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GUEST-IN-CHIEF

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INDIA

Energy Environment Symbiosis : Strategy for Sustainable Growth for India

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His Excellency the Governor of West Bengal and Chancellor of the University, Mr. Vice-Chancellor, Members of the Executive Council, distinguished faculty, graduating students, ladies and gentlemen.

Introduction

I am deeply honoured to be amongst you to deliver the convocation address and to join the company of great visionaries who have had the privilege to address the faculty and graduates of this outstanding institution of learning. Jadavpur University is a symbol of India's indomitable and everlasting nationalist spirit that challenged the mighty British Empire during the Partition of Bengal. It was an unique expression of defiance in the history of mankind where some of the worthiest sons of India including Rash Behari Ghosh, Rabindranath Tagore, Sri Aurobindo, Raja Subodh Chandra Mallik and Brajendra Kishore Roychowdhury had a collective vision of India empowered through quality education. They visualized and established the National Council of Education (NCE), the forerunner of this centre of excellence. This was a concept of far reaching significance in the history of pre independence India that laid the foundation for achieving self-reliance in education. Education is the key to nation building. It was perhaps natural, that this innovative and constructive step came from Bengal, the then hub of intellectual and nationalist activities.

Every Institution of learning develops a culture of its own by drawing from the cumulative wisdom of the men who built it and men who have passed through its corridors. Jadavpur

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University is again unique in this. There is a long list of luminaries who have left their indelible foot prints in the history of this university. Therefore, while offering my sincere congratulations to all the young men and women who are graduating today, I must remind of this rich heritage that all of them share and must cherish all their life. It is the heritage of nationalism, constructive nation building and spirit of self-reliance.

Friends, as we stand at the beginning of a new millennium, the first and foremost resolve must be to make India a completely self-reliant nation. Self-reliance means security in food, shelter, basic education, clean and abundant water, clean environment and quality healthcare for all our countrymen. All these needs can be met when cheap, abundant, clean and widely distributable energy is made available.

Current Energy Scenario

Energy has always been the primary index of human development. We now know for sure that the gross national product as well as the life expectancy is strongly correlated to the per capita energy consumption. Energy is the key driver in industrial production, transport, communication, agriculture, education, health care and consequently realistic growth of a nation. Three quarters of India's population remain in villages with a large number still below the poverty line. The desired energy strategy must be such as to uplift the quality of life of those millions and empower them socio economically.

In electricity generating capacity alone, our per capita generation is about 600 kWhr which is only about one-tenth of that in OECD countries. Our aim is to reach a per capita generating capacity of about 5000 kWhr by the year 2050. This would necessitate increasing our over all electricity generation capacity at least by twelve times. This is an extremely tall order and calls for a careful examination of issues related to composition of the energy mix, abundance of energy resource, technology status, economic competitiveness and accessibility to all sections of society. Most importantly, any future energy strategy must have environment as a basic ingredient.

The existing energy utilization profile in India is a mix of various forms of energy. There is a large non-commercial sector that includes firewood, animal dung, agricultural wastes as well as animal power and man power. The commercial sector is dominated by fossil fuel consisting of coal, oil and gas. This is followed by renewable energy sources where hydro, solar, wind and tidal energy are being tapped. We also have a vibrant nuclear energy program.

Fossil Energy

To reach a per capita annual energy target of 5000 kWhr, the installed capacities in each constituent of the energy mix must increase at a much faster rate. For fossil fuel based thermal power plants, this means capacity addition of about 500,000 MW_e within 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 contributor to the emission of greenhouse gases, especially carbon dioxide in atmosphere. The last century alone has experienced an increase in the concentration of various greenhouse gases by percentages varying from 30% to 150%. These greenhouse gases are responsible for trapping of solar radiations leading to severe global warming and changes in mean sea level. 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°C and a consequent rise in the mean sea level that will lead to large scale inundation of parts of lower gangetic plains. Continued global warming will also accelerate ozone destruction leading to increase in UV radiation levels. For India in particular, a large capacity building in fossil fuel burning thermal power stations would increase our share of global CO2 emissions from the present level of 5% to about 45%. This violates the basic tenets of sustainability of human civilization. Currently, it is an area of severe international concern.

Renewable Energy Sources

Amongst the renewable, hydroelectricity has the potential to deliver only about 70 - 90 Gigawatts of electricity. A considerable fraction of this capacity has already been harnessed. Some more capacity addition is expected in the north eastern region of India. The local ecological and habitat disturbance still remain a serious concern.

