Emerging energy challenges and opportunities

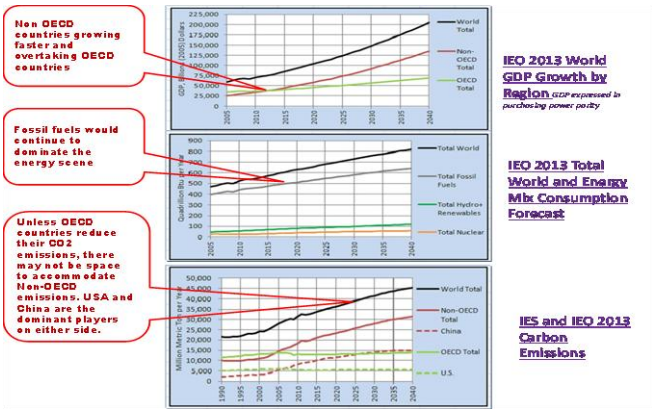
Anil Kakodkar

I would like to begin with an expression of gratitude for this opportunity to deliver the 4th Petrotech Subir Raha Memorial Lecture. This gives me an opportunity to pay respects to his memory. I did know him and have been an admirer of his leadership to ONGC and indeed the hydrocarbon sector of our country. Subir Raha has in his professional career dealt with both the upstream as well as downstream part of hydrocarbon activity in India which constitutes around a third of our primary energy supply and a backbone of transport sector in the country. Management and performance of this sector has thus huge strategic and economic implications for the country. We must therefore be very grateful to leaders like Subir Raha who infused renewed enthusiasm in this sector. Impact of his work can be judged from the fact that a number of organizations with whom he was connected run such memorial lecture series in his honour.

I come from the domain of atomic energy which is at the other end of the energy activity spectrum. Even so, I can cite some connections. When I joined atomic energy, Dr. N.B.Prasad who was an icon in BARC for an engineer like me, had already left. He later became Chairman of ONGC. Dr. P.K.Mukhopadhyay of IOC once told me that AERE Harwell had developed a pipe line inspection gauge for oil industry in Europe and so BARC should develop one for IOC in India. (That has since been done) I am happy that I am currently associated with ONGC energy centre trust. So when Shri Vasudeva asked me to deliver this lecture, I was naturally very happy.

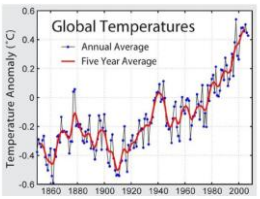
When I look at the long term horizon of the energy scene for our country, I get seriously concerned. So I have decided to share with you some of my perceptions in this regard. I feel this would be

the best tribute to memory of Subir Raha who has done so much to strengthen energy security in the country.



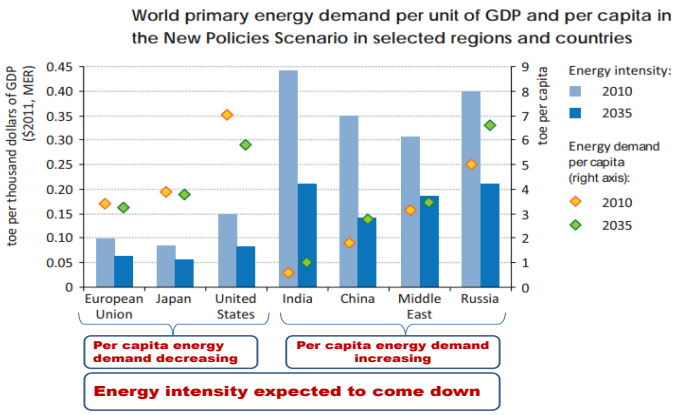
Global energy scene

The projections in the U.S. Energy Information Administration's (EIA's) Annual Energy Outlook 2013 indicate that the GDP of non OECD countries is growing faster as compared to OECD countries and is overtaking OECD countries around this period. Further it appears that fossil fuels would continue to dominate the energy scene in spite of so much of international discourse on sustainability and climate change. USA and China are the dominant players on either side in terms of CO_2 emissions. We do not know how close we are to the tipping point from a climate change perspective, on which there is now ample evidence that the threat is very real. Unless the OECD countries reduce their CO_2 emissions, there may not be space to accommodate non-OECD emissions in which we need adequate share. We should recognize that additional energy needs for India to reach a given level of quality of life are the largest as compared to any other country (China included). This is simply because of larger energy gap that we have to cover and our population which is in fact competing with that of China. While we must work hard to secure our interests during the ongoing international negotiations, in parallel we need to act now to secure the future of our coming generations.

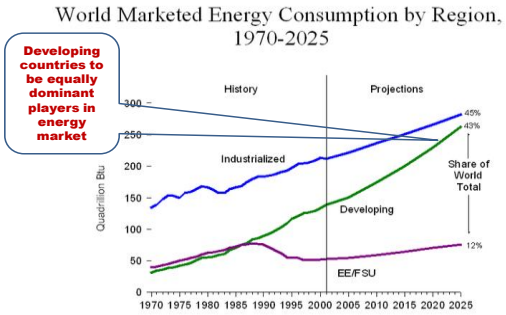


Global average temperature over last one and a half century showing a more or less steady increase over the last fifty years or so. The fluctuations and their cycles can be correlated with various events like solar cycles

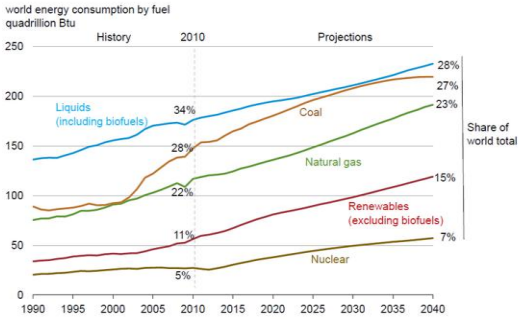
We do not know how close we are to the tipping point. However we need to act now to secure survival of our future generations.



