice the speed of conventional submarines. It can go upto a depth of 600 metres. It is one of the quietest nuclear submarines around, with noise levels next to zero.

INS Chakra has been taken on lease from Russia for 10 years and would provide the Navy the opportunity to train personnel and operate such nuclear-powered vessels. In 2004, India had signed a deal with Russia worth over $900 million for leasing the submarine. The only other nations possessing nuclear-powered submarines are - US, Russia, UK, France and China. India is back in this elite club after over a decade.

- **INS Arihant:**

India reached a milestone with the launch of the country's first nuclear submarine, INS Arihant at Visakhapatnam. Code-named Advanced Technology Vessel (ATV), the submarine was launched for sea trials at the Matsya naval dockyard in Vishakhapatnam. With the launch, India joined the exclusive club of US, Russia, China, France and the UK with similar capabilities. Symbolically the Arihant was launched on 26th July 2009, the anniversary of Vijay Diwas (Kargil War Victory Day).

As India has declared "no first use" of nuclear weapons, the country's weapons system must survive a first strike for retaliation. Therefore, Arihant's primary weapon is stealth as it can lurk in ocean depths of half a kilometre or more and fire its missiles from under the sea. The induction of ATV will help India to complete the nuclear weapons triad, as envisaged under its nuclear doctrine to deliver nuke-tipped missiles from land, air and sea.

Key facts

- The Rs. 30,000-crore secret nuclear submarine project was started in the 1980s though it was conceived by then Prime Minister Indira Gandhi in the 1970s.
- It can acquire surface speeds of 22 to 28 kmph and would carry a crew of 95 men and will be armed with torpedoes and missiles including 12 ballistic missiles.
- INS Arihant can also be armed with cruise missiles. The DRDO is already working on Sagarika project for a 700-km missile, capable of carrying nuclear weapons.

- **INS Trikand:**

INS Trikand, the last of the three "Follow On Talwar Class" frigates built in the Russian Federation, was commissioned into the Indian Navy on 29 June 2013 at Kaliningrad, Russia. The commissioning of INS Trikand marks the culmination of a three ship contract for "Follow On Talwar Class" ships built in Russia, and is therefore a milestone in the Indo-Russian military-technological cooperation. The other ships of the class viz, INS Teg and INS Tarkash were commissioned in 2012 and are now undertaking operations as part of the Western Fleet. The keel of INS Trikand was laid on 11 June 2008 and the ship was launched on 25 May 2011. Extensive Acceptance trials were conducted in the Baltic Sea in April and May 2013.

INS Trikand carries a state-of-the-art combat suite which includes the supersonic BRAHMOS missile system, advanced Surface to Air missiles Shtil, upgraded A190 medium range gun.

- **INS Vikrant (2013):**

It is the first vikrant-class aircraft carrier built by Cochin Shipyard Limited for the Indian Navy and the first Aircraft Carrier built in India. Construction is expected to be completed by 2016 and the ship is due to be commissioned in 2018.

- **INS Viraat:**

After retirement of Vikrant, Virat is performing as the main guard of Indian coastline. This ship has more capacity than Vikrant. Produced by the name of Harmiz, Virat was commissioned in Indian Navy on 12th May, 1987. After the upgrades, INS Viraat would be available for use till 2018.

- **INS Delhi:**

Indigenously made ballistic warship, commissioned in Navy on 15 November 1997. It has weight of 6700 tonnes. It is 163m long, 70 m wide and 6.4m high warship.

- **INS Prahar:**

World's fastest missile ship, commissioned in Indian Navy on 1 March, 1997.

- **Warship Ghariyal:**

Water surface attacker warship.

- **INS Mysore:**

Indian Navy's most modernized indigenously built warship.

- **INS Vikramaditya:**

It is a modified Kiev class aircraft carrier set to enter service with the Indian Navy and commissioned by November, 2013. It was purchased from Russia after retro-fitment for $2.35 billion.

- **INS Sagardhwani:**

INS Sagardhwani (A 74) is a marine acoustic research ship (MARS) based at Southern Naval Command, Kochi. The ship was launched in May 1991, and commissioned in 1994. The ship was built by Garden Reach Shipbuilders, Kolkata.

- **Sindhughosh-class submarine:**

Sindhughosh class submarines are Kilo class diesel-electric submarines in active service with the Indian Navy.

- **Sagar Nidhi**

India's deep sea exploration received a major boost with the induction of "Sagar Nidhi", a multi-purpose scientific vessel, acquired by the National Institute of Ocean Technology (NIOT), on 3rd March, 2008. The Rs 232-crore ship was built by Italian company Fincantieri, was a virtual floating laboratory and would be used for deep sea exploration and oceanographic studies. The Ice-class vessel was capable of undertaking deep sea explorations upto 45 days.

The vessel, which had taken part in a search and rescue operation in Red Sea during its maiden voyage from Italy to India, was also capable of cruising to Arctic and Antarctic regions. The multi-purpose vessel would be used by the scientists and engineers of NIOT, Indian National Centre for Ocean Information Services (INCOIS) at Hyderabad and National Centre for Antarctic and Ocean Research (NCAOR), Goa. Sagar Nidhi would fill the void experienced by Indian scientists till now for deep sea explorations.

DEFENCE RESEARCH IN INDIA

- **Food:**

The Defence Food Laboratory and the Central Food Technological Research Institute (CFTRI), Mysore of CSIR, have developed various products, processes preservatives and flexible packaging materials. The products include preserved chapattis, compressed ready to eat bars, preserved bread, canned Indian dishes, quick cooking foods, survival ration, and frozen dried products. They had also modified existing test methods and developed new analytical techniques to monitor the quality of food products. Chapattis packaged in paper foil laminate pouches could be preserved for six months.

- **Aeronautics**

In the area of aeronautics, the impetus has come from the defence project of Light Combat Aircraft (LCA) being executed by the autonomous Aeronautics Development Agency in Bangalore. The first military strike aircraft developed in the country was HF 24 (Marut).

The Aeronautical Development Establishment (ADE), and Gas Turbine Research Establishment (GTRE) in the Ministry of Defence and National Aeronautical Laboratory (NAL) in the CSIR were set up and their area of research were defined. While the NAL was asked to conduct R & D mainly related to the aircraft of the flight vehicle, GTRE was asked to concentrate on the development of prototypes of advanced technology gas turbines and ADE was directed to concentrate on the aircraft systems and such other tasks as may be given to it from time such as simulators, pilotless target aircraft, remotely piloted vehicles etc. The country is also involved in developing an Airborne Warning and Control Systems (AWACS) aircraft and several missile programmes.

Major products manufactured at the HAL are: Jaguar, Kiran, MIG, BIS, MIG 27 M and HBT 32 aircraft, Chetak and Cheetah helicopters, aero engines for various aircraft avionics, accessories and instruments, forgings and castings and parts required for space programme of the Indian Space Research Organisation. HAL is a major participant in the LCA development program.

- **Electronics Warfare**

Electronic Warfare (EW) is the focal theme of the Defence Electronics Research Laboratory, Hyderabad. The laboratory is engaged in several technique-oriented investigations in the EW area while developing hardware systems to meet the requirements of the services.

The Defence Science Centre (DSC) and Solid state Physics Laboratory (SPL), both at Delhi, are the two upstream laboratories engaged in an anticipatory research as well as engineering development in the field of solid state materials and devices. Several state of the art technologies such as gallium-arsenide devices, infra red detector arrays, charge coupled devices, acousto-optic devices, YAG laser crystals and gas laser sources are being developed. SPL has developed silicon solar cells which are likely to be used by the Indian Space Research Organisation. Several ferrite and garnet materials have been developed for microwave applications.

- **Ocean Science**

The Naval Physical and Oceanography Laboratory (NPOL), Kochi, has made significant contributions in understanding the ocean environment knowledge that is essential to the development of underwater sensors and weapon systems. Oceanographic instruments developed by the laboratory are being used extensively to collect data in respect of speed and direction of ocean currents, attention of visible light in the sea, sea wave and tidal records, and the sound velocity profile. The expendable bathy thermograph, developed by the laboratory, is being used by naval ships to determine the variation of temperature with depth, a factor critical to the underwater fire control problem.

The Naval Chemical and Metallurgical Laboratory (NCML), Mumbai, provides the navy with technology inputs that help protect the hulls of ships and submarines from corrosion and the hostile sea water environment. The laboratory has successfully developed underwater anticorrosive and antifouling paints in addition to the cathodic protection technology.

- **Life Sciences**

In the field of health, the Institute of Nuclear Medicine and Allied Sciences (INMAS), Delhi, has developed expertise in the areas of radiopharmaceutical, radioimmunoassay, radiobiology, health physics bioengineering and experimental medicine. It renders medical advice to the members of the armed forces as well as to others. The concept of radio iodine split dose therapy in the management of hyperthyroidism introduced by the institute’s prestigious Thyroid Research Centre has been well accepted in India and abroad.

The Defence Research and Development Establishment (DRDE), Gwalior is concerned mainly with toxicology and environmental pollution of importance to the defence services. It has devised procedures for identifying bacteriolysis principle, capable of producing 1,250 litres of potable water per hour from brackish water.

The Defence Bio-Engineering and Electro Medical laboratory at Bangalore studies problems related to bio engineering aspects of aviation, and also develops medical electronic instrumentation. Anti-G suits, oxygen masks and protective helmets have been developed by this unit. An automatic inflatable life jacket is being designed. In the field of electro medical instrumentation, a variety of equipment for patient monitoring cardiac care, cardiac pacemaker etc., have been developed. Presently, a medical data processing and automatic diagnosis system is under development.

- **Weapon System**

The Defence Research and Development Laboratory (DRDL) at Hyderabad has built up the technological base and facilities required for designing, developing and testing the diverse subsystems of guided missiles.

The Combat Vehicle Research and Development Establishment (VRDE) at Avadi near Chennai has been entrusted with the task of developing the Main Battle Tanks (MBT) to serve the Army in the late 1980s and 1990s. CVRDE is the system co-ordinator of this major project involving the cooperative efforts of several defence laboratories. In addition CVRDE has direct development responsibility covering vehicle design, its propulsion unit and auxiliary systems. The establishment is also engaged in the development of other armoured vehicle variants to fulfill different operational roles.

The Armament Research and Development Establishment (ARDE) at Pune has a long record of over twenty-five years of successful development of armaments required by the three services. Some of the important armament designed by ARDE which have been inducted into service are the well known Ishapore Rifle with its ammunition, 75/24 pack Howitzer and its ammunition for use in the mountainous regions, 105 mm Indian field Gun, unguided rockets for air to ground use. Currently ARDE is actively engaged in the development of a Fin Stabilized Armour piercing Discarding Sabot, a family of small arms with matching ammunition, a powerful gun for the Main Battle Tank, rapid fire multi barrel rocket system and several more weapons. A special explosive bore-hole charge developed by ARDE has been utilized by the Oil and Natural Gas Commission in petroleum exploration. Armament design is a multidisciplinary effort and for this purposes ARDE maintains a continuous interaction with other defence establishments.

BIOLOGICAL AND CHEMICAL WEAPONS

Like a nuclear bomb, a chemical or biological weapon is a weapon of mass destruction. An effective attack using a chemical or biological agent can easily kill thousands of people.

Biological warfare (BW) — also known as germ warfare — is the deliberate use of disease-causing biological agents such as bacteria, viruses, fungi, or biological toxins, to kill or incapacitate humans, animals or plants as an act of war. Biological weapons are living organisms or replicating entities (viruses) that reproduce or replicate within their host victims.