For India, with high solar insolation and large number of sunny days, solar energy is perhaps the most attractive and benign primary energy source with a huge potential. Globally, this is the fastest growing primary energy sector with an annual growth rate of 35%. In addition, this has the advantage of being a distributed energy source and ideal for replacing diesel pumps, off-grid lighting in rural areas, other agricultural applications like water pumping and harvest processing etc. Alternatively, in areas like Thar desert with thousands of square kilometer exposure, solar power stations could also operate at large capacities and supply electricity to the grid. It is environmentally most acceptable. The current share of solar energy is limited to only about 0.5% of the energy demand in India. This is due to the high cost of photovoltaic conversion and densely populated landmass. Nevertheless, solar thermal power still remains the largest potential source of clean and distributed electrical energy source.

Wind energy with a potential to add about 20,000 MW_e to the energy kitty is another fast growing sector where installed capacities have reached about 8757 MW_e. Suitable areas have been earmarked in Gujarat, Maharashtra, Rajasthan and west coast of India for harnessing wind power.

Nuclear Energy

The other primary energy source with a large growth potential and free of greenhouse gas emission is nuclear energy. Therefore, any India-specific energy strategy must consider nuclear energy as a major alternative. Though our known uranium resources are low, we have extremely rich resources of thorium. Natural uranium contains only 0.7% of ^{235}U, the only fissionable material available in nature. In principle, however, the fertile ^{238}U and thorium available in nature can be converted to fissionable form to be used for generating nuclear energy. The current share of nuclear power in India is about 3% but it is growing steadily.

The key to capacity building in nuclear power sector would critically hinge on development of reliable nuclear power stations, technology development in utilization of ^{235}U and rapid conversion of ^{238}U and thorium in to fissile material. This must be supplemented with a foolproof program for safety and management of long lived nuclear waste. India has already developed adequate core competence in all aspects of nuclear energy and its roadmap for the three stage nuclear program provides a blueprint for achieving sustainable energy security.

A roadmap for a three stage nuclear power program is in place. The first stage utilizes natural uranium in Pressurized Heavy Water Reactors (PHWRs). The choice of PHWRs with natural uranium fuel, heavy water moderator and pressure tube configuration has led to a completely indigenous nuclear program. At present, India has 17 reactors in operation, which include indigenously designed and developed 2 units of 540 MWe PHWRs at Tarapur, six more (3 PHWR, 2 LWR and 1 PFBR) reactors are under construction. The designs of these reactors have progressively evolved taking into account the needs for indigenization, operating experience and progressive evolution of enhanced safety features. India is now self sufficient in all aspects of PHWR technology. Average capacity factor of nuclear plants have steadily risen to over 90% with more than 200 reactor-years of operational experience free of any serious incident. It is significant to note that the plant capital cost per unit power is the lowest in India.

The second stage of the nuclear power 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 installed capacity. The high neutron yield in the fission process of Plutonium with high energy neutrons also allows conversion of thorium into fissile 233U. The Fast Breeder Test Reactor at Kalpakkam is operating with indigenously developed mixed uranium-plutonium carbide fuel which has achieved burn up of 155,000 MWd/tonne, a value three times larger than the original design value. The prototype fast breeder reactors of 500 MWe capacity is currently under construction at Kalpakkam. Introduction of metallic fuel in FBRs is the next objective which will enhance the rate of breeding of fissile material.

The third stage will be based on the thorium-uranium-233 cycle. Timely implementation of a programme for thorium utilisation in India's programme is very crucial to meet the increasing energy demands in the country. A small beginning has already been made by introducing thorium in a limited way in research reactors and in PHWRs. With sustained efforts over the past several years, India has small scale experience over the entire thorium fuel cycle. A research reactor KAMINI is operating in Kalpakkam based on Uranium-233 fuel which is derived from thorium. This fuel was bred, reprocessed and fabricated indigenously. An Advanced Heavy Water Reactor (AHWR) has now been designed at the Bhabha Atomic Research Centre (BARC) with the objective of developing several enabling technologies required for thorium based systems. Passive safety system of AHWR will be relevant for future generation of reactors built in close proximity to population centers. Thus, the Indian Nuclear Program has the potential to provide long term energy security to the country for several centuries to come.

Nuclear power does not release greenhouse gases or chemical pollutants (NOx, SOx, etc.). However, safety of and around nuclear power stations and management of nuclear wastes are areas where there has been a lot of apprehension. Current level of technology, operating experience, knowledge base and regulatory mechanisms are capable to manage the safety and waste management issues related to nuclear energy.

