Energy in India for the Coming Decades*

Anil Kakodkar
Chairman, Atomic Energy Commission, India

The reforms initiated in India since the beginning of the nineties have led to rapid economic progress and better growth rates. In the first decade of this century the growth rates seem to be still better. Studies by several academics and consultants forecast continued high growth rate for the next several decades. I shall quote two such studies, one by Dominic Wilson and Roopa Purushothaman of Goldmann Sachs [1] and the other by Dani Rodrik and Arvind Subramanian of the International Monetary Fund [2].

Wilson and Purushothaman write, "India has the potential to show the fastest growth over the next 30 to 50 years. Growth rate could be higher than 5 percent over the next 30 years and close to 5 percent as late as 2050 if development proceeds successfully."Rodrik and Subramanian write, "…..growth in capital stock together with growth in factor productivity will yield output growth of 5.4 percent. Over the next 20 years, the working age population is projected to grow at 1.9 percent per year. If educational attainment and participation rates remain unchanged, labour growth will contribute another 1.3 percent, yielding an aggregate growth rate of 6.7 percent per year, or a per capita growth rate of 5.3 percent. This is a lower bound estimate and, even so, would be significantly greater than the per capita growth rate of 3.6 percent achieved in the 1980s and 1990s. Over a 40-year period, a 5.3 percent growth rate would increase the income of the average person nearly 8-folds."

**Presentation at the Inter-ministerial Conference on "Nuclear Power for the 21 Centrury" organised by the International Atomic Energy Agency (IAEA) during March 21-22, 2005 in Paris, France*

Growth in economy is made possible by several inputs, the two most important being energy and human resource. In this conference, we are concerned about energy and so I shall confine myself to energy. Energy is the engine for growth. It multiplies human labour and increases productivity in agriculture, industry as well as in services. To sustain the growth rate in economy, energy supply has to grow in tandem.

For a large country like India with its over one billion population and rapid economic growth rate, no single energy resource or technology constitutes a panacea to address all issues related to availability of fuel supplies, environmental impact, particularly, climate change, and health externalities. Therefore, it is necessary that all non-carbon emitting resources become an integral part of an energy mix – as diversified as possible – to ensure energy security to a country like India during the present century. Available sources are low carbon fossil fuels, renewables and nuclear energy and all these should be subject of increased level of research, development, demonstration and deployment.

In the Department of Atomic Energy, we have conducted a study with the aim to quantify the likely growth in energy demand in India, and the role nuclear energy has to play in the decades to come. The ultimate objective was to formulate a strategic plan to meet the projected role to be played by nuclear energy [3]. Energy intensity of GDP, defined as the ratio of the energy consumption to the GDP, has been observed to follow a certain trend worldwide. Below a certain level of development, growth results in increase in energy intensity. With further growth in economy, the energy intensity starts declining. Based on data by International Energy Agency [4], overall energy intensity of GDP in India is the same as in OECD countries, when GDP is calculated in terms of the purchasing power parity (PPP). Energy-GDP elasticity, the ratio of the growth rates of the two, remained around 1.3 from early fifties to mid-seventies. Since then it has been continuously decreasing. Electricity is the most important component of the primary energy. Electricity-GDP elasticity was 3.0 till the mid-sixties. It has also decreased since then. Reasons for these energy–economy elasticity changes are: demographic shifts from rural to urban areas, structural economic changes towards lighter industry, impressive growth of services, increased use of energy efficient devices, increased efficiency of conversion equipments and inter-fuel substitution with more efficient alternatives. Based on the CMIE data [5], the average value of the Electricity-GDP elasticity during 1991-2000 has been calculated to be 1.213 and that of the primary energy-GDP elasticity to be 0.907. Estimating the future GDP growth rates of India from the projections made by Dominic Wilson and Roopa Prushothaman [1], taking the primary energy intensity fall to be 1.2 percent per year [6], extrapolating the electricity intensity fall from past data till 2022 and subsequently a constant fall of 1.2 percent year, the growth rates of the primary energy and electrical energy have been estimated as given in Table 1.

These rates are the basis of the projections reported [3]. It may be recalled that historical primary energy and electricity growth rates during

Table 1

Period	Primary Energy Annual Growth-%	Electricity Annual Growth-%
2002-2022	4.6	6.3
2022-2032	4.5	4.9
2032-2042	4.5	4.5
2042-2052	3.9	3.9

1981- 2000 were 6 percent per year and 7.8 percent per year respectively.

Based on the growth rates given in the above table, per capita electricity generation would reach about 5300 kWh per year in the year 2052 and total about 8000 TWh. This would correspond to an installed capacity of around 1300 GWe. Annual primary energy consumption would increase from about 13.5 EJ in 2002-03 to about 117 EJ in 2052-53. By then the cumulative energy expenditure will be about 2400 EJ.