Offensive biological warfare, including mass production, stockpiling and use of biological weapons, was outlawed by the 1972 Biological Weapons Convention (BWC). The rationale behind this treaty, which has been ratified or acceded to by 170 countries as of April 2013, is to prevent a biological attack which could conceivably result in large numbers of civilian fatalities and cause severe disruption to economic and societal infrastructure. Many countries, including signatories of the BWC, currently pursue research into the defense or protection against BW, which is not prohibited by the BWC.

In 1972, the United States signed the Biological and Toxic Weapons Convention, which banned the “development, production and stockpiling of microbes or their poisonous products except in amounts necessary for protective and peaceful research.”

A chemical weapon is any weapon that uses a manufactured chemical to kill people. The first chemical weapon used effectively in battle was chlorine gas, which burns and destroys lung tissue.

Modern chemical weapons tend to focus on agents with much greater killing power, meaning that it takes a lot less of the chemical to kill the same number of people. Many of them use the sorts of chemicals found in insecticides.

The Chemical Weapons Convention (CWC) is an arms control agreement which outlaws the production, stockpiling and use of chemical weapons. Its full name is the Convention on the Prohibition of the Development, Production, Stockpiling and Use of Chemical Weapons and on their Destruction. The main obligation under the convention is the prohibition of use and production of chemical weapons, as well as the destruction of all chemical weapons.

IAF’S VISION 2020

The Indian Air Force (IAF) in its recently held presentation entitled ‘Vision 2020’ made several suggestions of strategic importance to the Government. Primarily it suggested the formation of a nuclear air command even as it seeks two front capability and enhanced force levels in the years to come. The presentation was path-breaking since it advocated that the country’s strategic resources be placed under the nuclear air command because only the IAF had the required delivery platforms-meaning the strategic reach aircraft. According to the IAF, the Army did not need and in fact might not need a nuclear role because of the incongruity of tactical nuclear weapons in India’s draft nuclear doctrine. The third leg of the triad; nuclear submarine was still beyond the Indian Navy’s reach. The vision document recommended that as soon as the ‘Agni’ intermediate range ballistic missile became operational, it should be given the nuclear air command as the range of the 'Prithvi' missile was too short to qualify as a nuclear weapon delivery platform. This future defence strategy is a step ahead from the present stance of deterrence for Pakistan and dissuasion for China.

Public Sector Undertakings Under the Ministry of Defence

- Hindustan Aeronautics Limited (HAL)
- Bharat Electronics Limited (BEL)
- Bharat Earth Movers Limited (BEML)
- Mazagaon Dock Limited (MDL)
- Garden Reach Shipbuilders & Engineers Limited (GRSE)
- Goa Shipyard Limited (GSL)
- Bharat Dynamics Limited (BDL)
- Mishra Dhatu Nigam Limited (MIDHANI)

Other Organizations in Department of Defence Production are:

- Directorate General of Quality Assurance (DGQA)
- Directorate General of Aeronautical Quality Assurance (DGAQA)
- Directorate of Standardisation (DOS)
- Directorate of Planning and Coordination (Dte. of P&C)
- Defence Exhibition Organisation (DEO)
- National Institute for Research & Development in Defence Shipbuilding (NIRDESH)

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ENERGY RESOURCES

Energy is one of the most important building block in human development, and, as such, acts as a key factor in determining the economic development of all countries. In an effort to meet the demands of a developing nation, the Indian energy sector has witnessed a rapid growth. Areas like the resource exploration and exploitation, capacity additions, and energy sector reforms have been revolutionized. However, resource augmentation and growth in energy supply have failed to meet the ever increasing demands exerted by the multiplying population, rapid urbanization and progressing economy. Hence, serious energy shortages continue to plague India, forcing it to rely heavily on imports.

India is the fourth largest consumer of energy in the world after USA, China and Russia but it is not endowed with abundant energy resources. It must, therefore, meet its development needs by using all available domestic resources of coal, uranium, oil, hydro and other renewable resources, and supplementing domestic production by imports.

High reliance on imported energy is costly given the prevailing energy prices which are not likely to soften; it also impinges adversely on energy security. Meeting the energy needs of achieving 8 per cent 9 per cent economic growth while also meeting energy requirements of the population at affordable prices therefore presents a major challenge.

Social, economic and scientific developments are directly linked to the development of energy resources. However, the present stock of energy resources of the world is limited and can last only for a few decades. Moreover most conventional energy sources are non-renewable. Hence, mankind is searching new source of energy and the development of renewable sources of energy along with the rational use of existing non-renewable energy and their conservation.

ENERGY SOURCES IN INDIA

Energy resources are classified into conventional and non conventional forms on the basis of their use. Conventional or non-renewable sources are those especially coming from the fossils and which cannot be re-used once exhausted like coal, petroleum, wood, etc. However non-conventional or renewable sources, as the name suggests are inexhaustible pool of energy, ready at every moment to be used or re-used like tidal energy, wind energy, biomass energy, etc.

Establishment of new generation capacity and reducing cost of power will require action on many fronts:

- Availability of fuel such as coal or natural gas for new power plants must be assured;
- A national consensus on royalty rates for fuels and compensation for host states also needs to be worked;
- Long term finance should be made available to lower capital charge;
- The presently provided guaranteed rate of post tax returns for CPSUs should be lowered to reduce cost of power and augment resources of state power utilities;
- An efficient inter-state and intra-state transmission system of adequate capacity that is capable of transferring power from one region to another;
- An efficient distribution system which alone can ensure financially viable expansion;
- Rehabilitation of thermal stations through R&M to augment generating capacity and improve PLF;
- Rehabilitation of hydro stations to yield additional peaking capacity;
- Ensuring use of washed coal for power generation; and
- Harnessing captive capacity to support the grid.

1. Coal & Lignite

Coal is the mainstay of India's energy sector accounting for over 50 per cent of primary commercial energy supply in 2010–11. This share will actually increase to 57 per cent over the next 10 years. The gap between the demand and the domestic supply of coal has made it imperative to augment domestic production both from the public sector and the private sector and to expedite the reform process for realising efficiency gains through increased competition in the sector during the 12th Plan.

An important feature of the 11th Plan was the attempt to augment domestic coal production from captive mines. However, the programme slipped and expected production from captive blocks fell well short of the projected target of 104 million tonnes in the terminal year of the Plan.

The target for coal production at the end of the 11th Plan was initially set at 680 million tonnes and revised downwards to 630 million tones at the time of the MTA. The actual achievement was only 540 million tonnes. Since demand in the terminal year (2011–12) of the 11th Plan was around 640 million tonnes there was a large demand–supply gap of 100 million tonnes which was only partially met by imports. This adversely affected the coal supplies to end consumers, particularly the power sector.

It is estimated that out of capacity addition of 41,894 MW, around 25,000 MW of coal-based capacity commissioned is being sub-optimally utilized because of inadequate availability of domestic coal. The widening gap between demand and supply has to be met by imports because of which the share of imports in the total coal demand is likely to increase.

As on March 31, 2012 the estimated reserves of coal was around 293.5 billion tones, an addition of 7.64 billion over the last year. There has been an increase of 2.67 per cent in the estimated coal reserves during the year 2011-12 with Madhya Pradesh accounting for the maximum increase of 5.41 per cent.

Coal deposits are mainly confined to eastern and south central parts of the country. The states of Jharkhand, Odisha, Chhattisgarh, West Bengal, Andhra Pradesh, Maharashtra and Madhya Pradesh account for more than 99% of the total coal reserves in the country.

The estimated reserve of lignite was 41.96 billion tonnes against 40.91 billion tonnes in 2011. The increase in the estimated reserve of lignite during the year 2011-12 was 1.22 per cent, Tamil Nadu accounting for the maximum increase of 2.99 per cent.

Domestic production of coal and lignite account for two-third of total production of commercial energy in 2000–01 and is projected to be about the same in 2021–22. As a percentage of total consumption of commercial energy, the share of coal and lignite was projected to increase to 57 per cent, from a level of 50 per cent in 2000–01.

2. Oil and Gas

Petroleum is derived from dead animals that lived in remote past. Natural gas has also been produced in the Earth's crust by similar processes and this is also a combustible fuel. The exploitation of oil on a large scale really started after 1860, the year when the first commercial well is reported to have come into existence. With the discovery of oil and its refined products such as gasoline and diesel, new engines and machines came into existence and productivity increased. Indeed, this was a period of the industrial revolution. Oil and its derived products are very convenient and versatile as fuels and can be easily transported.

In India, efforts made by the Oil and Natural Gas Corporation (ONGC) and Oil India since the late 1950s have led to the identification of a number of oil and gas deposits both offshore and onshore. The onshore fields were mainly discovered in the Mumbai, Gujarat, Assam and Arunachal Pradesh; and the offshore fields in the sea were notably the Mumbai High fields such as North and South Basin and South Tapti. Oil and gas has also been discovered in the Godavari Basin and on the East Coast.

The new exploration strategy places emphasis on intensive exploration survey and drilling in order to add to petroleum reserves and to augment production as early as possible. In order to meet burgeoning demand for petroleum products in the country, the Ministry of Petroleum & Natural Gas has taken several measures to enhance exploration and exploitation of petroleum resources including natural gas and Coal Bed Methane (CBM), apart from improved distribution, marketing and pricing of petroleum products.

During the financial year 2011-12, crude oil production was about 38.09 million metric tonne (MMT), with share of national oil companies at 72.4 per cent. The projected crude oil production in 2012-13 was about 41.12 MMT which is about 8 per cent higher than the previous year crude oil production. The increase in crude oil production is mainly due to higher crude oil production from Barmer Fields, Rajasthan.

The average natural gas production in the year 2011-12 was about 130 million metric standard cubic metre per day (MMSCMD) which was about 9 per cent lower than the previous year mainly due to lower production from KG D6 deepwater block. The projected natural gas production in 2012-13 is about 118.3 MMSCMD, which was about 9 per cent lower than the previous year.

The Indian refinery capacity as on August 1, 2012 was 215.08 MMT which was expected to reach to 218.40 MMT by the end of 2012-13. Refinery production (crude throughput) during 2011-12 was 211.42 MMT (including crude throughput by RIL SEZ Refinery). At present, there are 22 refineries (17 under Public Sector, 3 under private sector and 2 in joint venture) in India.

Natural gas is emerging as an important source in India's commercial energy scene in view of large reserves of gas that have been established in the country, particularly, in South Basin off West Coast of India. Natural gas is also making significant contribution to the household sector by way of LPG extracted from associated gas. About 30 per cent of the country's output of LPG comes from this source.

The Dabhol-Bengaluru gas pipeline was commissioned by GAIL on February 18, 2013. The 1,000 kms pipeline, built at a cost of Rs. 4,500 crore, will carry gas from Dabhol LNG terminal into Bengaluru and feed industries in Belgaum, Dharwad, Gadag, Bellary, Davangere, Chitradurg, Tumkur, Ramanagram and Bengaluru.

India is highly dependent on import of crude oil. Both gross and net imports of crude oil have increased from 11.68 MTs during 1970-71 to 171.73 MTs during 2011-12. There has been an annual increase of 4.97 per cent during 2011-12 over 2010-11, as the net import increased from 163.60 MTs to 171.73 MTs. Although more than 70% of its crude oil requirements and part of the petroleum products is met from imports, India has developed sufficient processing capacity over the years to produce different petroleum products so as to become a net exporter of petroleum products. The import of petroleum products increased from only 1.08 MT in 1970-71 to 15.00 MT during 2011-12. However, there was a decline of 10.82% in import of petroleum products over the previous year.