Sustainable Energy Strategy

Therefore, the goal of achieving abundant, economically competitive, environmentally clean and widely distributable energy reduces to the following tasks that must be attempted during the next four decades.

a. Gradual reduction of dependence on fossil burning energy sources and development of technologies leading to higher cycle efficiencies.

b. Focused development of solar and nuclear power systems as primary energy sources through capacity building in robust and proven designs.

c. Development of hydrogen as a major energy carrier particularly replacing hydrocarbons in the transport sector.

d. Enforcement of safe and environmentally clean protocols through continuous advancement of waste management and inherently clean technologies.

e. Investment in research, development, consolidation and deployment of new, innovative and advanced technologies in existing power generation schemes like thermonuclear fusion or accelerator driven sub critical reactors.

If the dependence on fossil fired energy is to be reduced, the alternative is a massive increase in solar and nuclear capacities. Large scale capacity building in solar power plants to supply electrical energy at economically competitive rates would need global development and demonstration of new technologies. It is also a fact that grid compatible solar power stations are far away from realization.

In nuclear energy, the projected growth rate can not be achieved with the present inventory of fuel or reactor systems. So, the immediate need is for importing nuclear fuel and reactors only for a designated period to augment the program at this stage. This will also catalyze fuel breeding for our future programme. Recent studies show that import of 40 GW_e capacity of Light Water Reactor (LWR) or equivalent fuel during the period 2012 -2020 will help us in bridging the gap. The spent fuel of these reactors will be used for launching a series of FBRs, so that the energy deficit is practically wiped out by the year 2050. This may appear as an ambitious statement, but there is very little choice if we are to reach the power generation goal without submitting to the dangers of global warming and ozone depletion.

Much has been made of the nuclear deal that would enable India to establish international collaborations in importing nuclear fuel and other reactor systems to attain a larger power generation base and shorter fuel multiplication times. Doubts have been raised that we will be subject to international pressure under this mode of working and the oil shock could be replaced by nuclear shock. Suffice it to say that unlike oil sector, nuclear technology is one of India's greatest strengths. The nuclear deal provides us an opportunity to establish international collaborations to enable us to both import and export technologies as well as provide an additionality needed for capacity building in shortest possible time.

Hydrogen and Fusion

The need to develop hydrogen as a carrier of energy and use in transport sector has become significant in view of the severe environmental pollution issues associated with carbon burning. Coincidently, both the primary energy sources, solar and nuclear can do the job efficiently through water-splitting reaction. In fact, special titanium oxide ceramics can harvest sunlight and split water to produce hydrogen fuel at cheap rates. The high temperature processes for water splitting at about 800-900°C can also be carried out by a high temperature nuclear reactor. These nuclear reactors can work in dual mode by producing electricity in peak hours and hydrogen in off-peak hours. BARC has initiated a hydrogen generation program based on nuclear reactors. The hydrogen generation program is backed up by new generation fuel cells and new hydrogen storage devices.

Controlled thermonuclear fusion is the ultimate hope for achieving sustainable energy security of the entire planet. Fusion energy is produced by bringing together isotopes of hydrogen available from sea water in a plasma medium at few million degrees temperature and replicating the process of energy production in the sun and the stars. It is abundant, safe and environmentally cleaner being free of long lived radioisotopes. However, the biggest challenge facing the scientists and engineers world over, is to develop means to confine and hold a dense, hot magnetized plasma at few million degree Kelvin for sufficiently long time to be able to produce useful fusion energy. India has a well designed fusion reactor program in place with sufficient expertise in building experimental plasma fusion devices. India is also a full partner in International Thermonuclear Experimental Reactor (ITER) programme that aims at achieving commercial fusion reactor by 2050.

Technology is the Key

Development, consolidation and successful deployment of new technologies will be the key to secure symbiosis between energy and environment. Exploitation of both the primary energy sources namely, nuclear and solar, would need mastering of new technologies. The array of energy relevant technologies include reactor engineering, waste management, photovoltaics, silicon solar cells, accelerators, electromagnetics, ADS, computers, artificial intelligence, robotics, precision manufacturing, functionally tailored materials, cryogenics, super conducting magnets, laser and plasma beams, bio-nano assemblies etc. These are extremely challenging areas waiting to be explored and tamed.

Challenges and Excitements in Energy Science and Technology

Energy science and technology is a highly exciting field today. It blends exotic flavors of natural sciences with matching colours from engineering discipline to offer a subject of high societal relevance. As we prepare ourselves for achieving a sustainable energy security of India, we take a look at the various challenging areas where young men and women like you can contribute.