The present status of various fuel-resources in India is given in the Table 2. The domestic mineable coal (about 38 BT) and the estimated hydrocarbon reserves (about 12 BT) together may provide about 1200 EJ of energy. To meet the projected demand of about 2400 EJ, one has to tap all options including using the known fossil reserves efficiently, looking for increasing fossil resource base, competitive import of energy (including building gas pipe lines whenever and wherever permitted based on geo-political considerations and found feasible from techno-commercial considerations), harnessing full hydro potential for generation of electricity and increasing use of non-fossil resources including nuclear and non-conventional.

Before proceeding further, I would like to explain the status of nuclear power technology in India. Comprehensive expertise in all aspects of nuclear fuel cycle and Pressurized Heavy Water Reactors (PHWRs) has been acquired through self reliant means in India. PHWRs which constitute the mainstay of the first stage of our nuclear power programme are the most efficient systems in terms of uranium utilization and would enable about 10 GWe of nuclear installed capacity with our modest indigenous uranium resources. Having tied up the PHWR programme upto around half way mark, we have now embarked on the development of Fast Breeder Reactor (FBR) based second stage of our programme with the construction of the 500 MWe Fast Breeder Reactor launched in October last year. Our studies indicate that we should be in a position to support around 500 GWe power generation capacity based on plutonium bred from indigenously available uranium. This is a part of the strategy of three stage programme formulated by India right in the beginning of the programme aimed eventually at exploitation of our vast thorium resources. With decades of R&D in our laboratories and Industry, India has come a long way since the inception of the programme and the current efforts are aimed at further improving the economy, enhancing safety and expanding the programme to meet the increasing electricity demand in the country. The 540 MWe PHWR unit at Tarapur that went critical on 6th March, about 8 month ahead of schedule is an important landmark in terms of efforts in this direction.

In addition to the indigenous technology, the Indian power programme includes two GE-BWRs which were set up as turnkey projects right at the inception of our programme. While these reactors are running well as a result of comprehensive backfits and upgrades carried out indigenously, our experience in terms of securing reliable fuel supply has not been satisfactory.

Two 1000 MWe VVERs are presently under construction at Kudankulan and would contribute additional carbon free electricity to Indian grids when completed.

Coming back to the energy growth scenario [3], the study points out that it is necessary to develop metallic fuel for the fast reactors during the next one decade. Metallic fuels have short doubling time and can ensure a fast enough growth in nuclear installed capacity. Assuming that the fast reactors to be set up after 2020 are based on metallic fuel, the study calculates the maximum possible contribution that can be made by nuclear till the middle of the century. Hydro and non-conventional potential being limited, the remaining demand has to be met by the fossil fuels. The results indicate that it is possible to have one quarter of the contribution coming from nuclear by the middle of the century, if the fast reactor growth follows the course outlined.

Even after the growth projected by the study, there will be shortages and the country will continue to import energy as at present. Research and development plans have to be formulated to ensure that new technologies can be deployed to reduce energy imports. Three efforts being made by the Department of Atomic Energy are worthy of mention here in this context. Bhabha Atomic Research Centre is working on development of a Compact High Temperature Reactor with the aim of producing hydrogen, which could be the most important energy carrier in the future. Several institutions within the Department of Atomic Energy in

Table 2: Primary energy & electricity resources

	Amount	Thermal energy			Electricity potential
		EJ	TWh	GWYr	GWe-Yr
Fossil					
Coal	38 -BT	667	185,279	21,151	7,614
Hydrocarbon	12 -BT	511	141,946	16,204	5,833
Non-Fossil					
Nuclear					
Uranium-Metal	61,000 -T				
In PHWRs		28.9	7,992	913	328
In Fast breeders		3,699	1,027,616	117,308	42,231
Thorium-Metal	2,25,000 -T				
In Breeders		13,622	3,783,886	431,950	155,502
Renewable					
Hydro	150 -GWe	6.0	1,679	192	69
Non-conventional renewable	100 -GWe	2.9	803	92	33

Assumptions for Potential Calculations

Fossil

1. Complete Source is used for calculating electricity potential with a thermal efficiency of 0.36.
2. Calorific Values: Coal: 4,200 kcal/kg, Hydrocarbon: 10,200 kcal/kg.
3. Ministry of Petroleum and Natural Gas [7]has set strategic goals for the next two decades (2001-2020) of 'doubling reserve accretion' to 12 BT (Oil + Oil equivalent gas) and "improving recovery factor' to the order of 40%. Considering the fact that exploration is a dynamic process and India is one of the less explored countries, reference [3] assumes that cumulative availability of hydrocarbons up to 2052 will be 12 BT.

Non-Fossil

Thermal energy is the equivalent fossil energy required to produce electricity with a thermal efficiency of 0.36.