Share of oil in total commercial energy consumption is expected to decline from 37.5 per cent in 2000–01 to 23.3 per cent in 2021–22, the share of natural gas and liquefied natural gas (LNG) is projected to rise from 8.5 per cent to 13 per cent in the same period. The combined share of oil and natural gas in energy consumption was 24.7 per cent in 2011–12 and is expected to be about the same in 2021–22.

The estimated reserves of crude oil in India as on March 31, 2012 stood at 759.59 million tonnes (MT). Geographical distribution of Crude oil indicates that the maximum reserves are in the Western Offshore (44.46%) followed by Assam (22.71%), whereas the maximum reserves of Natural Gas are in the Eastern Offshore (34.73%) followed by Western offshore (31.62%). There was an increase of 0.29 per cent in the estimated reserve of crude oil for the country as a whole during 2011-12. There was an increase of estimated Crude Oil reserves by 7.09 per cent in Andhra Pradesh followed by Tamil Nadu (4.48%).

The estimated reserves of natural gas in India as on March 31, 2012 stood at 1330.26 billion cubic meters (BCM). In case of Natural Gas, the increase in the estimated reserves over the last year was 4.08 per cent. The maximum contribution to this increase has been from Cold Bed Methane (11.32%), followed by Tripura (8.95%).

3. Crude Oil and Natural Gas Production

During the year 2011-12, production for crude oil was 38.09 MMT, which is about 1.08% higher than the actual crude oil production of 37.684 MMT during 2010-11. Natural gas production during 2011-12 was 47.559 BCM against production of 52.219 BCM during 2010-11 which is lower by 8.92 per cent due to lower production from KG D-6 basin.

The Government of India launched the ninth bid round of New Exploration Licensing Policy (NELPIX) and fourth round of Coal Bed Methane Policy (CBM-IV) during October 2010 to enhance the Country's energy security. In addition, in order to supplement domestic reserves the oil and gas PSUs have acquired assets abroad, the production of oil and natural gas of ONGC-VIDESH Ltd during 2011-12 was 8.75 MMT of oil and equivalent gas (MMTOE) from its assets abroad.

4. Hydrogen-CNG Fuel Centre

The Renewable Energy Ministry on 7th June,2007 unveiled a Rs 25,000 crore roadmap to promote use of hydrogen, with an estimated one million vehicles using it as fuel by 2020 and the gas being used to fire electricity generation units for an aggregate 1,000 mw of electricity. As part of the new initiative, a demonstration project for setting up a hydrogen dispensing set-up at a petrol pump in Delhi has been sanctioned as a joint venture with Indian Oil Corporation. The project would enable dispensing of neat hydrogen and CNG blended with hydrogen as fuel for vehicles. The station will have a hydrogen generation capacity using an electrolyser system and facilities for storing and dispensing neat hydrogen as well as blended with CNG in varying ratios. The H-CNG blends will be used in the modified CNG vehicles and are expected to further reduce emissions from such vehicles as compared to when burning only CNG. The project would also generate operational experience in handling hydrogen as an automotive fuel.

NON-CONVENTIONAL SOURCES OF ENERGY

In the long run, new and renewable sources of energy will be necessary since the reserves of conventional fuels, such as, oil and coal are limited in the world and the pressure on their availability and prices will steadily mount as demands increase. Even in India, at the current level of production, coal is expected to last for only 245 years, oil for 21 years and natural gas for another 38 years. Such alternate sources of energy are renewable by nature and have also the advantage of generally producing energy in a non-polluting form. Thus, the twin objectives of energy production and environmental preservation can both be largely met by recourse to these renewable forms of energy.

1. Solar Energy

The Sun provides us enormous amounts of energy in the form of solar radiation-energy that travels in small wave packets called photons, reaching the surface of the Earth from a distance of 93 million miles. Radiation energy is released due to thermo-nuclear fusion going on continuously in the Sun. The solar energy reaching per square metre of the Earth's atmosphere is called the 'Solar Constant' and is equal to 1.36 KW in 12 hours. The total energy being received by the atmosphere is about 1.5x1018 KWh per day. It is believed that with just 0.1% of the 75000 trillion KWh of solar energy that reaches the Earth, the energy required by plants can be satisfied. Application of solar energy can broadly be sub-divided as follows:

1. Conversion of solar energy into heat.
2. Conversion of solar energy directly into electricity.
3. Conversion of solar energy to plants, vegetable or other biological forms and application of solar energy to convert these forms into usable forms of fuel. This may broadly be termed as bio-energy.
4. Indirect application of solar energy, such as, harnessing of winds, waves, temperature gradients from the ocean, etc. All of which are the consequences of incident solar energy.

Applications

Solar Cooker: Depending upon the type of cooker, the temperature in the range of 120° to 300°C can be attained. This can save 30-50% of commonly used cooking fuels like wood, coal, LPG, Kerosene, etc. The drawback with such cooker is that the cooker has to be directed towards the Sun after every 10-15 minutes and if the automatic devices for such tracking are provided, the cost increases. In 1982, India became the first country in the world to start regular large scale commercial production and marketing of solar cookers.

Solar Pond: Solar pond is one of the most promising technologies in solar energy utilization for varied purposes. It's a large-scale solar energy collector with integral heat energy storage by various ways, such as, process heating, water desalination, refrigeration and drying.

Fluids such as water and air become lighter and rise above when heated. Similarly, when water is heated by the Sun's rays, hot water from the bottom of the pond rises and it reaches the surface, and loses whatever heat it has gained to the atmosphere. The result is that the pond water remains at nearly atmospheric temperature. To prevent this heat loss by convection in a solar pond, salt is dissolved in the bottom layer of the pond. This makes the water too heavy (i.e. dense) to rise even when hot, to the surface, and cool. Thus, the solar energy remains entrapped in the pond.

A solar pond consists of three zones — The top zone or the surface zone is at atmospheric temperature and has little salt content. The bottom zone is very hot (100°C) and very salty with specific gravity of about 1.20. It is this zone which collects and stores the solar energy in the form of heat and is, hence, known as storage zone. Separating these two zones is the gradient zone that acts as a transparent insulator, permitting sunlight to reach the bottom zone and its thermal energy to remain entrapped there. The useful energy is then withdrawn from the solar pond in the form of hot brine from the storage zone.

Solar ponds have three major advantages over the other solar technologies:

(i) they have a low cost per unit area.

(ii) they can be constructed over large areas enabling the diffused solar radiation to be concentrated on large scale; and

(iii) they can supply energy even during the monsoon season.

India is the first Asian country to have a solar pond (6000 sq. metres) in Bhuj, Gujarat. The project was sanctioned under the National Solar Pond Programme by the Ministry of Non-conventional Energy Sources in 1987 and completed in 1993. The Bhuj solar pond has been designed to supply about 220 lakh KWH of thermal energy per annum; about 1,25,000 KWH of electricity per annum; and about 80,000 litres of potable water per day.

Solar Water Heaters: This system consists of Flat-plate solar collector and storage tank. This system has many applications in the domestic and industrial sectors. It can provide hot water for different applications such as in textile engineering, directly or as boiler feed and in the hotels and canteens, apart from domestic sector. Today, such water heaters are being manufactured by many industrial manufacturers in India and abroad.

Solar Desalination: It works on the water heating principle. It can be used to provide water for drinking in areas where only salty or brackish water is available. It can also be used to provide distilled water needed for batteries and other applications. About 3 to 4 litres of pure water can be obtained from one square metre area of the system per day.

Solar Air Heaters: It can be used for various applications like drying of Foodgrains, vegetables, fruits, wood, etc. Products dried in a solar dryer are as good, if not better, in quality and food value as compared to those dried in conventional dryers. Temperature as high as 130°C can very easily be attained with this simple system. This hot air can be utilised to dry any material, such as, wood or agricultural crops, increasing the speed and efficiency of such drying several times more than the traditional method of direct exposure to the Sun. The heated air can also be used to operate engines.

Solar Space Conditioning: A number of solar houses have been built in different countries of the world with heating systems comprising of flat-plate collectors and storage units, proper heat distribution and control system. Such systems are normally based on absorption refrigeration cycle. However, the cooling of residential and office buildings can also be done by following the solar cooling process.

Solar Refrigeration: Utilization of solar energy for production of low temperature has been found to be an attractive proposition because the cooling effect is most needed when the Sun is shining. Solar cooling is a most required application for developing countries where considerable quantity of food produce are spoiled due to inadequate and improper processing and lack of storage facilities.

Solar Stem Generators: This is done by concentrating the solar radiation using concentrating collectors like parabolic line focusing systems, parabolic point focusing systems or plane reflector central tower systems. Temperature as high as 3000°C can be achieved. The steam can be utilised in industry to operate engines, or to generate power.

2. *Wind Energy*

Wind energy is the kinetic energy associated with movement of large masses of air resulting from the differential heating of the atmosphere by the Sun. Hence, wind energy is nothing but the converted form of solar energy. It is estimated that about 106 to 107 MW of usable power is continuously available in the Earth's winds. Though the total quantity of this resource is extremely large, it is concentrated in certain regions, and can vary a great deal with time at given location. For the utilization of wind energy, the speed of wind must be between 8 to 22 m per second. Wind energy is renewable and possess no major environmental threats.

A total capacity of 18,420 MW has been established up to December 2012 in the country. India is now the fifth largest wind power producer in the world, after China, USA, Germany and Spain. As per Indian Wind Atlas, the on-shore wind power potential has been estimated as 49,130 MW at 50 m height.

Wind Energy Conversion: The shaft power from the wind turbine can be utilized for a wide variety of purposes, including electricity (AC & DC generation), direct pumping, direct mechanical work, etc. The most common wind turbine system involves a tower mounted multi-bladed rotor facing into the wind, rotating around a horizontal axis and turning an electrical generator or a mechanical gearbox connected to its axis. The maximum power that can be extracted from a wind turbine is 59.3 per cent.

Water Pumping Windmills: Small windmills with direct mechanical drive matched to a pump and tank storage are in extensive use in many parts of the world. These hold significant potential for pumping water irrigation, drinking needs, etc. Improved types of soil water pumping windmills have also been developed in several countries, including India.

Wind Electric Conversion Systems: Wind energy is a high-quality form of mechanical energy that can be converted into electrical energy with minimal energy losses. Since the rotor of a windmill moves periodically, the output may be obtained in the form of alternating current either by using a gearbox or fixing the rotational speed or by allowing speed variations and transforming the generated electrical power to the desired frequency, electronically. Application ranges from small scale use in rural and remote communities interconnected with other power plants to large scale generation of electricity, which is fed into electric utility network. It can also be used for battery charging by driving brushless DC generators, to supply electric power to isolated communities, weather stations, navigation and communication aids, etc. A number of countries like Denmark, Sweden and USA have launched major wind energy testing programmes in an effort to integrate large scale wind-generated electric power into grid power supply. The combination of wind power system and hydroelectric system is considered to have high potential. Stored water can be used in low wind periods. Favourable wind regimes on islands, coastal areas and mountain regions could be taken advantage of in setting up large numbers of wind turbines.

Tapping wind power

The Union Ministry of Non-conventional Energy Sources (MNES) has recently assessed that the potential of the wind power sector in India is 45,000 MW, which is more than twice the earlier estimates (i.e., 20,000 MW). Thus, India's potential for using wind power is much more than was previously thought. Presently, India occupies the fifth position in the world with a wind power installed capacity of 18.4 GW. During the year 2012-13 1,067 MW wind power projects were commissioned.