Exploration and Mining of Uranium

Recent reports indicate that on the basis of available geological features, the uranium reserves in India could be as high as 10% of the global reserves. Therefore, there is an urgent need to develop new technologies like time domain electromagnetic surveys and instrumentation for identification of deep-seated uranium deposits. This is essential for large scale capacity expansion based on indigenous uranium.

Development of Innovative Reactors and Fuel Cycle

As mentioned earlier, development of Advanced Heavy Water Reactor and High Temperature Reactor is offering exciting opportunities to the young scientists and engineers. The Advanced Heavy Water Reactor designed to produce nearly two-third of its power from thorium, provides a platform to demonstrate several unique passive safety features for achieving the highest levels of safety. The High Temperature Nuclear Reactor is being developed primarily for the generation of hydrogen by a thermochemical process of splitting of water molecules. Many advanced fuel cycles are being contemplated for achieving better economy, higher levels of safety and reduction in the waste volume. Continuous development is under way in isotope enrichment technologies. All these demand intense research efforts and extensive innovations.

Fast Reactor Research

There is a need for introduction of metallic fuel in place of mixed oxide fuel to increase the fuel breeding ratio in fast breeder reactors. It necessitates studying irradiation behaviour of metal alloy fuels to generate the database necessary for physics design, development of technology for fabrication, characterization and novel processing techniques. The challenges foreseen for large scale expansion of reprocessing capacity of spent fuel from PHWRs, development of fuel cycle technologies for spent fuel from FBRs and AHWR are indeed challenging tasks.

Electromagnetic and Fusion Technologies

Electromagnetic technologies have an extremely important role in implementation of both solar and nuclear energy programs. Large accelerators for ADS, RF and pulsed power sources for strategic applications, MHD converters, lasers, plasmas, electron beams for materials processing in the entire fuel cycle, development of efficient photovoltaic technology etc. offer challenging areas of research to be tackled. Thermonuclear fusion is an important area of research in the world. The thrust of fusion research in India is directed towards understanding in Plasma generation, heating and control, Superconducting magnets, Cryogenic technology, Ultra high Vacuum Technology, Material technology for fusion reactors and Liquid metal MHD technology for blanket heat transfer provide cutting age research opportunities.

Nature's Energy Conversion Technologies

Nature is the smartest engineer. Its technologies are simple, eco-conserving and highly scalable. Though there are myriads of interesting examples, one can only marvel and learn from the way nature has engineered energy conversion in plants and other bio-organisms. The plant system takes the carbon dioxide released by animals and manufactures carbohydrates through an anabolic reaction in the presence of sunlight. The process of energy conversion in photosynthesis occurs infinitely slowly, carried out at near thermodynamic equilibrium conditions, near ambient conditions with low efficiency. Such processes facilitate reduction in entropy generation and bulk level scalability. It is worthwhile looking at natural processes and mechanisms in order to find alternative energy solutions. This would be extremely relevant for utilization of low-density energy sources in an environmental friendly manner.

Paradigm Shift in Energy Utilization

It is apparent that during the next few centuries human innovations in achieving sustainability in energy strategy would be limited to a roadmap where carbonaceous fire burning around us for the last ten thousand years would be gradually extinguished and replaced by a new fire burning in nuclei of heavy atoms like uranium or light atoms like hydrogen. This is actually a scenario of extreme significance to the entire philosophy of energy utilization. This is a paradigm shift where energy utilization is being conceived to change from stored energy of fossilized plants to primary energy sources like nuclear and solar. Hydrogen, whether existing in the sun or on earth, is poised to be the most important element in the scheme of things related to the growth of human civilization. This route to energy security involves multitude of complex non-trivial technologies to be developed by future generations of scientists, engineers and technologists.

The homo sapiens in their long history of evolution on earth have passed through many momentous events. The most significant was the day they started standing on two legs. Immediately, their entire horizon got broadened and perspective greatly expanded. Since then, they were no longer mere food searchers and their purpose of life changed from instinctive living to cognitive existence. The next significant event occurred when they discovered fire. They became technologists and started exploiting external energy for improving quality of life through technology. To my mind, the paradigm shift in energy utilization from stored fossil sources to primary sources is an equally important turning point of human evolution.

Young graduates receiving their Degrees in this Convocation can seriously consider contributing towards the big challenge of the development of energy science and technology.

THANK YOU.

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