TIndia's Energy Needs – Strategic Imperatives*

Dr Kirit S Parikh**

I am delighted to be here and be asked to deliver Colonel Pyara Lal Memorial Lecture. I learnt from General Nambiar that Colonel Pyara Lal served this Institution for thirty long years from 1957 to 1987 and passed away while still serving the USI. That is really a remarkable sense of commitment. Institutions create a sense of continuity and the benefits are derived by future generations. This annual memorial lecture is a befitting tribute to the contribution that Colonel Pyara Lal has made to this great Institution.

We face really enormous challenges in meeting our energy needs. The country needs to grow by 8 to 10 per cent economically, if we are to meet our human development goals. We will also need to provide clean, convenient and reliable energy for all. We need to increase primary energy supply by three to four times. Electricity is not the primary energy. Coal, oil, gas, wood etc. are primary energy sources and currently, we are consuming something like 425 million tons of oil equivalent worth of primary energy and we need to increase all these by three to four times over the next 25 years. Our electricity supply has to go up by five to seven times and we will have to improve the quality and the quantity of supply of all kinds of energy sources. It is also clear that coal shall remain the leading energy source in India for the next 25 years at least, if not longer.

If you compare India's energy consumption with other countries, you will find that our per capita energy consumption is very low. In comparison with other countries, the consumption per person of primary energy in India is one of the lowest in the world and much less than the World average. We consume one half of that of China and 1/20th of what an average American consumes in terms of primary energy. It is the same story in electricity consumption as well.

See Table 1.

Region/Country	Total Primary Energy Supply (TPES) Per Capita (kgoe)	Electricity Consumption Per Capita (KWh)
India	439	550
China	1090	1380
USA	7835	13070
World	1688	2430

kgoe stands for kg of oil equivalent

Some people also say that India is not very energy efficient, but if you look at it in a slightly different way you will find that we are quite efficient users of energy and it is understandable. Anyone who is as poor as we are and whose energy cost is so high is understandably using energy very efficiently. No one can afford to use energy in a wasteful manner.

If you compare how much energy we use for a dollar worth of Gross Domestic Product (GDP) adjusted in Purchasing Power Parity (PPP) terms, you can see that we are quite an efficient user of energy. See Table 2. We are using only 0.16 kgoe worth of energy for adding one-dollar worth of GDP in PPP terms whereas, the USA takes 0.22 kgoe. The world, on an average takes 0.21 kgoe and China takes 0.23 kgoe. Even in terms of KWh we are quite efficient. PPP corrects for the difference between actual purchasing power and the nominal exchange rate. One dollar costs nearly 40 Rupees, but if you go around buying things in the USA, what you can buy for one dollar you can buy that in India for about Rs 10. In a sense, the purchasing power of a rupee is much more than what our exchange rate indicates.

Table 2 : Energy Use Efficiency Per GDP $: PPP-2000

Region/Country	Primary Energy (kgoe)	KWh
India	0.16	0.20
China	0.23	0.29
USA	0.22	0.37
World	0.21	0.31

We use large amounts of traditional fuels. Mainly women in rural households are currently using these. In fact, 90 per cent of the rural households continue to use firewood and dung cakes and 20 per cent of the urban households also use firewood and chips. Only five per cent of the rural households and 44 per cent of the urban households use LPG. Similarly, kerosene is used by only 2.7 per cent of rural households and 22 per cent of urban households.

Traditional fuels cause huge burden on health, particularly women's health. If you quantify the time that women spend in gathering fire wood, in gathering dung and so on, you will find that on an average, 3000 crore hours are spent by Indian women per year in just fire wood gathering in the country. They also cause all kinds of respiratory diseases and the symptoms are quite widespread. The economic losses that people suffer in terms of lost opportunities, sickness time, employment that they miss, the money they spend on medicines, etc have been estimated to be around Rs 30,000 crores per year. It also illustrates that you just cannot neglect to provide clean and convenient energy to our people in rural areas. This has to be an important objective of any kind of energy policy.

India consumed 121.04 metric tons (mt) of crude oil products (including refinery fuel) in 2005-06, whereas, domestic production of crude oil was only about 33.98 mt during the same period. We are virtually importing more than 70 per cent of our oil needs and this dependency on oil imports keeps on increasing. The total consumption of petroleum products has been growing at the rate of around 5.1 per cent between 1980-81 and 2005-06; though over the last five years it has grown at a lower rate of around 4 per cent because the crude price has gone up significantly in the international market.