In order to generate greater wind power, the domestic wind power-generating sector has to be more professional. It must not be bogged down by constraints like weak grids, inadequate data on winds and incompatibility with imported infrastructure. 14 States, based on the guidelines of MNES, have introduced policies, which entail banking facility, third party sales of power, etc. MNES is in the process of preparing a 'master plan' for wind power in 10 States, for 80 potential sites. There is no denying the fact that without imaginative use of wind power, the energy crunch could not be tackled.

3. Ocean Energy

The sea, which is constantly receiving solar radiations and acts as the world's largest natural solar collector, has potential to provide a means of utilizing renewable energy. It acts not only as collector, but also has an enormous storage capacity. Energy from the ocean is available in several forms such as ocean thermal energy, wave energy, tidal energy, salinity gradients, ocean currents, ocean winds and bio-mass.

Ocean Thermal Energy Conversion

There exists a temperature difference of the order of 20°C between the warm surface water of the sea and the cold deep water, and this natural temperature difference can be used to generate energy. In one OTEC plant, the warm water from the surface with the temperature of 24 to 30°C is brought into one pipe and the cold water at the temperature of about 4 to 8°C is brought in another pipe in the depth of about 1000 metres. These two pipes are used in conjunction with fluid such as ammonia, propane or neon. The warm water evaporates liquid ammonia into vapour at high pressure and is made to pass through a turbine which rotates it and generates electricity. The ammonia vapour coming out of the turbine is condensed back into liquid ammonia by cooling it with the cold sea water brought up from the deep part. The liquified ammonia is then pumped back to the evaporator, thus, completing the cycle, which can then run continuously.

Energy from OTEC can be converted into either electrical, chemical or protein form. These plants could be combined with energy intensive industries like ammonia, hydrogen or aluminium production. Furthermore, OTEC plants can be combined with aquaculture or desalination for obtaining fresh water. The cold water from the deeper sea which is rich in nutrients can be placed in a lagoon or lake where these nutrients can help to raise fish, oysters or other types of biological life.

Being a tropical country, India has the OTEC potential of about 50,000 MW. The most promising site identified so far is on the Lakshadweep Islands where the necessary geographical conditions for a shore-based OTEC plant exist. In these islands, the alternative cost of producing electricity by transporting diesel from the main land as is being done at present, is very high. India has also tied up with a US-firm to set up an OTEC Plant in Tamil Nadu.

Wave Energy

Movement of large quantities of water up and down can, in principle, be harnessed to convert it into usable form of energy, such as, electricity or mechanical power. Several types based on flats, flaps, ramps and oscillating air water columns have been worked upon to harness wave energy. It is more reliable than the wind energy because here the fluctuation is less than the wind. However at present, due to infant stage of its technology, the cost per unit of energy converted is high because of the need for special structures at sea, corrosion problem associated with the use of sea water and the problem of transmitting the power onshore.

Tidal Energy

Tides are created by the combined gravitational effect of the Earth, the Moon and the Sun. Though the tide is the universal phenomenon of the Earth's sea-water body, some regions are more favourable for the establishment of such power plant for the commercial production of tidal energy. Primary requirements for the construction of an installation having a capacity over 200 MW are (i) an average tide of 5-12 metres; (ii) the possibility of linkage to a grid in order to accommodate the variable power output of the tidal plant; (iii) favourable geographical location and favourable socio-economic and ecological conditions. Bulb type turbines as used in conventional hydro-electric stations have proved to be reliable for generating power from the tides.

In India, three potential sites have so far been identified, namely, the Gulfs of Kutch and Cambay on the west coast in Gujarat and the Sunderbans along the east coast in West Bengal. According to the estimates of the Indian government, the country has a potential of 8,000 MW of tidal energy. This includes about 7,000 MW in the Gulf of Cambay in Gujarat, 1,200 MW in the Gulf of Kutch and 100 MW in the

Gangetic delta in the Sunderbans region of West Bengal. 'Central Electricity Authority' in India has the overall responsibility for developing it. A power plant of 600 MW capacity is proposed to be set up in the Gulf of Kutch.

The Gujarat government is all set to develop India's first tidal energy plant. In 2012, the state government had approved Rs. 25 crore for setting up the 50 MW plant at the Gulf of Kutch.

4. HYDRO ENERGY

India is blessed with immense amount of hydro-electric potential and ranks 5th in terms of exploitable hydro-potential on global scenario. As per assessment made by CEA, India is endowed with economically exploitable hydro-power potential to the tune of 1,48,700 MW of installed capacity. Today, about 23 per cent of the total electric power in the world comes from hydropower.

India is endowed with economically exploitable and viable hydro potential assessed to be about 84,000 MW at 60 per cent load factor (1,48,701 MW installed capacity). In addition, 6780 MW in terms of installed capacity from Small, Mini, and Micro Hydel schemes have been assessed. Also, 56 sites for pumped storage schemes with an aggregate installed capacity of 94,000 MW have been identified. However, only 19.9 per cent of the potential has been harnessed so far.

The total hydro-electric potential in India has been estimated at about 472x109 kilowatt hours or 472 terawatt hours normally. But, we have exploited only a little more than 19 per cent of the total potential. In addition, it is also estimated that an annual energy generation of about 25 terawatt could be obtained economically through mini and micro-hydels, coal drops and other possible low- head developments. A centre for the development and demonstration of alternate small hydro technologies has been set up at Roorkee University by the Department of Non-Conventional Energy Sources for development of newer and more economic designs of micro-hydel units, water mills and hydrams. Several field projects in Haryana, Himachal Pradesh, Uttar Pradesh and Jammu and Kashmir are being initiated to utilise the potential availability of canal drops, falls, run-off-river systems, etc.

The National Hydro-Electric Power Corporation (NHPC) was incorporated in 1975 with the objectives to plan, promote and organise the integrated development of hydro-electric power. NHPC Limited presently has an installation base of 5295 MW from 14 hydropower stations on ownership basis, including projects taken up in Joint Venture. Some important hydro-electric power projects constructed by NHPC are at Salal and Dulhasti (both in J&K), Tanakpur (Uttarakhand), Chamera (HP), Baira Siul (HP), Chutak (J&K), Teesta Low Dam – III (W.Bengal), Sewa - II (J&K), Teesta - V (Sikkim), Omkareshwar (MP), Dhauliganga - I (Uttarakhand), Indira Sagar (MP), Rangit (Sikkim), Uri - I (J&K), and Loktak (Manipur).

NHPC Limited is presently engaged in the construction of 10 projects aggregating to a total installed capacity of 4502 MW. Given the renewed thrust on development of hydro power in the country, NHPC Limited has drawn up a massive plan to add over 10,000 MW of hydropower capacity by the end of XIIth Plan (year 2017).

The National Projects Construction Corporation (NPCC) was set up in 1957 as a joint venture of central and state governments as a construction-contracting agency for the execution of multipurpose river valley projects, power projects and other heavy engineering projects. As a part of diversification plan, the Corporation proposes to take up the work of transmission lines also.

5. GEOTHERMAL ENERGY

Geothermal energy is the exploitation of heat energy of Earth within 10 km of the Earth's upper crust. Geothermal energy can be processed for generation of power, where the geothermal fluid has a temperature of 130°C. Geothermal manifestations are widespread in India in the form of 340 Hot Springs localities. Only a few direct utilization schemes have been launched by various agencies. They are in Puga, Chhumuthang, Manikaran and Bakreshwar. Of these, India's most promising geothermal field is in Puga valley in Ladakh. There are number of geothermal wells drilled in the valley. Tattapani in Madhya Pradesh is another promising geothermal area in India.

Magneto Hydro-dynamics Power

MHD power generation is a method, whereby thermal energy is directly converted into electrical energy instead of thermal energy being converted to mechanical energy and then to the electrical energy as is done in the power plants. In this process, coal is burnt to produce hot and high speed gas which is allowed to pass over a strong magnetic field and this result in the direct conversion of thermal energy into electrical energy. It is capable of achieving net efficiency of around 60 per cent, while in the conventional power plants it is only 35 per cent.

Bio-Engery

Bio-energy includes those processes where biological forms of matter, such as, plants, vegetables, enzymes, etc. provide the basis for energy or its conversion from one form to another form of energy. The widest use of bio-energy is in the traditional way, where wood plants and agricultural matter are directly burnt to provide heat. Vegetable biomass is a new name for plant organic matter, wherein solar energy is trapped and stored through the process of photosynthesis in which carbon dioxide and water are transformed and form energy-rich organic compounds.

Biomass covers a wide range of materials, encompassing all kinds of animal, organic and synthetic wastes and a special variety of vegetation-wild grass, shrubs and some plants and trees, especially cultivated to derive energy and useful by products and this biotechnology is one of the oldest manufacturing activities, having started ever since man learnt to produce bread, wine, beer and cheese. However, only recently the process is well understood and mankind has started to move in the right direction to make better use of this revolutionary technology. The major components of biomass are mainly carbohydrates - sugars, starches and cellulose - with variable nitrogen and phosphorous contents. Animals, organic and synthetic wastes cover the balance components. There are three basic systems for conversion of biomass into energy resources.

(a) **Combustion Pyrolysis:** Chemical decomposition through high temperature. (upto 5000°C) in partial or total absence of air to produce fuel gas, oil (methanol) and charcoal.

(b) **Biogasification:** Anaerobic digestion of biomass to produce combustible gas (biogas) comprising of methane, hydrogen, etc.

(c) **Fermentation:** Conversion of sugar and starch into alcohol to produce ethanol and solid residual fuel.

The potential of biomass in India is estimated at 1250 MMTPA which is about one-eightieth of the global total. Energy available from such a massive biomass is equivalent to about 300 MMT of oil.

6. *ALTERNATIVE FUELS*

Compressed Natural Gas or CNG is a cleaner alternative to the liquid petroleum. CNG is already in use in countries such as the USA, Japan, Italy, Brazil and New Zealand. In Delhi, the Supreme Court has directed the operation of city buses exclusively on CNG fuel mode.The government on its part launched CNG pilot project in Delhi as early as 1993. Thanks to this project, CNG is now available in the NCR and most cities of the country.

CNG is cleaner fuel than the conventional fuel (petrol and diesel) as far as PM is concerned. Further, CO, HC and NOX emission for CNG based car are lower because of the catalytic converter fitted with them.

Gasohol: It is a mixture of absolute alcohol and petrol and is being tried as a fuel to run a car. A programme of 5 per cent blending of ethanol with petrol is already underway with effect from November 2006 targeting 20 States and 4 UTs. Subject to availability, the percentage of blend can be enhanced to 10 per cent as specification for petrol with 10 per cent ethanol blend is already given by the BIS. At present, the EBP Programme is successfully running in 14 States and three UTs; OMCs have been able to contract 55.87 crore litres of ethanol against the requirement of 105 crore litres of ethanol for 5 per cent blending in the entire notified area.

The Mysore Sugar Company of Madya tried out a 25:75 proportion mix of absolute alcohol and patrol for maximum efficiency. A fuel economy of 3 to 5 per cent has been reported when gasohol is used as a fuel.

Hydrogen: Hydrogen appears to be a favoured alternative due to its high specific energy per unit weight, its almost universal availability as a component of water, good combustion characteristics and the fact that it is environment-friendly. The primary combustion product is water vapour and apart from low nitric oxide fractions, there are virtually no harmful exhaust gases, in particular no carbon monoxide, hydrocarbons and particulates which are the bane of petrofuel combustion.

