Shri Sunil Tatkare, Hon'ble, Minister for Water resource and Guardian Minister of Raigad district, Professor Raju B. Mankar, Vice Chancellor, Dr Babasaheb Ambedkar Technological University, Members of the Executive and Academic Council, Heads of Departments, Distinguished Faculty, Guests, Non-teaching Staff, Dear Young Students who are graduating today, Ladies and Gentlemen.

I feel very privileged to be here today for being part of the 14th Annual Convocation of Dr Babasaheb Ambedkar Technological University which is located in the ranges of western ghats, in the vicinity of the Raigad Fort from where Chhatrapati Shivaji Maharaj administered his kingdom. The University is aptly named after Dr Babasaheb Ambedkar, a social reformer, who was the Chairman of the committee to draft constitution of India and a messiah of dalit and downtrodden people of India who spearheaded movement to bring the downtrodden people at par with others in the Indian society.

This University established on 5th May 1989 is also unique as it is one of the few Technological Universities dedicated for the development of technologists and researchers. The University offers eight B. Tech, seven M. Tech programmes and 8 Diplomas apart from advanced diploma and Ph.D programmes in the various disciplines of Science, Engineering and Technology.

In the current scenario of growth through knowledge and technology based industries, the Industry-Academia linkage is very important. Department of Atomic Energy has recognized this fact and has evolved several novel ways to develop and strengthen continuous interaction between nuclear energy sector and academia.

The convocation day is a day of fulfillment, pride, hope and aspirations for the students. This day is the pinnacle of their academic pursuit and it gives them a feeling of being someone important and recognized, having acquired certified knowledge and skills. My young friends, you will be looking forward to a better tomorrow — a career full of opportunities and promise. And, knowingly or unknowingly, one reckons the need to contribute to the welfare of the society at large.

Education is a route to enlightenment and a tool for empowerment. Education can transform our youth into huge human capital and make India one of the most powerful nations of the world. We have such a huge pool of talent but somehow we have been vulnerable to foreign dependencies. This could be due to disconnect between knowledge activity and its transformation into robust technology.

Friends, today India has emerged as a strong and resurgent nation as a consequence of a robust foundation in science and technology, which has been built on the vision and wisdom of greats like Homi Jahangir Bhabha, Vikram Sarabhai, Shanti Swarup Bhatnagar, Prafulla Chandra Mahalnobis, M. S. Swaminathan, V. Kurien and the indelible intellectual influence of the geniuses like C.V. Raman, J.C. Bose, S.N. Bose, S. Ramanujam and K.S. Krishnan. Their efforts have resulted in building of institutes of international repute for the development of sophisticated and difficult technologies, which have made our country a technologically advanced nation. The spectacular achievements in the field of nuclear energy, space science and technology, and agriculture are some of the examples of this success story.

We need to further build on this foundation. Our first and foremost resolve must be to make India a completely self-reliant nation and an economic powerhouse of the world. Self-reliance means security in food, shelter, education, clean environment and quality healthcare for all our countrymen. Implicit in all these demands is the availability of cheap, abundant, clean and green, and widely distributable energy.

Energy is the key driver in every enterprise of a modern human being, be it industrial production, transport, communication, agriculture, education, health care or even entertainment. Energy has always been the primary index of human development, so much so that we now know for sure that the gross national products as well as the life expectancy are strongly correlated to the per capita energy consumption.

India is the largest democracy with nearly one sixth of world population. Our per capita electricity consumption is merely 610 kWh compared to about 10,000 kWh in the OECD countries. In recent years, we are witnessing an impressive growth of economy, and in order to fuel and further sustain this growth, it is essential to have a matching growth in the availability of electricity. Our aim is to reach a level of per capita electricity consumption of about 5000 kWh by the year 2050. By that time, our population would have reached about 1.5 billion. That amounts to having the total electricity generation capacity of about 1200 GWe by 2050, which is nearly eight times the capacity at present. This is an extremely tall order and calls for a careful examination of issues related to the composition of the energy mix, abundance of energy resources, development of technological infrastructure, economic competitiveness and accessibility to all sections of the society. Intimately related to the production of energy is the question of environment. Every one of us knows about the burning issue of global warming and hears the stories of melting of glaciers, rising of sea levels, Asian Brown Cloud that pervades many regions of Asia and the failures of monsoons and crops; all making the basic life unsustainable on this planet. Consequently, any future energy strategy must necessarily treat the protection of environment as an essential ingredient.