For a long-term energy perspective, we have to make some assumptions about how much energy we would need 25 years down the line and how fast our economy would grow, how fast our population would grow, what kind of measures can we take for energy conservation, what would be our energy policy, what would be the availability of different fuels etc? There are so many imponderables in making projections for the future that one needs to find a method that gives a broad idea of what our options are, what the feasible space is, what are the parameters within which we can act, and what all can we do?

One way to do this is to look at energy elasticity. The notion of energy elasticity is- if GDP grows by one per cent, how many percentage points would the energy consumption increase? If you look at the Indian data in the past then you will find that our GDP consumption elasticity for Total Primary Commercial Energy Supply (TPCES) is around 1.08 from 1980-81 to 2003-04, but it has come down slightly and we have now become a little more energy efficient. This is illustrated in Table 3.

Table 3 : Energy Use Elasticity wrt GDP

(Percentage change in commercial energy use for one per cent growth in GDP)

		Per Capita
TPCES wrt GDP	1980-81 to 2003-04	1.08
	1990-91 to 2003-04	0.82
Electricity Generated wrt GDP (Utilities + Captive)	1980-81 to 2003-04	1.30
	1990-91 to 2003-04	1.06

Now let us take electricity generation. If you look at electricity generated, we are becoming a little more efficient. Earlier, we used to add 1.3 per cent of electricity for every one percent increase in GDP. Now we are adding only 1.06 per cent for every one per cent increase in GDP. We can also compare how other countries have done in this regard. If you look at them with different levels of per capita income, you can see that globally also, countries' elasticities keep going down once their per capita income increases and this is also true for electricity consumption. This is illustrated in Table 4.

Table 4 : Energy Use Elasticity wrt GDP from Cross-Country Data of 2003

TPES (kgoe/capita) wrt per capita GDP ($ PPP 2000)	All Countries	0.83
	2000 <GDP <8000	0.79
	GDP >8000	0.76
Electricity Consumption (kWh/capita) wrt percapita GDP ($ PPP 2000)	All Countries	1.24
	2000 <GDP <8000	1.25
	GDP >8000	1.09

Based on such elasticities, for growth rates of 8-9 per cent, we get the primary commercial energy required. It would be around 1500-1800 metric tons oil equivalent (mtoe) by 2031-32. By oil equivalent, I mean-1 Kg of oil gives you 10,000 kilo calories of energy whereas, 1 kg of Coal in India gives only 4,000 kilo calories. So one kg of coal equals nearly 0.4 kg of oil; in energy terms these are equivalent. One uses such energy equivalence numbers to aggregate all the different types of fuels and one gets the kind of broad numbers as shown in Table 5.

Table 5 : Total Estimated Primary Commercial Energy Requirement (TEPCER) in 2031-32 for 1.47 billion Population (mtoe)

GDP Growth Rate	8%	9%
GDP (Rs. in billion at 1993-94 prices)	122170	156689
TEPCER (mtoe) (Falling Elasticities)	1514	1823

Similarly, we can make projections for electricity requirement in 2031-32 as shown in Table 6. The installed capacity required would be around 800,000 to 960,000 Giga Watts (GW) or approximately a million GW (1GW = 100 MW).

Table 6 : Electricity Requirement 2031-32

GDP Growth Rate	8%	9%
Total Energy Requirement (billion kWh)	3880	4806
Energy Required at Bus Bar	3628	4493
Projected Peak Demand (GW)	592	733
Installed Capacity Required (GW)	778	960

Now, if we really translate this into plan-wise projected installed capacity addition, then we get a picture that for the 11th Plan we need 75,000 to 80,000 MW of additional capacity and you can see from Chart 1, how it is growing. When you look at these numbers, you do not really feel surprised that China, which has a much higher per capita income than we have today, is adding perhaps 50,000 MW of capacity every year whereas, during the entire 10th Five Year Plan, we added a capacity of 20,000 MW over five years. 75,000 MW may look large but it is not certainly difficult and certainly not impossible for us to attain, if we really mean to do so.}

Plan-wise Projected Installed Capacity Addition (MW)

The electricity requirement we have projected can be generated in many different ways. We can use coal, hydrocarbons or nuclear. So, to get a fix on how much of coal, oil etc we require, we first project what we require by way of coal, oil and natural gas for non-power and for non-transport modes. These are very small users and one can make fairly reasonable projections and this is what has been done based on the studies carried out by various researchers in India. Then we put this in a programming model, that is to say: I need to generate so much of electricity, so much of transport demand in terms of billion passenger kms and billion ton kms of goods movement and so many MW of electricity. And, for so many billion units of electricity generated, what is the best way to do so? What are our options?'