From the safety angle, there is however one major problem with hydrogen, its low density and high diffusion capacity, which leads to a high permeation capability through systems which are normally considered to be gas-tight. The low density of hydrogen means that it rises quickly into the atmosphere if proper venting is done. Today, the technology to make hydrogen leak-proof components is available. Also any leakages can be monitored and displayed with hydrogen sensitive sensors.

Hydrogen is being aggressively explored as a fuel for passenger vehicles. It can be used in fuel cells to power electric motors or burned in internal combustion engines (ICEs). It is an environmentally friendly fuel that has the potential to dramatically reduce our dependence on imported oil, but several significant challenges must be overcome before it can be widely used.

NON-CONVENTIONAL ENERGY PROGRAMME

The need to increase total domestic energy production in order to reduce import dependence, combined with the need to move away from fossil fuels in the longer run in view of climate change considerations, points to the need for stronger efforts to increase the supply of energy from renewables. Union Minister of New and Renewable Energy, Dr. Farooq Abdullah has said that India is committed to increasing the share of renewable power in the electricity mix to 15 per cent by the year 2020. He said an action plan has already been developed that aims at accelerating the deployment of renewable energy with a target of around 30 GW of renewable power by 2017.

The potential for renewable power has been revised upward over time. In the early 80s, India was estimated to have renewable energy potential of about 85 GW from commercially exploitable sources, viz. (i) Wind: 50 GW (at 50 m mast height) (ii) Small Hydro: 15 GW (iii) Bio-energy: 20 GW and (iv) solar radiation sufficient to generate 50 MW/sq. km using solar photovoltaic and solar thermal energy. These estimates have since been revised to reflect technological advancements. Initial estimates from Centre for Wind Energy Technology (C-WET) suggest that wind energy potential at 80 metres height (with 2 per cent land availability) would be over 100 GW. Some studies have estimated even higher potential ranges up to 300 GW. The MNRE has initiated an exercise for realistic reassessment of the wind power potential, whose results are expected by the end of 2013.

India's renewable energy installed capacity has grown from 3.9 GW in 2002-2003 to about 27.3 GW in January 2013. Wind energy has been the predominant contributor to this growth. It also accounts for 68% of the installed capacity, followed by small hydro power (3.55 GW), biomass power (3.56 GW) and solar power (1.4 GW).

The Indian renewable energy programme has been in place for a little over two decades during which period the renewable energy industry has taken a number of initiatives that have given a major thrust to the programme. Way back in 1980, the Government created the Commission on Additional Sources of Energy (CASE) under the department of Science and Technology. In September 1982, the Department of Non-conventional Energy Sources (DNES) was set up, and then in July 1992, it grew into a full fledged Ministry of Non-conventional Energy Sources (MNES). In 2006, this ministry was renamed as Ministry of New and Renewable Energy (MNRE). Interestingly, India is the only country in the world to have a dedicated ministry responsible for implementing a non-conventional energy trajectory in India.

The Ministry of New and Renewable Energy is the nodal Ministry of the Government of India for all matters relating to new and renewable energy. The broad aim of the Ministry is to develop and deploy new and renewable energy for supplementing the energy requirements of the country.

The Mission of the Ministry is to ensure:

- **Energy Security:** Lesser dependence on oil imports through development and deployment of alternate fuels (hydrogen, bio-fuels and synthetic fuels) and their applications to contribute towards bridging the gap between domestic oil supply and demand;
- **Increase in the share of clean power:** Renewable (bio, wind, hydro, solar, geothermal & tidal) electricity to supplement fossil fuel based electricity generation;
- **Energy Availability and Access:** Supplement energy needs of cooking, heating, motive power and captive generation in rural, urban, industrial and commercial sectors;
- **Energy Affordability:** Cost-competitive, convenient, safe, and reliable new and renewable energy supply options; and
- **Energy Equity:** Per-capita energy consumption at par with the global average level by 2050, through a sustainable and diverse fuel- mix.

POLICY ON NON-CONVENTIONAL ENERGY

The MNES implements one of the world's largest programme on renewable energy. The programme objectives are:

(a) Increase the share of renewables in the overall installed capacity of power generation.

(b) Meet the energy needs of rural and remote areas for variety of applications.

(c) Minimise the drudgery and health hazards faced by rural women in following the age old practice of cooking with fuel wood collected from long distances, and

(d) Extract energy from urban and industrial wastes, besides ocean, chemical and geothermal sources.

According to the Annual Report of the MNES, the underlying idea of the programme is not to substitute but supplement the conventional energy generation in meeting the basic energy needs of the community at large.

The government started off with programmes in research and development (R & D) in all renewable energy technologies with a view to standardising and ensuring that the technologies were in a position to deliver reliable and safe energy. In order to offset partially the high first cost, the MNES offered incentives by way of upfront capital subsidy and also interest subsidy in order to reduce the cost of financing for renewable technologies by individuals and the private sector. In addition, 100 per cent accelerated depreciation was allowed for firms that invested in RETS.

Technical back-up units (TBUS) were set up in different parts of the country to provide support to various institutions wanting additional support on RETs. The TBUs also undertook promotional programmes and training for the local agencies working on RETs. The Indian Renewable Development Agency (IREDA) was set up to finance exclusively renewable energy programmes.

The MNES has taken up special programmes for renewable energy in the north-eastern region including Sikkim and has earmarked 10 per cent of the Plan funds for this region towards enhanced and special subsidies. A special programme to electrify the Kargil and Ladakh areas districts with 90% as grant from the centre is also under implementation.

INITIATIVES TAKEN BY THE GOVERNMENT

1. Urja Grams

The Department of Non-Conventional Energy Sources has taken up a programme on Rural Renewable Energy System (RRES) designed to make villages self-sufficient in energy. This system is called Urja Grams, and are based on local renewable energy sources and being environmentally benign, could ensure availability of electric power as well as cooking energy at the village level and spearhead all round rural development.

In an Urja Gram, the renewable energy devices can find their applications to meet the just energy requirement. For example, a biogas plant working on locally available animal and agricultural waste would supply the cooking fuel and also fuel for lighting or for irrigation wherever required. Requirement of drying, cooking, hot water, etc. can be met by Solar Thermal Systems.

Measures to promote non-conventional energy:

- 10% share of new capacity addition or 10,000 MW, to come from renewables by 2012.
- 18,000 remote villages to be electrified by 2012.
- Over 3,500 MW of power generating capacity from renewables has been set up, which is contributing about 3.3 per cent of the total installed generating capacity in the country.
- 8.8 billion Units of electricity generated from wind power projects.
- Centre for Wind Energy Technology (C-WET) and Wind Turbine Test Station are fully operational.
- 750 KW and 1000 KW unit size wind turbines introduced for the first time in the country.
- A 40 KW solar power plant inaugurated at Nyoma, Ladakh.
- 30 MW capacity SPV products exported to various developed and developing countries.
- More than 40 different applications of solar photovoltaic systems for rural, remote areas and other applications developed.
- More than 4500 solar photovoltaic pumps are in use for agriculture and related uses.
- 2 MW grid connected SPV power projects are in operation in the country.
- Over 4,000 potential sites for small hydro power projects have been identified with 10,000 MW capacity.
- A 5.25 MW small hydro project commissioned at Kalpong in Andaman & Nicobar Islands.
- 440 MW power projects including 156 MW biomass power and 284 MW bagasse-based cogeneration projects under installation.
- A project for generation of 5 MW power from municipal solid waste is under installation in Lucknow City.
- A project, first of its kind, for generation of 2500 cubic meter biogas from 60 Tonnes per day of slaughter house solid waste installed at M/s. Al-Kabeer, Medak in Andhra Pradesh.
- A Project for treatment of 5 Tonnes of tannery waste and generation of biogas and 62 kW power plant installed at Melvisharam in Tamil Nadu, which is also first of its kind in the country.
- Masons, fabricators, potters, women, etc. trained as self-employed workers for construction of biogas plants and improved chulhas.
- 125 renewable energy sales and servicing outlets and 150 women self help groups promoted.
- Sardar Swaran Singh National Institute for Renewable Energy established in Kapurthala in Punjab.
- Four IREP centres are operational at Bakoli (Delhi); Chinhat (Lucknow) U.P., Jakkur (Bangalore) Karnataka; and Village Amrol, Kheda District, Gujarat.
- Zero emission vehicles including two, three & four wheelers and large capacity passenger vehicles are being promoted through support for research and development, demonstration and operations.

2. *Tidal Energy in Sunderbans*

The Union Ministry of Non-conventional Energy Sources (MNES) has sanctioned a 90 per cent grant for the Rs.48-crore project in Sunderbans. The West Bengal government will meet the remaining cost of this project. The National Hydroelectric Power Corporation (NHPC) has been chosen the contractor for the project, which is being executed by the West Bengal Green Energy Development Corporation, the corporate entity which has been formed by the West Bengal government to commercialize its renewable energy forays.

The Sunderbans project will be a demonstrative project which may be replicated, although the Kutch and the Gulf of Cambay in

Gujarat are the only two regions in the country where there is known potential of this form of green energy. For the people living in the villages around the Durgaduani Creek, solar home lighting systems is the only form of electricity known, with the slightly better-off burning gallons of diesel to run polluting generator sets to draw power. An eight MW capacity has been created so far for 4.4 million people, who may never have had any access to electric power since they stay in remote areas where conventional power may never reach. Efforts are now on to bring an additional five million people under this coverage by 2012.

3. Electricity Generation from Human Waste

An electricity generation fuelled by sewage has been developed. The waste we flush down the toilet could one day power the lights at home. A generator does the job of a sewage-treatment plant at the same time as it breaks down the harmful organic matter as it generates the electricity. Harnessing chemical techniques similar to those the body uses to break down food, Pennsylvania State's microbial fuel cell (MFC) diverts the electrons liberated in the reaction to produce electrical energy.

The MFC comprises of a sealed 15 cm long can with a central cathode rod surrounded by a proton exchange membrane (PEM) which is permeable only to protons. Sewage processing plants are needed in developing countries but they are expensive, as they use too much power. Producing electricity at the same time will offset this cost. A slurry of bacteria and undigested food consisting of organic matter such as carbohydrates, proteins and lipids are contained in sewage. In a process that releases electrons, the bacteria found in sewage treatment works use enzymes to oxidise organic matter. Normally the electrons power respiratory reaction in the bacteria cells, and are combined with oxygen molecules. The organic waste is broken down by bacteria that cluster around the anodes as organic waste is pumped in releasing electrons and protons with no oxygen to help mop up the electrons, bacteria's enzymes transfer them to the anodes, while the protons migrate through protons are encouraged to pass through to the cathode by polarised molecules on the P&M (Proton exchange membrane) which is permeable only to protons. There they combine with oxygen from the air and electrons from the cathode to produce water. It is this transfer of electrons at the electrodes that sets up the voltage between them, enabling the cell to power an external circuit.

NATIONAL SOLAR MISSION

The Jawaharlal Nehru National Solar Mission, also known as National Solar Mission, is one of the eight key National Mission's which comprise India's National Action Plan on Climate Change (NAPCC). NAPCC was launched on 30th June 2008 which identified development of solar energy technologies in the country as a National Mission. Finally on January 11, 2010 Government of India approved National Solar Mission.

