India's energy vision to 2030

Goldman Sachs recently published on their website a paper titled, "Dreaming with BRICs: The Path to 2050". The abbreviation BRIC stands for Brazil, Russia, India and China. Bits and pieces of this paper have been widely, albeit selectively published in the media. For the period 2003 – 2050, it forecasts a GDP growth for India varying from 5.1% to 6.2% year over year and expects India to become the third largest economy of the world by the year 2050. The forecast comes with a caveat. The policy settings have to be growth-supportive and if not, the actual growth could be below the forecast. How do we look at this forecast? All citizens have to do their bit to create a situation such that the policies formulated by the Government of India can be supportive of growth. Scientists and engineers and particularly experts in this gathering have a very important role to play. Let us see how this can be done.

India's GDP in recent years has been increasing at 6% per year. Development aspirations of its people demand that growth at this or even at a higher rate be sustained for a long enough time. Indian government has taken several steps to realize these aspirations. These include policy initiatives as well as planning and launching of projects aimed at improving the energy, transport and water infrastructure in the country. Examples include the ongoing project to build a network of national highways, setting up a task force to prepare a blueprint for linking major rivers in the country to solve the problem of recurring floods in some parts and drought in the other parts of the country and ongoing reforms in the electricity sector with Electricity Bill 2003 having been already enacted. Several other initiatives have been taken such as new telecom policy which has already resulted in rapid growth of telcom infrastructure in the country. All these are steps towards achieving an average annual growth of 8% during the ongoing 10th Five-Year Plan (April 2002 to March 2007).

Energy is the engine for the growth. It multiplies human labour and increases productivity in agriculture, industry as well as services. Easy access to modern energy services holds the key to development. Availability of commercial energy services to the rural poor can free the women and girls from the drudgery of collecting firewood for cooking and give the girls time to attend school and the women time to pay more attention to growing children. This can lead to more rural income and the growth of the country. At the time of independence in 1947, total installed electricity generation capacity was 1,363 MWe. It rose to 30,214 MWe in 1980-81, 66,086 MWe in 1990-91[1] and 136970 MWe[2] in 2002-03. The growth rates over these periods turn out to be 9.54%/yr, 8.14%/yr and 6.26%/yr. The average growth rate over the entire period thus has been an impressive 8.6%/yr. In spite of this impressive growth, per capita energy consumption is still very low. In addition, share of non-commercial energy resources continues to be much higher than what it is in the developed countries. The electricity generation in the fiscal year 2002-03 was about 532 billion kWhr from electric utilities and depending upon what capacity factor one assumes, additional 104 to 127 billion kWhr were generated by the captive power plants. On per capita basis, this works out to be about 610 kWhr per year. It is an order of magnitude lower than advanced countries. Assuming that energy intensity of GDP will continue to decline as in the past several decades and the fact that being a tropical country, India does not need energy for heating, India would have to plan to reach a modest target of electricity generation of 5000 kWhr per year per capita so as to provide a decent quality of life to its citizens. India's population could rise to 1.45 to 1.5 billion by the year 2050. This would call for a total electricity generation of 7250-7500 billion kWhr per year. This is an order of magnitude higher than the generation in the fiscal year 2002-03 and calls for developing a strategy for growth of electricity generation based on a careful examination of all issues related to sustainability including abundance of available energy resources, diversity of sources of energy supply and technologies, security of supplies, self sufficiency,

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[1] RKD Shah, "Strategies for Growth of Thermal Power", Energy for Growth and Sustainability, Indian National Academy of Engineering, 1998.

[2] i. Power from Utilities: Thermal, Hydro, Nuclear and Wind: 107,972.8 MWe (http://cea.nic.in/exec_summ/chapters.htm#GENERATION%20INSTALLED%20CAPACITY(MW),

ii. Captive Power: 29,000 MWe PowerLine, November 2001 gives estimates of captive power installed capacity in India and these have been extrapolated based on data given in PowerLine, December 2002.

security of energy infrastructure, effect on local, regional and global environment, health externalities and demand side management.