Using the above model, we could develop various scenarios. These scenarios are extreme scenarios. One scenario says, everything will be coal-based development that would give you maximum demand for coal and minimum demand for others. Another scenario says, let us maximise nuclear, third scenario would be to say, let us maximise hydro, the fourth scenario would be, we maximise both hydro and nuclear together, the fifth scenario could be - along with hydro and nuclear, we say 25 per cent electricity could come from natural gas. The next scenario could be that we have demand management and energy efficiency to significantly reduce the demand for energy in the country. We know that options are available. Electricity consumption can at least be reduced by 20-25 per cent, if we really push for energy efficiency. Similarly, the next scenario says that we also work on the supply side i.e. improving its energy efficiency. For example, increase coal power plant efficiency. Today, bulk of coal (some 70 per cent) goes into generating power. We are burning coal with an efficiency of 30.5 per cent, i.e., if you take the energy of electricity produced and the energy of coal that is burnt, the ratio would be about 30.5 per cent. Now the best plants in the world today, for example, in Germany give an efficiency of 46 per cent. We cannot get the same efficiency as in Germany, their ambient temperature is lower and they have certain advantage. But even accounting for our higher ambient temperature, we should be able to achieve at least 40-42 per cent efficiency with the available technology. So, one could say that if we increase our technical efficiency from 30 per cent for burning coal in power plants to 40 per cent, we would achieve a significant reduction in coal requirement, because 70 per cent of the coal is going into power plants. Thus, we achieve 33 per cent reduction in coal that can be quite significant.

Then in another scenario, we could have a higher freight share of the railways. What happens is, if a ton of goods is moved from Bombay to Delhi by truck, it costs you five or six times the energy as moving it by train. So, if a larger share of the goods movement is carried out by train, you would have reduced the energy requirement and increased the energy efficiency. Of course, that would require making the railway services as efficient and reliable as the road transport but that can be achieved. We can also increase the vehicle efficiency so that oil demand would go down and, finally, we put a lot of renewables into the system. The above scenarios are summarised below-

(a) Coal-Based Development
(b) Maximise Nuclear
(c) Maximise Forced Hydro
(d) Maximise Hydro & Nuclear
(e) Scenario (d) plus forced Natural Gas
(f) Scenario (e) plus Demand Side Management
(g) Scenario (e) plus higher Coal Power Plant Efficiency
(h) Scenario (f) plus higher Coal Power Plant Efficiency
(j) Scenario (h) plus higher freight share of Railways
(k) Scenario (j) plus increased vehicle efficiency
(l) Scenario (k) plus renewables

We do everything to the best extent possible and the combination would indicate to us the space within which we can operate. See Table 7. What we get here is that the oil requirement towards the end of 2031-32 would be anywhere between 352-486 million tons. Domestic production, in a pessimistic sense, has been estimated to be around 35 million tons of oil only and the range of imports would be between 315-451 million tons, i.e. import dependence would be anywhere between 90-93 per cent. Similarly, for gas, our import dependence can be 0 per cent - 50 per cent, for coal 10-45 per cent and for total commercial primary energy, it could be anywhere between 30-60 per cent. So, we could be importing 0 per cent - 60 per cent of the energy; 30 per cent if you go for all the efficiency, all the renewables, all the hydel, all the nuclear and everything. We have to recognise the fact that India would be required to import large amounts of energy. Nothing wrong in importing energy, if we have the money, if we are exporting things and if we can buy this at reasonable competitive prices in the international market. Then one can say: these are my requirements, what are really my options, what can I really do and what can I develop?