The Solar Mission recommends the implementation in 3 stages leading up to an installed capacity of 20,000 MW by the end of the 13th Five Year Plan in 2022. It serves twin purpose:

(i) Long term energy Security

(ii) Ecological Security

Objective:

Objective of National Solar Mission is to establish India as a global leader in solar energy, by creating the policy conditions for its diffusion across the country as quickly as possible. The Mission adopts a 3-phase approach:

Phase 1: spanning the first year of the 12th Plan

Phase 2: the remaining 4 years of the 12th Plan

Phase 3: the 13th Plan

The immediate aim of the Mission is to focus on setting up an enabling environment for solar technology penetration in the country both at a centralized and decentralized level. Also the Mission anticipates achieving grid parity by 2022 and parity with coal-based thermal power by 2030.

The mission targets are:

- To create an enabling policy framework for the deployment of 20,000 MW of solar power by 2022.
- To ramp up capacity of grid-connected

solar power generation to 1000 MW within three years – by 2013; an additional 3000 MW by 2017 through the mandatory use of the renewable purchase obligation by utilities backed with a preferential tariff. This capacity can be more than doubled – reaching 10,000MW installed power by 2017 or more, based on the enhanced and enabled international finance and technology transfer.

- The ambitious target for 2022 of 20,000 MW or more, will be dependent on the 'learning' of the first two phases, which if successful, could lead to conditions of grid-competitive solar power.
- The transition could be appropriately upscaled, based on availability of international finance and technology.
- To create favourable conditions for solar manufacturing capability, particularly solar thermal power for indigenous production and market leadership.
- To promote programmes for off grid applications, reaching 1000 MW by 2017 and 2000 MW by 2022.
- To achieve 15 million sq. meters solar thermal collector area by 2017 and 20 million sq.mts. by 2022.
- To deploy 20 million solar lighting systems for rural areas by 2022.

HYDROCARBON VISION 2025

It is provided for the first time a comprehensive long term framework for development of the oil and gas sector in India under globally competitive scenarios. This was governed mainly by the following consideration:

- To assure energy security by achieving self-reliance through increased indigenous production and investment in equity oil abroad.
- To enhance quality of life by progressively improving product standards to ensure a cleaner and greener India.
- To develop hydrocarbon sector as a globally competitive industry which could be benchmarked as the best in the world through technology upgradation and capacity building.
- To have a free market and promote healthy competition among players and improve the customer service.
- To insure oil security for the country keeping in view strategic and defence considerations.

NATIONAL HYDROGEN ENERGY ROAD MAP

Hydrogen holds the promise to provide clean, reliable and sustainable energy supply for meeting the growing energy needs for transportation and power generation in the coming years. Hydrogen can be used directly as a fuel for producing mechanical/electrical energy through internal combustion engines. It can also be used in fuel cells to generate electricity for stationary, portable and transport applications. Hydrogen is environmentally benign and has the potential to replace liquid fossil fuels in the future and thereby provide energy security to India.

Recognizing the importance of hydrogen as an energy carrier for the future, the Ministry of New and Renewable Energy, as the nodal Ministry for this sector, has been implementing a broad based Research, Development and Demonstration Programme on Hydrogen Energy and Fuel Cell Technologies for more than two decades. In recent years, significant progress has been reported by several countries, including India in the development of hydrogen as an alternative fuel both for automotive and stationary applications.

A National Hydrogen Energy Road Map (NHERM) was prepared by a Steering Group set up by the National Hydrogen Energy Board, under the Chairmanship of Shri Ratan Tata. The National Hydrogen Energy Road Map was approved by the National Hydrogen Energy Board in January, 2006.

The NHERM has identified research, development and demonstration efforts to be undertaken in the country for bridging the technological gaps in different areas of hydrogen energy, including its production, storage, transportation and delivery, applications, safety, codes and standards and capacity building for the period up to 2020. The Road Map has emphasised on development of the total hydrogen energy system, which includes all the above components of hydrogen energy sector. Keeping in view the present status of development of hydrogen energy, the NHERM has recommended two major initiatives for promoting the use of hydrogen as a fuel for Green Transportation (Green Initiative for Future Transportation-GIFT) and Green Power Generation (Green Initiative for Power Generation-GIP).

The National Hydrogen Energy Road Map has visualized that by 2020, one million hydrogen fuelled vehicles, mostly two and three wheelers and 1,000 MW aggregate hydrogen based power generation capacity would be established in the country. A total investment requirement of Rs. 25,000 crores has been projected in the Road Map for creating the required hydrogen supply infrastructure to realize the goals of one million vehicles and 1,000 MW power generation capacities by 2020, including Rs. 1,000 crores for research, development and demonstration activities. The Road Map is a public-private partnership driven process.

Hydrogen is high in energy content as it contains 120.7 MJ/kg, which is the highest for any known fuel. However, its energy content compared to volume is rather low. This poses challenges with regard to its storage for civilian applications, when compared to storage of liquid fossil fuels. When burnt, hydrogen produces water as a by-product and is, therefore, environmentally benign. Although no CO2, etc. are produced if hydrogen is burnt in air, yet NOx will be formed at high temperatures. One of the advantages of hydrogen as a fuel is that it can be used directly in the existing internal combustion engines and turbines. It can also be used as a fuel in fuel cells for electricity generation. Hydrogen applications, besides industrial application, cover power generation, transport applications and heat. However, when compared to other alternatives, use of hydrogen in transport sector appears to be more beneficial as it is possible to store hydrogen on-board.

Initiatives Taken So Far

The Ministry has supported research, development and demonstration projects on various aspects of hydrogen energy including its production, storage and use as a fuel for generation of mechanical/thermal/electrical energy. The application of hydrogen in fuel cells for power generation has been demonstrated as a result of initiatives taken by this Ministry. Hydrogen fuelled small power generating sets, two wheelers (motor cycles), three wheelers and catalytic combustion systems for residential and industrial sectors have also been developed and demonstrated.

A Demonstration Project for setting up of a Hydrogen Dispensing Station at a petrol pump in New Delhi has been sanctioned as a joint project of Ministry of New and Renewable Energy and Indian Oil Corporation Limited. The project would enable dispensing of neat hydrogen and H-CNG blends as fuel for automotive vehicles. The project was commissioned in March, 2010. The H-CNG blends used in the modified CNG vehicles and are expected to reduce emissions from H-CNG vehicles, as compared to CNG vehicles. The project is also generating operational experience in handling hydrogen as an automotive fuel. H-CNG is a vehicle fuel which is a blend of compressed natural gas and hydrogen, typically 8-50% hydrogen by volume.

The research was initiated by the Ministry of Petroleum and Natural gas in 2003. A Hydrogen Corpus Fund (HCF) of Rs 100 crore was created with contribution from all PSU oil and gas companies and Oil Industry Development Board (OIDB). Out of the total allocated amount of Rs 100 crore to the oil industry, IOC R&D has utilised Rs 14 crore for various demonstration projects. This is in addition to other projects funded by MNRE and also IOC R&D's own budget. IOCL is all praise for H-CNG's efficiency.

Another project for the introduction of H-CNG blends on a trial basis in existing CNG Vehicles has been undertaken by the Ministry of New and Renewable Energy jointly with the Society of Indian Automobile Manufacturers (SIAM). The project is the first public-private partnership project in this new technology area. The project aims for the introduction of H-CNG blend as a fuel on trial basis in buses, cars and three wheelers. The Indian Oil Corporation is also participating in this project and the existing hydrogen dispensing facility set up at its R&D

Centre at Faridabad used for fuelling the vehicles. Under this project, the engines of the existing CNG vehicles and fuel injection systems would be modified. The project aims at optimizing the H-CNG blend ratio for optimal vehicle performance and minimal emissions.

Several new R&D Projects in the area of Hydrogen Energy and Fuel Cell technology have been sanctioned to Universities, IITs and R&D organizations and further proposals are in the pipeline. A National Centre for Hydrogen Energy and Fuel Cell Technology is being set up at the Solar Energy Centre Campus of the Ministry at Gurgaon, Haryana.

The National Hydrogen Energy Road Map had recommended 8 Technology Missions to be taken up in this area. Work has been initiated in two of these areas i.e. on the Development of Solid Oxide Fuel Cells, for which the CGCRI and BHEL have submitted a joint - R&D project proposal to the Ministry. A proposal for accelerated commercialization of PEM Fuel cells in mission mode is being developed.

In June 2012, to make India a fuel efficient country by switching to a hydrogen-based fuel cell economy, the Indian Oil Corporation (IOC) has developed hydrogen mixed CNG. It is 15-20 per cent more efficient than normal CNG. The use of Hydrogen-CNG fuel is expected to reduce carbon monoxide emissions up to 25 per cent, THC (total hydrocarbon) emissions by 5 per cent and carbon dioxide emissions by 5 per cent as compared to CNG, revealed the IOC (R&D), Faridabad.

BIOFUEL MISSION

Karanj (Pongamia pinnata) and Jatropha (Jatropha curcas) are the two plants India is emphasizing on for promoting alternative energy sources, as the country launches a nationwide biofuel mission.

A committee of experts was set up by the Federal Planning Commission, which will study and suggest measures for the promotion of biofuels development. In a report submitted by the committee before the commission, the committee has recommended the government to launch a countrywide biofuels mission focusing on encouraging the cultivation of Karanj and Jatropha. Karanj and Jatropha are two seed-bearing, drought-tolerant perennial tree-crops.

The national mission launched in two phases with one goal:

- The objective of the mission is to attain the goal of 20% blending of biofuels with diesel and gasoline nationwide.
- Under a first demonstration phase Jatropha and Karanj plantations would be established on 400,000 hectares of government-owned land.
- In the second phase of the mission, Jatropha will be cultivated on not less than 11.2 million hectares of government-owned as well as private land for increasing biodiesel production.

There's a requirement of 2.6 million tons biodiesel in India in order to achieve its goal of 5% blending with fossil fuels.

The Government of India approved the National Policy on Biofuels in December 2009. The biofuel policy encouraged the use of renewable energy resources as alternate fuels to supplement transport fuels (petrol and diesel for vehicles) and proposed a target of 20 percent biofuel blending (both bio-diesel and bio-ethanol) by 2017. The government launched the National Bio-diesel Mission (NBM) identifying Jatropha as the most suitable tree-borne oilseed for bio-diesel production. The Planning Commission of India had set an ambitious target covering 11.2 to 13.4 million hectares of land under Jatropha cultivation by the end of the 11th Five-Year Plan. The central government and several state governments are providing fiscal incentives for supporting plantations of Jatropha and other non-edible oilseeds. Several public institutions, state biofuel boards, state agricultural universities and cooperative sectors are also supporting the biofuel mission in different capacities.

Biofuels market in India is largely based on Ethanol - derived from the molasses of sugarcane - and biodiesel that's obtained through non edible oil seeds for example Pongamia and Jatropha. The primary objectives of the govt. for encouraging biofuels industry include environmental factors, plus security and diversity of energy supply. This is also working as the key driver for the growth of biofuel industry in India.

Biogas: Biogas is a clean, unpolluted and cheap source of energy in rural areas. It contains

55 to 70 per cent methane, which is inflammable. Biogas is produced from cattle dung in a 'Biogas Plant' commonly known as 'Gobargas Plant', through a process called 'digestion'. The manurial value of the dung is enhanced in the process. A biogas plant helps in obtaining both cooking fuel and enriched manure from the same quantity of cattle dung. Village sanitation is also improved. Environmental conditions are upgraded as the forest cover is protected by saving fuelwood. Biogas is also used for lighting purpose. It could also be used for running engines of small horsepower. Large scale promotion of biogas plants helps to generate employment for masons, village technicians and unskilled workers in rural areas.