Nuclear

1. PHWR burn-up = 6,700 MWd/T of U-oxide, thermal efficiency 0.29
2. It has been assumed that complete fission of 1kg. of fissile material gives 1000 MWd of thermal energy. Fast reactor thermal efficiency is assumed to be 42%. Fast breeders can use 60% of the Uranium. This is an indicative number. Actual value will be determined as one proceeds with the programme and gets some experience. Even if it is half of this value the scenario presented does not change.
3. Breeders can use 60% Thorium with thermal efficiency 42%. At this stage, type of reactors wherein thorium will be used are yet to be decided. The numbers are only indicative.

Hydro

1. Name plate capacity is 150 GWe.
2. Estimated hydro- potential of 600 billion kWh and name plate capacity of 150,000 MWe gives a capacity factor of 0.46.

Non-conventional renewable

1. Includes: Wind 45 GWe, Small Hydro 15 GWe, Biomass Power/ Co-generation 19.5 GWe and Waste to Energy 1.7 GWe etc.
2. Capacity factor of 0.33 has been assumed for potential calculations.

India are together working for the development of Accelerator Driven Systems, so that one could sustain growth with thorium systems and move towards incineration of long lived radioactive wastes. The Institute for Plasma Research (IPR), is spearheading the Indian effort in developing a fusion based system for the production of energy. One of the world's first super conducting steady state tokamak with elongated diverter plasma having 1000 second operation capability is nearing completion at IPR.

The Indian population corresponds to one sixth of world population. However, the carbon dioxide emission from India is only around 4% of the global emissions. On the basis of current energy mix and the present day technologies for electricity production, the CO_2 emission from India alone could become as much as half of the present level of global emission in a few decades from now. A larger share of nuclear power in India beyond what would be realized through indigenous efforts would, in principle, contribute to further avoidance of CO_2 emission which otherwise would be inevitable.

To conclude, the first stage of the indigenous nuclear power programme involving setting up of pressurized heavy water reactors is now in industrial domain. With the start of construction of the 500 MWe fast reactor in October last year, the second stage has been launched. It is time for India to accelerate the implementation of the second stage and development of the third stage of the nuclear power programme. In parallel, India has to continue to work towards development of emerging nuclear energy technologies to address its long term energy requirements which are indeed very large.

References

[1] Dominic Wilson and Roopa Purushothaman, "Dreaming with BRICs: the path to 2050" Global Economics Paper No 99, Goldmann Sachs, 1st October 2003.

[2] Dani Rodrik and Arvind Subranium, "Why India can grow at 7 percent or more: projections and reflections", IMF Working Paper, WP/04/118, July 2004.

[3] R. B. Grover and Subhash Chandra, "A strategy for growth of electrical energy in India", Document No 10, Department of Atomic Energy, Mumbai, India, August 2004.

[4] International Energy Agency (IEA), Key World Energy Statistics, 2003.

[5] Centre for Monitoring Indian Economy (CMIE) 2002, "Energy", April 2002

[6] International Energy Agency (IEA), 'World Energy Outlook 2002 Highlights' p 32.

Unit-1 of Kakrapar Atomic Power Station achieves the longest uninterrupted run of 272 days

Unit-1 of Kakrapar Atomic Power Station (KAPS-1) near Surat, in Gujarat, surpassed today the longest record of uninterrupted operation of 272 days held by the Unit-2 of Narora Atomic Power Station. It has delivered 1070 MUs to the grid since its last synchronization. The Kakrapar Station consists of two pressurized heavy water reactors (PHWRs) of 220 MWe each. KAPS-1 had started commercial operation from May 6, 1993 and KAPS-2 from September 1, 1995. These units have been performing very satisfactorily.

KAPS has been designed, constructed and is operated by the Nuclear Power Corporation of India Ltd (NPCIL), a Public Sector Undertaking of DAE.

KAPS-1 was adjudged the best reactor amongst all the PHWRs operating in the world. KAPS -1 had earned this distinction on the basis of annual gross capacity factor of 98.4% for the period October 2001 to September 2002. This special achievement was recognized at the international level and Station Director of KAPS was conferred with the World Association of Nuclear Operators (WANO)'s Nuclear Excellence Award.

Earlier this month, India's largest nuclear reactor, Unit-4 of Tarapur Atomic Power Project (TAPP-4), was synchronised to the grid on June 4, 2005. At 540 MWe, TAPP-4 is also the largest power producing unit in the country. This reactor had achieved criticality within 5 years of first pour-of-concrete, which is comparable to international benchmarks. The unit is presently delivering power to the grid and is expected to start commercial operation in August 2005, almost 8 months ahead of schedule.

NPCIL operates 14 reactors in the country having aggregate capacity of 2770 MWe. It is also constructing another 8 reactors aggregating 3960 MWe. NPCIL has comprehensive capability to design, construct, operate and maintain nuclear power plants.

S.N. Ahmad
Executive Director (Corporate Services)
NPCIL