Table 7 : Range of Commercial Energy Requirement, Domestic Production and Imports for 8 Percent Growth for Year 2031-32

Fuel	Range of Requirement inScenarios	Assumed Domestic Production	Range of Imports*	Import (Percentage)
Oil (mt)	350-486	35	315-451	90-93
Natural Gas (mtoe)	100-197	100	0-97	0-49
Coal (mtoe)	632-1022	560	72-462	11-45
# TCPES	1351-1702	-	387-1010	29-59

* Range of imports is calculated as follows:
Lower bound = Minimum requirement – Maximum domestic production
Upper bound = Maximum requirement – Minimum domestic production
TCPES stands for Total Commercial Primary Energy Supply

Generally, it is believed that we have a lot of coal in the country. The extractable coal that we have and the amount of coal that we can bring out from the coal mines at our current level of consumption would last for 86 years. But, of course, our coal requirement is not stagnant at the current level of consumption. If the economy is growing at 8-9 per cent, then our coal consumption would grow at five per cent per year and at five per cent growth rate of coal consumption, the reserves would not last for 86 years but only for 40-45 years. So, even the so-called vast coal reserves that we have will run out in 45 years. Now one can say that we have not exploited all the coal bearing areas and 30 per cent of the coal-bearing areas are yet to be explored. Add that 30 percent and instead of 45 years it will run out in 60 years. Coal is a finite resource. Apart from the concerns about climate change that coal imposes, we have to recognise that we would be short of even coal. Similarly, our current known reserves of oil, at the current consumption rate would last only for 23 years and gas only for 38 years. So, we are clearly short of these conventional energy reserves.

If you look at Uranium, even here we are very short of it. The total amount of Uranium that we have in the country is sufficient for only 10,000 MW of the first generation nuclear power plants called Pressurised Heavy Water Reactors (PHWR). These are the kind of reactors that we have built in Rajasthan, Madras and Narora. We are continuing to build these kind of reactors in the country. With these PHWRs, we can generate at the most, 10,000 MW of nuclear power. Put that 10,000 MW in the context of our requirement of 800,000 MW to a million MW, 25 years down the line and we have a clearer picture of our energy deficiency. Today, nuclear power is around 3000 MW and is contributing less than 2 per cent. If we rely only on our own natural Uranium, it cannot contribute more than 10,000 MW. But our strategy right from day one has been to install 10,000 MW of first generation nuclear power plants i.e. PHWR. This PHWR generates electricity and the Uranium we feed in comes out as depleted Uranium, which also contains Plutonium. We separate the Plutonium and the depleted Uranium, and once we have enough Plutonium available, we can build what is known as a Fast Breeder Reactor. The Fast Breeder Reactor has the characteristics that while it generates electricity it also converts some of the depleted Uranium into more Plutonium than we put in. So, it breeds Plutonium. But though the name is called Fast Breeder Reactor, its breeding rate is very slow and it takes number of years of operation before you get enough Plutonium to start another Fast Breeder Reactor. But we can do that and then after a while it grows very rapidly and we can have exponentially growing availability of Fast Breeder Reactors in the Country. The total capacity for Fast Breeder Reactors with the same Uranium that can give you only 10,000 MW of first generation plant, can give us 500,000 MW from Fast Breeder Reactors. Another advantage of Fast Breeder Reactor is that some of the more long lasting isotopes in the depleted Uranium are burnt into it. So what comes out in the end is somewhat safer and easier to dispose of as nuclear waste than what comes out from a first generation power plant. Our strategy is to go to third stage and use our Thorium reserves. But first we need to develop Thorium technology, which is 30 years down the line. With this technology, we can build very large capacity, may be around five million MW of additional nuclear energy.

Now, what is the importance of all this? What is called pessimism here means that we are not importing any nuclear power from anywhere? In 2030, that would give us only about 48000 MW out of a million MW. Now, if we are able to import some Uranium, say 8000 MW of nuclear capacity is imported in the next 10 years, then that 48000 becomes 63000 MW. It may not seem very large, but look at 2050 numbers. By the year 2050, 8000 MW of nuclear capacity we import today, creates the possibility of increasing nuclear power from 208,000 MW to 275,000 MW, and if we can have the 123 Agreement and can import not just 8000 MW but 16000 MW of nuclear power and process it, then may be, instead of 2,75,000, this would become 3,50,000 MW, and of course 20 years further down the line, it would be very large. So, the whole importance of being able to import nuclear power or Uranium today and reprocessing it, is that it gives a huge opportunity to find an additional source. Since we will run out of coal and other things, this could be our insurance mechanism. We really need a fallback energy source and here is the one that is really feasible and that insurance becomes much better, if you are able to import Uranium. We can do that without importing but what we can achieve by the end of the 21st Century; with the import of small amount of nuclear power, we can achieve the same results by the year 2070.