The National Project for Biogas Development (NPBD) is being implemented by the Department of Non-conventional Energy Sources in co-operation with State Departments, State Nodal Agencies and Non-Governmental Agencies. NPBD caters to the promotion of family type biogas plants. It was started in 1981-82. The broad objectives of the project are:

(a) To provide energy in a clean and unpolluted form;

(b) To produce enriched manure to supplement the use of chemical fertilizers;

(c) To bring improvement in the life of rural womenfolk and children by relieving them from drudgery; and

(d) To improve sanitation and hygiene.

Setting up of community and institutional biogas plants was initiated in 1982-83 to provide benefits of biogas technology to weaker sections of society also, who otherwise cannot afford family type biogas plants. This programme provides financial assistance upto 90% of the capital cost of village-based community biogas plants. Plants set up by Central and State Government institutions, Co-operatives or Trusts tied to such bodies are eligible to receive financial assistance upto 70% of the capital cost.

Biogas production is a clean low carbon technology for efficient management and conversion of organic wastes into clean renewable biogas and organic fertilizer source. It has the potential for leveraging sustainable livelihood development as well as tackling local (land, air and water) and global pollution. Biogas obtained by anaerobic digestion of cattle dung and other loose and leafy organic matters/ wastes can be used as energy source for cooking, lighting and other applications like refrigeration, electricity generation and transport applications.

Bio-Alternative to Diesel: After introducing ethanol-blended petrol in selected states, the centre has now drawn up a Rs. 1,430 crore plan to make use of oil from the seeds of the Jatropha plant as a bio-alternative to diesel. The plan, which is to be implemented with a mission mode approach, is expected to generate six lakh tonnes of diesel-quality oil valued at Rs. 1,020 crore per annum at the end of a gestation period of four years.

For the purpose of the project, Jatropha plantations would be raised in an area of four lakh hectares spread over eight states- Andhra Pradesh, Karnataka, Uttar Pradesh, Maharashtra, Gujarat, Rajasthan, Madhya Pradesh and Chhattisgarh.

National Bio-Diesel Policy

As per the announcement of Ministry of Petroleum & Natural Gas, beginning from January 1, 2006, the public sector oil marketing companies (OMCs) will be purchasing bio-diesel (B100) at Rs. 25 a litre for blending with diesel (HSD) to the extent of 20 per cent in phases. To start with, five per cent of bio-diesel, a non-edible oil extracted from 'Jatropha' and 'Pongamia,' would be mixed with diesel during trial runs. At a later stage, in phases, the B100 blending with diesel is to be increased to 20 per cent. Automobile engines would not require any modification for using diesel doped with 20 per cent bio-diesel as fuel.

Only those bio-diesel manufacturers who get their samples approved and certified by the oil companies and registered as authorised suppliers will be eligible for assured purchase of product. Accordingly, starting January 1, 2006, the OMCs - Indian Oil Corporation (IOC), Bharat Petroleum Corporation Limited (BPCL) and Hindustan Petroleum Corporation Limited are purchasing, through select purchase centres, bio-diesel that meets the fuel quality standards prescribed by the Bureau of Industrial Standards (BIS).

Biodiesel: Jatropha plantation is a subject for state governments. Public-sector petroleum companies and private sector firms have entered into a MoU with state governments to establish and promote Jatropha plantation on government wastelands or to contract with small and medium farmers. However, only a few states have been able to promote actively Jatropha plantation despite the government's incentives and encouraging policies.

There are about 20 large-capacity biodiesel plants (10,000 to 200,000 metric tons per year) in India that produce biodiesel from alternative feed stocks such as edible oil waste (unusable oil fractions), animal fat and inedible oils.

Presently, commercial production and marketing of Jatropha-based biodiesel in India is small, with estimates varying from 140 to 300 million litres per year. The biodiesel produced is sold to the unorganized sector (irrigation pumps, mobile towers, kilns, agricultural usage, owners of diesel generators, etc.) and to experimental projects carried out by automobile manufacturers and transport companies. However, as per industry sources, there has been no commercial sale of biodiesel to state owned transport companies except for trials.

Additionally, there has been no commercial sale of biodiesel across the biodiesel purchase centres (set up by the GOI) as the government biodiesel purchase price of Rs. 26.5 per litre is still below the estimated biodiesel finished production cost (Rs 35 to Rs 40 per litre). Unavailability of feedstock supply (Jatropha seeds), rising wage rates and inefficient marketing channels are a few of the major factors that have contributed to higher production costs.

NEW TECHNOLOGIES AND PROJECTS

Various programmes are being implemented under the MNES to promote new and emerging renewable energy technologies such as fuel cells, hydrogen energy, electric vehicles, geothermal energy and tidal energy.

(a) **Fuel Cells:** Through this device the chemical energy of a fuel can be converted into usable electricity and heat without combustion as an intermediate step. Hydrogen is the primary fuel in this device, which can be produced from renewable sources of energy. Because of modular nature, fuel cells are ideally suited for distributed power generation.

(b) **Geothermal Energy:** Geothermal energy is collected from a vast reservoir of heat in the interior of the earth. About 340 geothermal hot springs have been identified throughout the country. Use of geothermal energy has been demonstrated for small scale power generations and thermal applications.

(c) **Ocean Energy:** The Ocean acts as a natural collector of solar energy. The temperature gradients, waves and tides contained by ocean can be used to generate electricity in an eco-friendly manner. Likewise, flowing tidal water contain large amounts of potential energy.

INDIA'S ENERGY SECURITY

Energy security involves ensuring uninterrupted supply of energy to support the economic and commercial activities necessary for sustained economic growth. Energy security is obviously more difficult to ensure if there is large dependence on imported energy. This calls for action in several areas.

1) The domestic production of coal, oil and gas and other energy sources has to be stepped up. Some of the recent issues in this regard have been availability of land, clearances for environment and forest and implementation of the Scheduled Tribes and Other Traditional Forest Dwellers (Recognition of Forest Rights) Act, 2006. Uncertainty about production sharing contracts has also posed problems. Management strategies and procedures will have to be devised for ensuring effective implementation of fuel development projects while meeting the requirements of above policies and legislations.

2) A stable and attractive policy regime has to be provided to ensure substantial private investment, including foreign investment in oil and natural gas blocks and new capacities for renewable energy. Producers must have clarity in the price they will receive and an assurance of a stable tax regime. Since oil exploration is a global industry the terms India offers must be comparable with those offered elsewhere. In this context the entire structure of New Exploration Licensing Policy (NELP) contracts for oil and gas need to be reviewed.

3) Investments in renewable energies need to be strongly emphasised. By present projections, the share of renewable energy in total energy consumption will only reach 2 per cent by 2021.

4) Investments in energy assets in foreign countries, especially for coal, oil and gas and uranium should be stepped up.

5) To meet any possible disruption in oil supplies, on which we are import-dependent to the extent of more than 80 per cent, storage capacities need to be created. The Organisation for Economic Cooperation and Development (OECD) countries have generally created these capacities to the extent of 90 days of their domestic demand. We have created the capacity for 5 million tonnes. It has, however, not been fully utilised so far. There will be a need to increase this gradually and utilise it fully. Innovative ways will have to be found to fill up these tankages.

RAJIV GANDHI GRAMEEN VIDYUTIKARAN YOJNA

A scheme 'Rajiv Gandhi Grameen Vidyutikaran Yojana' for a Rural Electricity Infrastructure and Household Electrification was launched in April, 2005 for the attainment of the National Common Minimum Programme of providing access to electricity to all Rural Household in five years. The scheme involved electrification of all unelectrified villages plus a free connection for BPL households.

The Ministry of Power has been entrusted with the responsibility of providing electricity to the uncovered villages through the programme instrument of Rajiv Gandhi Grameen Vidyutikaran Yojana. Rural Electrification Corporation (REC) would be the implementation agency of the scheme which covers the entire country. To achieve this objective, Rural Electricity Distribution Backbone will be set up as village electrification - infrastructure. The scheme deployment of franchisee system has also been made mandatory so as to bring about revenue sustainability in the rural distribution system.

The scheme provided a subsidy of 90 per cent of the total project cost and balance 10 per cent of the project cost was to be provided by the Rural Electrification Corporation (REC) as loan. Initially, Phase I of the RGGVY scheme was approved for implementation with a capital subsidy of `5,000 crore during the remainder of the 10th Plan period. Subsequently, the scheme was approved to be continued in the 11th Plan with a capital subsidy of 28,000 crore. Overall, by the end of 11th Plan, out of the total 5,93,732 villages in India (Census 2001), 5,56,633 villages (93.8 per cent) ought to have been electrified as per CEA report.

The States of Delhi, Goa and Union Territories of Andaman & Nicobar Islands, Chandigarh, Dadar & Nagar Haveli, Daman & Diu and Puducherry have not participated in RGGVY Programme as they had achieved 100 per cent electrification of villages. In remaining 27 states, RGGVY Projects for 579 districts have been sanctioned.

Salient Features

(A) The Scheme: (i) The Scheme had aimed at electrification of about One lakh villages and providing access to electricity to 7.8 crore rural households, including 2.34 crore BPL households by 2009.

(ii) The Government estimated an outlay of Rs. 16,000 crore under RGGVY for attainment of stipulated objectives of the programme, of which, Rs. 5000 crore was approved as capital subsidy during 10th plan period for implementation of Phase-I of the programme.

(B) Scope: Under the scheme, projects could be financed with capital subsidy for provision of -

1. Rural Electricity Distribution Backbone (REDB)
   (a) Provision of 33/11 KV substations of adequate capacity and lines in blocks where these do not exist.
2. Creation of Village Electrification Infrastructure
   (a) Electrification of unelectrified villages.
   (b) Electrification of unelectrified habitations.
   (c) Provision of distribution transformers of appropriate capacity in electrified villages/habitation.
   (d) 25,000 remote villages covered for

financing under MNES not included.

(e) Decentralised generation-cum-distribution from conventional sources or villages where grid connectivity is either not feasible or not cost effective.

3. Rural Household Electrification of Below Poverty Line Households

(a) Electrification of unelectrified Below Poverty Line (BPL) households would be financed with 100 per cent capital subsidy as per norms of Kutir Jyoti Programme in all rural habitations.

(b) Households above poverty line would be paying for their connections at prescribed connection charges and no subsidy would be available for this purpose.

THREAT TO ENERGY SECURITY

The threat to energy security arises not just from the uncertainty of availability and price of imported energy, but also from the possible disruption or shortfalls in domestic production. The second concern is not disruption of supply but the market risk of a sudden increase in oil price. While we may be able to pay for imports, a high oil price can cause inflation, slow down the economy and impose hardship on the people. Any disruption in access to energy can be very expensive in welfare terms as energy is critical not only for economic growth but also for human survival and well-being.

Reduce Energy Requirements

Improvement in energy efficiency or conservation is akin to creating a new domestic energy resource base. Such efficiency improvements can be made in energy extraction, conversion, transmission, distribution and end-use of energy. All of these efficiency improvements can come using currently available commercial technologies.

Energy efficiency and demand side management also have a large scope to reduce energy requirement. These include the use of energy efficient appliances and automobiles, hybrid cars, energy efficient buildings, efficient lighting, cogeneration, distributed generation with Combined Heat and Power (CHP) use, energy efficient and well-maintained irrigation pumps, smokeless improved woodstoves, etc.