We are thus at the threshold of a great race for a significant increase in energy generation keeping an eye on resource preservation and protection of environment. My young friends, this is the challenge that awaits you as you enter a new phase of your life. At this point, let me point out that this is not for the first time that the human race is facing such a conflicting scenario. Two centuries ago the industrial revolution had seen the widespread use of coal fired steam power after James Watt's invention, which altered the way of life of millions of people. Some of the consequences were quite serious mainly leading to large scale migration of people to the cities which caused unhealthy living conditions in urban areas, enormous industrial and environmental pollution and dreadful working conditions. The management of the contradictions in the human development requires innovative technology solutions, and today our country and the humanity as a whole are looking forward to such solutions in the energy production scenario. It is the process of innovation that delivers new technology to the society. This is where, my young friends, lies the challenge for the future.

By innovation, we necessarily mean deviating from the well-trodden path. The traditional energy generation scenario is heavily dependent on the fossil fuels consisting of coal, oil and natural gas. In the Indian context, to reach a per capita annual energy target of 5000 kWh by the year 2050, the fossil fuel based thermal power plants will be required to add a capacity of over 600 GWe in the next four decades. Apart from the resource limitations in oil and gas sectors, this will lead to unacceptable stress on the global environment. The fossil fuel fired thermal power stations are the major contributors to the emission of green house gases, especially carbon dioxide in the atmosphere. Last century, as a result of rapid industrialization, has experienced an increase in the concentration of various green house gases by 30-150%. These gases are responsible for trapping the solar radiation leading to global warming. Rigorous climate modeling and measurements carried out across the globe have indicated the inevitability of a rise in the mean temperature of our planet by as much as 5^0 C and a consequent rise in the mean sea level that will lead to the large scale inundation of parts of lower Gangetic plains. Continued global warming will also accelerate ozone destruction leading to increase in the ultra violet radiation level. For India, in particular, a large capacity building in fossil fuel based power stations will increase our share of global CO_2 emission from the present level of 5% to 45%, which is a matter of severe concern.

In order to avoid the major risk of potentially catastrophic effects of climate change, it is necessary to stabilize atmospheric concentration of CO_2 in the range of 600-650 ppm that is about twice pre-industrial concentration. In order to do so, we must increase in a sustained manner the carbon-free sources of energy, that is some combination of nuclear, renewable and fossil fuels with sequestration.

Nuclear energy is a primary source of energy with a large growth potential and, therefore, any India-specific energy strategy must consider nuclear energy as a major alternative. The essence of a conventional nuclear reactor is the controlled fission chain reaction of U-235, which occurs at only 0.7% isotopic composition in the natural uranium, the rest being the un-fissionable, but fertile isotope U-238. While our known uranium resources are low, we have extremely rich reserves of thorium, which can be converted to the fissile form, i.e. U-233, for generating nuclear energy. Consequently, large-scale utilization of thorium must form an important element of our energy strategy.