This is a gigantic task, but considering the way India has developed since independence, it is doable. However, we have to tap every energy available resource including fossil, hydro, nuclear and non-conventional. At present, coal is contributing maximum percentage share to electricity generation and will continue to do so for several decades. India has large reserves of coal and is the third largest coal producing country of the world. The working group on coal and lignite for the X Five Year Plan tentatively projected the extractable coal to be only 37.86 Bt. This is a very small figure and is quite disturbing.

We have to tap full hydro potential of the country and in this respect we have to do a lot. As on end of March 2003, only about 27 GWe has either been developed or is being developed. A vision paper prepared by the Ministry of Power envisions harnessing of entire balance hydropower potential of India by 2025-26. It is proposed to add 16,000 MWe of new capacity in the X Plan and 19,300 MWe in the XI Plan[3].

The estimated potential of non-conventional renewable energy resources in our country is about 100 GWe. Wind, small hydro and biomass power/co-generation have potentials of 45 GWe, 15 GWe and 19.5 GWe respectively[4]. All these resources will be increasingly used in future especially in remote areas. The medium term goal is to ensure that 10% of the installed capacity to be added by 2012, i.e. about 10 GWe, comes from renewable sources.

We are already generating nuclear electricity. During the year 2002-03, nuclear power plants generated 19.358 TWh of electricity and this was about 3.7% of total electricity generated in the country. In percentage terms, it may not be significant, but does signify the fact that we have been able to master this advanced technology. We are now poised for rapid growth of nuclear generating capacity in the country. In around four years from now, we would reach an installed capacity of around 4500 MWe with pressurized heavy water reactors, the main stay of the first stage of our indigenous nuclear power programme, and another 2320 MWe with light water reactors making a total of around 6800 MWe as against the present capacity of 2770 MWe. In September this year, the Government of India has approved construction of a 500 MWe prototype fast breeder reactor marking the launching of the second stage of the nuclear power programme and successful implementation of this programme will open up a vast source of energy for the development of the country. Our medium term plan is to increase the nuclear installed capacity to about 20,000 MWe by the year 2020.

This installed capacity will still be less than 10% of installed capacity in the year 2020, but I will come to nuclear later, let me first talk about coal.

Coal, of course will continue to dominate the energy scene, but considering the fact that economically mineable coal reserves are very low, there is a need to mount extensive R&D effort to augment the coal reserves. Our estimates indicate that unless economically mineable coal reserves are identified, coal will be a scarce commodity after the middle of the century. There is a need to develop improved technologies for coal mining as well as coal utilization. This apart, extensive burning of coal as per the present day practice can have serious deleterious effect on environment. US Department of Energy has funded 8 projects under the Clean Coal Initiative and has also announced plan to develop a pollution free coal fired power plant (Code named 'FutureGen') of the future[5]. Proactive efforts are needed in India in the area of coal based power plant technologies to develop pollution free technologies and to improve thermal efficiency of power plants. Proactive efforts are also needed to improve mining practices to enable extraction of a larger amount of coal from a given deposit and to harness coal deposit found at greater depths by innovative techniques such as in-situ gasification.

We have to take an integrated view with regard to energy planning and a recent study carried out at DAE examines all available energy resources in the country, prospective plans of the various Departments of the Government of India and imperative to keep the energy import at manageable levels and constructs a scenario calling for generating a quarter of electricity generation based on nuclear by the middle of the century. Considering India's nuclear fuel resource, it is necessary to take recourse to fast breeder reactors in a big way and fast breeder technology has the potential of meeting India's electricity requirement for several years. To tap this potential fully, we have to work on several new developments. In the case of FBRs, the aim has to be to develop short doubling time fuel and corresponding fuel cycle facilities to ensure fast growth in FBR installed capacity along with reduction in the capital cost, O&M costs, fuelling cost and improvement in safety. PFBR being built in Kalpakkam has to be followed by about 4 similar units and we have to carry out R&D on several fronts to ensure that we can meet the goal of generating about a quarter of India's electricity needs by 2050 based on nuclear technology. With regard to fast reactors, one can break up the thrust areas for development in two phases viz. one for the reactors to be set up before 2020 and the other to be set up subsequently. Specific thrust areas to achieve the first phase objectives are the following.