In the long-term, promotion of public transport in urban areas can significantly reduce energy consumption, particularly the need for imported oil and gas. Develop effective and attractive mass transport such as underground, elevated trains, light rail, monorail or dedicated bus lanes in existing metros.

Substitute Domestic Alternatives

Energy security can be increased by reducing the need for imported energy by substituting it with other forms of energy. Though this does not reduce the need for total energy, it reduces import dependence. Some important options include:

1. Wood plantations with a potential of yielding up to 20 tonnes of wood per hectare per year in a sustainable way could significantly expand the domestic energy resource base. Wood can be burned directly or gasified for power generation. This would reduce the need for future gas/coal imports.
2. Bio-diesel and Ethanol can substitute diesel and petrol. Ethanol can be obtained from molasses, which may have other economically more paying uses. Ethanol can also be obtained from other starchy crops and from cellulosic plant matter.
3. If hydrogen can be produced as a byproduct of industry or with locally available energy sources, hydrogen based vehicles could provide an option to reduce dependence on oil imports.
4. Coal can be converted into oil as is done in South Africa. The technology is well-developed and in use for years.

Develop Alternative Sources

Enhanced Recovery: Enhanced oil, gas and coal recovery from existing fields is an obvious option. India's recovery of in-place reserves can improve easily by 5-10 percentage points. Better mine design and the use of technologically advanced mining techniques are valid options.

Coal Bed Methane: Methane is absorbed in coal seams. This Coal Bed Methane (CBM) usually escapes into the atmosphere when coal is mined. Tapping and utilizing the CBM as a source of commercial energy has been in vogue in the US and Australia for several years. The estimated potential of CBM in India is in the range of 1400-2600 billion cu. metres (BCM).

The potential of Coal Bed Methane/Coal Mine Methane was recognised in a new policy of Government of India in 1997. The Ministry of Coal and the Ministry of Petroleum and Natural Gas are working together for the development of Coal Bed Methane and the Government has offered 33 blocks in four rounds of bidding for CBM covering 17,416 sq. km of area. One block in Raniganj coalfield has commenced commercial production in 2007 and two blocks are in advanced stage of commencing production.

The Director General of Hydrocarbons is the regulator for CBM activities in the country. The CBM/CMM clearance house has been established in CMPDIL, Ranchi, in collaboration with United States Environment Protection Agency (USEPA) which will provide information for development of CBM/CMM in India. The current level of production, being only 0.2 mmscmd, is confined mostly to the private sector. There is no separate pricing regime for CBM and the gas prices are determined by the developer, subject to Government approval.

Coal to Oil: Rising oil prices in the world market makes conversion of coal to oil economically attractive. India should establish the viability of Sasol technology with domestic coal and establish the breakeven price at which coal to liquids would make sense for Indian coal.

New Domestic Sources: The domestic resource base can also be expanded through developing hitherto poorly developed or new sources of energy. Some of these resources may require R & D to make them economical. Among these are:

1) **Nuclear Power:** With meagre availability of Uranium in the country and vast resources of Thorium, any long-term nuclear strategy has to be based on Thorium. The three stage strategy of development of nuclear power from pressurized heavy water based reactors to fast breeder reactors to Thorium based reactors require a sustained R & D effort. Success in these efforts could deliver some 2, 50,000 MW of nuclear power by 2050 and much more thereafter.

2) **Gas Hydrates:** Very large reserves exist in Indian waters and have the potential to provide vast amount of gas. Technology to exploit these economically in ecologically safe ways is yet to be developed.

3) **Wind:** The potential for onshore wind power has been assessed to be 45,000 MW. The Wind Energy Society of India claims it to be as high as 65,000 MW. However, given that the average capacity factor realized by India's wind farms is only about 17 percent, the total contribution to energy from these plants would be relatively small. Thus while wind power may be pursued for environmental and economic reasons, its contribution to energy security will remain very limited.

4) **Solar:** Solar energy, if it can be economically exploited constitutes a major energy resource for the country. Solar electricity generated through either the thermal route or using photovoltaic cells provides comparable amounts of electricity per unit of collector area. Both methods currently provide about 15 percent conversion efficiency.

5) **Energy Plantations:** Growing fuel wood for running power plants either directly or after gasification can save the coal or gas used for generating power. Since the country's energy needs are growing, imports of coal and LNG are also likely to grow. Fuel wood plantations can help improve energy security. The scope for such plantations is substantial.

CONSERVATION OF ENERGY

With the development of civilization and commercialization coupled with urbanisation the needs of the people have grown significantly. Human beings have exploited the resources endlessly. These activities based upon resource consumption have led to the problems of degradation and depletion of energy resources. A grim scenario of the energy resource has been created in the form of energy crisis. A detailed study of the background of the situation compels us to think about the major cause of such a situation. One can pronounce on an unequivocal term that it is the cost of industrial development coupled with over dependence on conventional sources. Past generations in coping the pace of development have harnessed the conventional sources at an exorbitant rate with deaf ears to future problems. A want of rationale is enshrined in the behavioural approach of society vis-a-vis energy consumption.

Rural Electrification Corporation

Rural Electrification Corporation Limited (REC), a Navratna Central Public Sector Enterprise under Ministry of Power, was incorporated on July 25, 1969 under the Companies Act 1956. Its main objective is to finance and promote rural electrification projects all over the country. It provides financial assistance to State Electricity Boards, State Government Departments and Rural Electric Cooperatives for rural electrification projects as are sponsored by them.

REC provides loan assistance to SEBs/State Power Utilities for investments in rural electrification schemes through its Corporate Office located at New Delhi and 17 field units (Project Offices), which are located in most of the States.

The Project Offices in the States coordinate the programmes of REC's financing with the concerned SEBs/State Power Utilities and facilitate in formulation of schemes, loan sanction and disbursement and implementation of schemes by the concerned SEBs/State Power Utilities.

Ultra Mega Power Projects

Ministry of Power launched a unique initiative in 2005-06 to facilitate the development of Ultra Mega Power Projects (UMPPs) each having a capacity of about 4000 MW each, at both the coal pitheads and coastal locations aimed at delivering power at competitive cost to consumers by achieving economies of the scale. The Central Government has accordingly taken the initiative for facilitating the development of UMPPs under tariff based competitive bidding route using super critical technology on build, own and operate (BOO) basis. Central Electricity Authority (CEA) is the Technical partner and Power Finance Corporation (PFC) is the Nodal Agency.

The Ultra Mega Power Projects (UMPPs) Programme, which brings in private investment into power generation, was a major initiative of the Eleventh Plan. So far power purchase agreements have been signed for four UMPPs of 4,000 MW each on the basis of competitive tariff-based bidding. They are based in Sasan (Madhya Pradesh), Mundra (Gujarat), Krishnapatnam (Andhra Pradesh) and Tilaiya (Jharkhand). Out of these, one unit of 800 MW of Mundra by Tata Power has been commissioned in March 2012. 12 more supercritical UMPPs are being planned covering Chhattisgarh, Gujarat, Tamil Nadu, Andhra Pradesh, Odisha, Maharashtra and Karnataka. An important element of this programme is the induction of supercritical technology, which is an important shift towards energy efficiency. Unfortunately, some of these projects are plagued with uncertainties regarding fuel supply because they were based on imported coal and changes in government policies in the countries where the coal mines were located have raised the cost of coal whereas the power tariff is based on a competitive bid which does not contain a provision for passing on such increases.

MAJOR NEW INITIATIVES

The following are some of the new initiatives in the area of renewable energy:

1. **National Institute of Solar Energy:** The existing Solar Energy Centre would be converted into an autonomous institution for undertaking applied research, demonstration and development in solar energy, including solar hybrid areas.
2. **National Bioenergy Corporation of India:** National Bio Energy Corporation of India (NBECI) will be set up to implement bioenergy mission, including cook stove programme.
3. **Renewable Energy Development Fund:** In order to address the financing constraints for the grid connected as well as the off-grid applications of renewables, it is proposed to create a Renewable Energy Development fund. The fund will plug the gap between the sector financing needs and the amount that falls short of the banks' obligations to their lending to this priority sector.
4. **National Bioenergy Mission:** Biomass energy for electricity generation has turned out to be one of the most attractive sources of power which is scalable, has the largest potential for improving energy access and which can be linked to generating additional rural income. In view of the success of such biomass-based off-grid

renewable models in rural areas of Bihar, it is proposed to launch the Biomass Mission with an objective to create a policy framework for attracting investment and to facilitate rapid development of commercial biomass energy market based on utilisation of surplus agro-residues and development of energy plantations.

5. **Renewable Power Evacuation Infrastructure:** Special emphasis will be placed on creating evacuation infrastructure and transmission facilities for renewable power in a time-bound manner to support the large expansion in consumption and production of renewable power. Judicious planning of transmission system, that is, creating pooling substation for cluster of renewable power generators and connecting them with receiving station of STU/CTU at appropriate voltage level, will lead to optimal utilisation of transmission system.

6. **National Biomass Cook Stove Programme:** The proposed initiative plans to universalise access of improved biomass cook stoves by providing assistance in exploring a range of technology deployments, biomass processing and delivery models leveraging public-private partnerships.

ACHIEVEMENTS IN POWER SECTOR DURING THE PERIOD OF 11TH PLAN

- Capacity addition during the 11th Plan period has been at 54,964 MW which is 69.8 per cent of the original target and 88.1 per cent of the reduced target of 62,374 MW set in the Mid-term Appraisal (MTA). It is more than 2.5 times that of any of the earlier Plans.
- Total installed capacity as on 31 March 2012, including renewable energy sources of the country was 1,99,877 MW. The share of renewable energy capacity being about 12.2 per cent.
- Total number of villages electrified till March 2012 was about 5.6 lakhs, indicating that more than 93 per cent village electrification has been achieved. However, a large number of small habitations still remain unconnected.
- Various activities under different schemes of Bureau of Energy Efficiency (BEE) and Ministry of Power (MoP) have resulted in saving in avoided power capacity of 11,000 MW.
- Works relating to 18 units for life extension aggregating to 1,931 MW and 69 units for repair and maintenance (R&M) aggregating to 17,435 MW have been completed during the 11th Plan.

12TH PLAN PROGRAMME

The Working Group on Power has estimated a capacity addition requirement of 75,785 MW corresponding to 9 per cent GDP growth during the Twelfth Plan period. However, in order to bridge the gap between peak demand and peak deficit, and provide for faster retirement of the old energy-inefficient plants, the target for the Twelfth Plan has been fixed at 88,537 MW. The share of the private sector in the additional capacity will be 53 per cent, compared to a target of 19 per cent in the Eleventh Plan. Since the growth rate of GDP for the Twelfth Plan is likely to be 8.2 per cent and not 9 per cent, the target for capacity addition contain an element of slack of about 10 per cent.

The share of power based on non-fossil fuel plants is very low at present and should be increased over time to promote low carbon growth strategy. The share of coal and lignite in the additional capacity being created during the Twelfth Plan is 79 per cent, up from 76 per cent in the target from the Eleventh Plan which actually ended up at 79 per cent. The projected capacity addition in non-fossil fuel plants covers addition of hydro capacity of 1,0897 MW and nuclear capacity of 5,300 MW. Besides this, 1,200 MW import of hydro power from Bhutan has also been considered. In addition, it is planned to add a grid interactive renewable capacity addition of about 30,000 MW comprising of 15,000 MW wind, 10,000 MW solar, 2,100 small hydro, and the balance primarily from bio mass.

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