The current share of nuclear power in India is about 3%, but it has received a major fillip in recent years and it is poised to grow steadily. The key to the capacity building in nuclear power sector critically depends on the development of reliable nuclear power stations and an integrated system encompassing the complete fuel cycle, waste management and fissile fuel breeding. I take pride in informing you that India has already developed adequate core competence in all aspects of nuclear energy and its roadmap for the three-stage nuclear programme provides a blueprint for achieving sustainable energy security. The first stage utilizes natural uranium as fuel and heavy water as moderator in Pressurized Heavy Water Reactors (PHWRs), which have been developed completely indigenously. India is now self sufficient in all aspects of PHWR technology. The second stage of the nuclear energy programme is based on Fast Breeder reactors (FBR), which are fuelled by plutonium obtained by reprocessing of spent fuel of the thermal reactors. Fast reactors produce more fissile material than what they consume and thus enable multiplication of fissile inventory and enhancement of the installed capacity. The high neutron yield in the fission process of plutonium also allows conversion of thorium into fissile U-233. The Fast Breeder Test Reactor at Kalpakkam, operating with indigenously developed mixed uranium-plutonium carbide fuel, has achieved burn up of 155,000 MWd/tonne. The Prototype Fast Breeder Reactor of 500 MWe capacity is currently under construction at Kapakkam. The third stage will be based on the thorium-U-233 cycle. Timely implementation of this stage is very crucial for meeting the increasing carbon-free energy demands in the country. I would like to stress here that the entire thorium utilization programme would eventually require several new technology inputs. Many of these technologies have to be developed for the first time and independently in India, since no other country is as much dependent on the early implementation of the thorium fuel cycle as India is. With sustained efforts over the past several years, India has developed sufficient experience, which has led to operation of a research reactor KAMINI based on U-233 fuel at Kalpakkam and design of an Advanced Heavy Water Reactor (AHWR) with the objective of developing several enabling technologies required for thorium based systems at BARC. Thus, the Indian Nuclear Programme has the potential to provide long-term energy security to the country for several decades to come.

At this point, let us inquire whether this vision of abundant nuclear energy based on fission reaction be sustained forever? For nuclear power to meet more than a few percent of the world's greenhouse constrained energy needs in the 21st century would require thousands of gigawatts of nuclear capacity. One of the greatest obstacles in realization of this vision is how to properly handle the highly radioactive waste, in particular, long-lived transuranic elements, e.g., Plutonium, Neptunium, Americium, Curium, and fission products, e.g. I-129, Cs-135, Tc-99, Zr-93, Pd-107, etc. The radio-toxicity of transuranic elements is about 20000 times that of the fission products after 1000 years. While the current strategy of partitioning and waste disposal schemes involving long-term geological storage is satisfactory, there exist environmental concerns relating to the long-term hazards and it is a matter of continued discussion. In order for nuclear energy to realize its full potential as a major source of energy, there must be a safe and effective way to deal with this waste.

Here comes the innovative concept of a hybrid system for energy production and transmutation of long-lived radioisotopes, i.e., combination of a sub-critical reactor with a high-energy accelerator. A sub-critical reactor is a nuclear fission reactor that produces fission without achieving criticality. Instead of a sustaining chain reaction, a sub-critical reactor uses additional neutrons from an outside source. The system would convert highly radioactive materials with half-lives as long as one million years to non-radioactive materials or materials with much shorter half-lives. In addition, the hybrid system can generate electricity while converting the transuranic waste.

Another source of abundant energy is the fusion driven nuclear power. Fusion offers the possibility of high power density without the generation of high-level radioactive waste with long half life and green house gases. It is the process that powers the Sun and ultimately provides all the energy to support life on the earth. In fusion, two lighter nuclei of hydrogen (deuterium, tritium) fuse together to form a heavier nucleus and in doing so release a large amount of energy. In the Sun, immense temperature and pressure help to overcome the Coulomb repulsive forces between two positively charged nuclei as they approach each other. On earth, such conditions are re-produced in a Tokamak where the plasma of deuterium and tritium is heated to 100 million degrees and held by powerful electromagnetic forces. In India, we have two such experimental facilities, Steady State Tokamak (SST) and ADITYA at the Institute for Plasma Research, Gandhi Nagar in Gujarat. The Joint European Torus (JET) is the largest experimental facility in the world today. In 1997, JET produced a peak of 16.1 MW of fusion power (65% of input power) with fusion power over 10 MW sustained for over 0.5 seconds. Based on this success, International Thermonuclear Experimental Reactor (ITER) designed to produce several times fusion power than the power put into the plasma over many minutes was announced in 2005. I am delighted to inform you, Ladies and Gentlemen, that India is a partner in this international fusion experiment along with European Union, USA, Japan, Russian Federation, China and South Korea. ITER aims at achieving commercial fusion power by 2050.