Now let us look at the renewable energy resources shown in Table 8. Many people feel that while we do not have hydrocarbons but what about renewables? There are a lot of opportunities there. The main problem with renewables is that many of these are bio-mass based and require large amount of land and the country is also short of land. Let us look at the options. Suppose, I have 60 million hectares which is considered waste land and if we take 60 million hectares of waste land and convert it into productive fuel wood plantations and run them in an efficient and sustainable way, we can get almost every year 620 million tons of oil equivalent worth of wood which is quite large but that is the limit. The assumption is that we are using all 60 million hectares of wasteland, which is not really available, because 60 million hectares of wasteland also includes Himalayas and other places where it would not be possible to grow anything. But if we grow 30 million hectares of forests for wood plantation, we can get 300 million tons of oil equivalent of energy out of wood plantations; not a small quantity.

Table 8 : Renewable Energy Resources

Resources	Unit	Present	Potential
Hydro-power	MW	32,326	1,50,000
Wood	mtoe/year	140	620
Bio-gas	mtoe/year	0.6	4
Ethanol	mtoe/Year	<1	10
Solar Photovoltaic	mtoe/year	–	1,200
Solar Thermal	mtoe/year	–	1,200
Wind Energy	mtoe/year	<1	10
Small Hydro-power	mtoe/year	<1	5

Let us look at bio-gas. The dung availability is restricted and the quantity is quite small. Bio-diesel, with 20 million hectares (jhatropha plantation) at today's level of yield can give us only about 20 million tons of bio-diesel from it. That is not to be neglected as it provides local renewable energy resource. Therefore, bio-diesel is not the magic bullet to solve our energy problems. Ethanol (sugarcane based) may provide about 10 million tons.

Take solar photovoltaic. With only five million hectares of land covered with today's solar photovoltaic cell, which has 15 per cent efficiency, we can get 1200 million tons of oil equivalent worth of energy and if you have 10 million hectares of land, we can have twice as much. Solar, in a sense is a very large resource that we have. We have abundance of it. The only catch is that the cost is high. Today, a kwh of energy generated by solar photovoltaic costs about Rs 20 per KWh whereas, pithead coal based power plant generates at Rs 2 per unit. Now, if you say that since solar is available at the consumer's end, we can compare it with Rs 4 or Rs 5 per unit, we still need to bring down the cost of solar from Rs 20 to Rs 5 per unit, if solar energy is going to be a viable option.

With wind energy also, there is a problem that it operates only for part of the time. We get electricity for about 20 per cent of the time it operates. Our current load factor on wind power is around 18 per cent. Even if you assume that 20 per cent of wind power is available, all the 65000 MW of wind power potential in the country operating at 20 per cent is really no more than 20,000 MW of coal based power plant operating at 70 per cent load factor. This is very less. There is no other magic bullet other than solar energy, which is very expensive.

Currently in Brazil, people are using sugarcane to convert it into ethanol and run their cars on that. Ethanol can also be made from cellulosic bio-mass, i.e. rice stock and wheat stock. the entire crop residues can be used to generate ethanol. If we can make cellulosic bio-mass ethanol, then we can have a large amount of ethanol. Since we have so much of crop waste that can be used, we can have 300 million tons of oil equivalent of ethanol, which is possible. Again, the technology is not currently economical but many people are working on it and may be, with time it would become economically viable a few years down the line.

So, what are our strategic imperatives? One thing has emerged very clearly that we are short of energy. We need to use all our energy resources. We need to push energy efficiency in demand management. We must augment our resources in whatever way we can, to get maximum out of what we have. We need to think about energy security, including that for the households, because the households do suffer a lot for want of clean and convenient energy. We need to worry about environment sustainability, see how we can improve that and we even need to think about a carbon free scenario, with the rising global concerns about climate change. Can we think of a scenario without emitting carbon? Finally, we should think about energy independence. Is it needed and is it a possibility?