[3] Report of the Steering Committee on Energy Sector for 10th Five Year Plan, Government of India, Planning Commission (Sr. No. 1/2001, March-2002).

[4] Annual Report, Pg.4, 2001-02, Ministry of Non-conventional Energy resources, Government of India.

[5] "Bush takes the Initiative on Clean Coal", Modern Power Systems, April 2003, page 3.

- Long design life of about 60 years. This would also reduce the cost of decommissioning.
- Improving the thermal efficiency by 4 to 5 % points by using higher steam temperature. This would require better materials and an enhancement in structural analysis capability.
- Reducing the dimensions of some of the components by better engineering e.g., reactor assembly diameter, length of control and safety rod drive mechanisms.
- Reduction in the number of steam generators.
- Integrated sodium purification circuit for primary and secondary circuits. This would improve safety and reduce construction time.
- Optimising the plant layout.
- Development of large diameter fuel pins and quick reprocessing.
- Fast reactor fuel reprocessing technology development and fuel refabrication technology development.
- Development of technologies for remote refabrication of fuel.

Specific thrust areas to achieve the second phase objectives are the following.

- Increasing the plant rated capacity to 1000 MWe or higher.
- Development of short doubling time fuel to increase the rate of capacity growth of fast breeder reactors. The fuel material could be metal or nitride.
- Development of high burn up fuel (~200 GWd/t) to maximize heavy metal utilization with minimum number of recycling, reduce fuel cycle costs, fuel handling costs, radwaste etc. This would require development of better materials for the hexcan of fuel assembly.
- Design optimization to ensure economy in plant construction as well as plant operation.
- Long design life of about 100 years. This would require a full ferrite reactor.
- Development of advanced fuel reprocessing techniques such as pyroprocessing.

In view of the importance of the fast reactor programme for meeting India's energy requirements, we have already taken the first steps by reprocessing the spent fuel discharged from PHWRs and initiating the setting up of 500 MWe PFBR. The extent to which we expand this programme is going to depend on requirement of energy of the country. The potential of available nuclear fuel resources is enormous and technologies already developed can keep India immune from any restrictive international regimes as they might emerge in the years to come presumably to meet the goals of non-proliferation. However, India is a large country and has the capability and capacity to go alone. Experts on fuel cycle technologies have a very important role to play to meet the challenges that lie ahead to ensure that electricity is available to Indian populace at affordable prices.

While fast reactors will begin to replace the PHWRs as the mainstay of Indian nuclear programme after 2020, we have to continue to develop technologies for thorium utilization, which is a nuclear resource available in plenty as a beach sand mineral in coastal areas of India. Timely implementation of a programme for thorium utilisation is very crucial for us 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, we have 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 developed at Bhabha Atomic Research Centre (BARC) to expedite transition to thorium-based systems. The reactor physics design of AHWR is tuned to generate about 65% power from thorium. The design incorporates several advanced safety features. The detailed project report of this reactor has been prepared and is undergoing a structured peer review before we launch its construction in the financial year 2004-2005. AHWR design has been carried out with a futuristic vision. The design incorporates several passive safety features enhancing its operator forgiving characteristics. Being a thorium system, the long-lived waste in the form of minor actinide is expected to be much smaller.

As a further step towards self sustained thorium utilization with a potential for growth, a roadmap for the development of accelerator driven system (ADS) has been prepared. Development of such a system offers the promise of shorter doubling time with thorium-uranium-233 systems, incineration of long-lived actinides and fission products. ADS along with thorium-uranium 233 reactors and fuel cycle have the potential to provide a robust eco-friendly technology base to large-scale thorium utilization.

Steps already initiated for thorium utilization viz. design and development of AHWR and development of accelerators for ADS have to reach a stage such that it becomes possible to commission a demonstration unit of ADS by 2020. A prototype unit of large capacity could then follow by around 2030. Subsequently many such units can be set up so as to make significant contribution to electricity generation as well as to primary energy by the middle of the century. It is necessary to prepare a detailed roadmap for carrying out all the activities and implement the roadmap as per the schedule prepared so that India can do even better than the predictions of the Goldman Sachs paper. That is where all of you have a very important role to play.

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