I must acknowledge here that while the fusion power offers the potential of a limitless source of clean energy for future generations, it also presents some formidable scientific and engineering challenges — plasma generation, heating and control, super-conducting magnets, cryogenic technology, ultra-high vacuum technology, material technology, liquid metal magneto-hydrodynamic technology for blanket heat transfer.

While attempting to duplicate the fusion reaction that powers the Sun, it is prudent for us to invest our efforts to harvest energy from the Sun itself. This brings us to the most important renewable energy source— the solar energy. India is endowed with a rich solar energy resource with average incidence at a robust 4-7 kWh per square meter per day and most parts of the country have 300-330 sunny days a year. This is equivalent to an energy exceeding 1600 kWh per square meter per annum. Further in the Indian context, where 44% of the population is without the grid access, the solar energy can be used in much more effective manner. The current share of solar energy is limited to only about 0.5% of the energy demand in the country. The projections indicate that by 2020 installed solar capacity will be 20-40 times the current levels, but that will amount to only 3-6% of the total energy generation. The major bottleneck, at present, in tapping the potential of solar energy is the high cost photovoltaic conversion. For achieving 'grid parity', i.e. cost comparable with the conventionally generated electricity, several innovative technology solutions are needed. These include, for example, thin film based high concentration photovoltaics, nanosolar systems that use nanomaterials, and manufacturing technologies that significantly cut back on material use and cost.

Ladies and Gentlemen, the energy resources and their utilization have continuously evolved in the history of mankind, thanks to the human innovations. From the time of the recorded history of human being till the start of the 20^{th} century, wood and later coal provided energy for cooking and manufacturing, and the animal power for transport. In the next phase of human development, electrical power generated from various thermal and hydro electric sources has been providing energy for lighting, manufacturing and all household requirements and combustion of fossil fuel directly provide energy requirement for the transport sector. While this change was fundamental to the technological advances, the energy provision was still carbon-based, produced from fossil fuels, i.e., coal, oil and natural gas. Today, we are witnessing the disastrous effects of this on the environment. Now that we are standing at the crossroads, there has to be a paradigm shift in the entire philosophy of energy utilization. In future the energy will have to come from burning of atoms in fission reactions in a critical or sub-critical nuclear reactor and in fusion reactions in a thermonuclear reactor on the Earth or from that of the Sun.

My young friends, the question that must be coming in your mind is whether the educational background you have attained is adequate for entering into this field of advanced energy technologies. The answer is affirmative 'yes' provided you have the spirit of taking challenges and the inclination to learn more and more as you advance in your career. As you can well appreciate the accelerator technology will require in-depth knowledge of electrodynamics, accelerator physics and high power electronics. When you wish to couple a charged particle accelerator with a nuclear reactor it will be necessary to master the concepts of reactor physics and for handling the intense energy density involved in such a system thermal engineering will be equally important. The demands from the materials will also be extreme and, therefore, science and engineering of materials will also play a major role. I am only trying to emphasize that a program like this will throw open several challenges to practically every disciplines of science and engineering. Those of you who wish to experience the excitement of developing new technologies, which are based on advanced scientific ideas, should build their career accordingly. I can assure you from my personal experience that the satisfaction you derive in facing and meeting such challenges is indeed immeasurable.

Finally I may say that every one of you must cherish a dream — a dream of a better tomorrow, for yourself and also for the people at large. As you are all aware that we have recently celebrated the birth centenary of Dr. Homi Bhabha, who dreamt of India as an advanced nation in nuclear technology and worked passionately for it. What we see today on the nuclear science and technology front is the realization of Dr. Bhabha's dream. It is a saga of self-reliance, self-confidence, commitment to the development of indigenous technology and faith in our high quality human resource.

Let me once again congratulate the graduating batch, all the prize winners, and the teachers of this great institution of learning.

Thank you.