Let us look at all these. The energy efficiency and demand management are one of the first and foremost options that we should really take. For every MW that is saved, or you can say every negawatt (negative watt) that is produced by saving a MW, it is even more than a MW that is produced, because the wastage in transmission and distribution is not there. There are many things we can do. We should promote urban mass transport system because that would really reduce energy consumption. We can increase the share of railway freight movement. We should benchmark our energy consumption for all energy intensive sectors in the country. There are many energy intensive sectors. an industry could be told that they were wasting a lot of energy. If we let the investors know-how efficient or inefficient a particular firm is, I think that should be sufficient motivation to make the energy sector efficient.

We can also have annual energy audits for specific energy intensive industries. To promote energy efficiency, we have a Bureau of Energy Efficiency (BEE), which is now labelling products. It gives ratings of 1 star, 2 star, 3 star or 4 star etc. It is labelling the major energy products. What we need to do is that we should make it possible for government procurement agencies to buy a product with least cost on lifetime basis and not just first cost basis. For example, if you want to buy an air conditioner, then the procurement officer would call for tenders and would be required to buy one with the lowest quote. But if the lowest cost, let us say, consumes 20 per cent more energy than another one, he would not be able to prefer that one, because the Central Vigilance Commission (CVC) would come after him. So, we need to develop a mechanism by which a rational choice can be made. It is not very difficult to do so. One can easily imagine and ensure that there is no CVC hassle involved and a person can take honest and correct decisions. I think we should promote this culture and these are the kind of measures we need to take.

The next strategic option we have is that we must augment our resources. We need to accelerate our exploration of coal, oil and gas. We must accelerate nuclear power because this is what really increases the availability of energy. We need to develop the Thorium cycle for nuclear power and also exploit non-conventional energy sources. We should go for in-situ coal gasification and also enhance recovery of oil and gas. For energy security, we should reduce our dependence on import of energy. In some sense, we must see that diversification is there; we ought to buy oil from as many sources as possible and not just one place. We should use, not only oil, but spread out our consumption over many different resources of fuels. We should set up buffer stocks. We need to provide clean fuel and electricity to all. How do we do that?

Currently, we are giving kerosene and LPG at highly subsidised rates. However, a part of the kerosene that is earmarked for households, at least 35 per cent, leaks out and goes out for adulteration of diesel. Inspite of all kinds of measures that we have, these leakages continue.

Similarly, many people using LPG can afford to pay more than what they are currently paying, but they are used to getting subsidised LPG. I think what we need to do is to make sure that every household should have some entitlement of subsidised kerosene and electricity. For example, first 30 units of electricity a month or may be 8 cylinders of gas per year are made available at a subsidised price and the rest is available at a higher price. To prevent leakages, what we need to do is give everyone a smart card with which a person can buy the product from any dealer at the market price and the difference between the market price and the ration price is charged to the Government account, and the person only pays the ration price. That way, there will be only one price for the market and there would be no incentive to divert kerosene or diesel or LPG to other uses and that it will be available. However, we have to recognise the poor and evolve leak proof methods to subsidise them.

What about environmental sustainability? From the global point of view, carbon emissions are the main concerns but from the local point of view, we are concerned more about the air that we breathe in the cities. Degradation of local natural resources is important. If you dig a coalmine, then the land is carved. You need to worry about these issues as well. Sulphur or particulate emissions from power plants are also of importance. Our CO_2 emissions would rise significantly. By 2031-32, it would be 5.3 billion tons per year in the high coal use projection, but if we use all the low coal technologies, putting everything together, it can be brought down to 3.8 billion tons per year. The USA's CO_2 emissions today are in excess of 5.5 billion tons. So, 25 years down the line, even in our worst case scenario and with a much larger population of 1.5 billion people, we would not reach the USA's level. How can we think of a carbon free world? We should have adequate nuclear energy. We will use all our hydel, solar, wind and other renewables for electricity. This is possible even today, but the costs are very high. We need to bring down the costs of all these. For oil substitutes, we can go for electric traction, electric vehicles, cellulosic ethanol and bio-diesel. These are all technically feasible but their cost is high and they need technological breakthrough.

If we want to have energy security, we ought to develop all resources and need to go for energy efficiency and demand management, as strongly as possible. We also need to follow a strategy for energy saving. It will reduce carbon emissions and also help in achieving energy independence.

.*Edited text of the Eleventh Colonel Pyara Lal Memorial Lecture 2007 delivered at the USI on 12 September 2007.

**Dr Kirit S Parikh is Member, Planning Commission, Government of India.

Journal of the United Service Institution of India, Vol. CXXXVII, No. 570, October-December 2007.