In terms of the sustainability of energy resource we need to recognize that while energy intensity in all countries and per capita energy demand in industrially advanced countries is coming down, per capita energy demand is expected to increase in emerging economies. Increasing demand for energy in developing countries is expected to raise world marketed energy consumption in developing countries making them as dominant players in energy market as are industrialized countries. On the whole the world energy demand is expected to expand by around 45% between now and the year 2030; an average rate of increase of 1.6% per year, most of which would comprise of fossil energy with coal accounting for more than a third of overall rise. Fossil fuel prices as a consequence are expected to continuously rise with increasing degree of volatility. Clearly developing countries such as India would find accessing energy from international market increasingly difficult both on account of depleting fossil energy resources as well as their rising prices. As we know, China has been aggressively proactive in securing energy assets. As mentioned earlier, considering that our additional requirements would be larger, we need to be far more

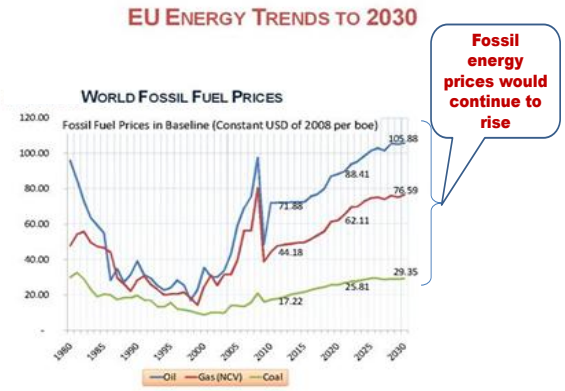


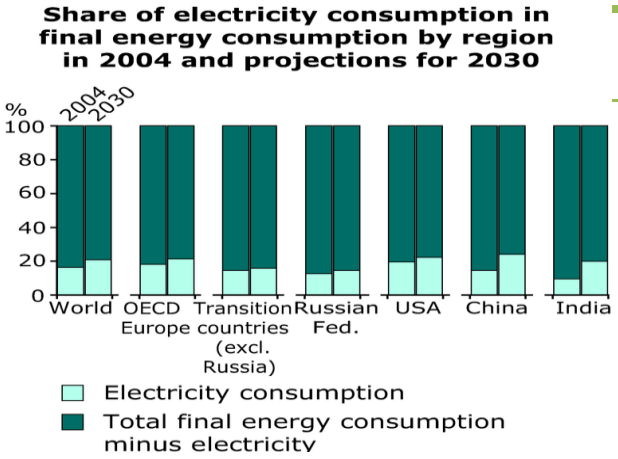
Source: EIA, *International Energy Outlook 2004*



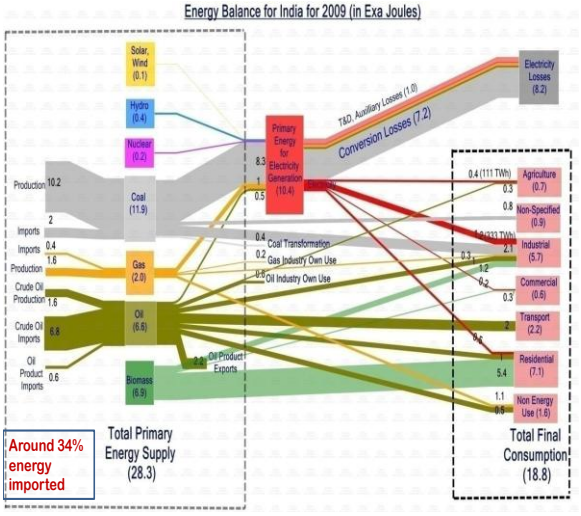
World energy demand expands by 45% between now and 2030- an average rate of increase of 1.6% per year-with Coal accounting for more than a third of overall rise.

World Primary Energy Outlook by EIA (as of 2011-09)





proactive in the matter of securing energy assets.



Ref. Energy Technology Vision 2035 (Draft TIFAC Report)

At the consumption end, the share of electricity in the total energy consumption is naturally expected to increase. In countries like India and China this increase is expected to be more spectacular than industrialized countries.

Indian energy scene

A look at the current energy scene in our country indicates that only around two third of our primary energy requirement is met by domestic resources. The rest is imported. Bio-mass may be contributing to around a fourth of primary energy, a large part of which gets consumed in households. Electricity supply caters to around 12% of energy consumed.

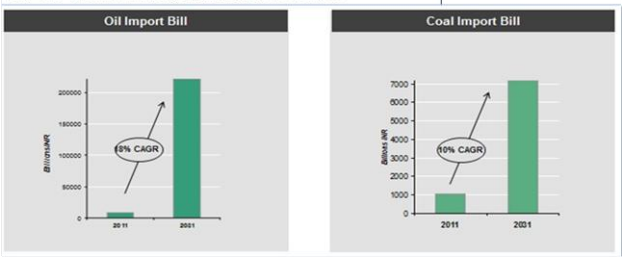
Table 1.4: Range of Commercial Energy Requirement
(Estimates for 9 percent Growth by 2031-32)

Fuel	Energy use in 2003-04	Range of Requirement in Scenarios	Assumed Domestic Production	Range for Imports#	Import (Percent)#
		(R)	(P)	(I)	(I/R)
Oil (Mt)	119	397-555	35	362-520	91-94
Natural Gas (Mtoe)	29	125-235	100	25-135	20-57
Coal (Mtoe)#	167	860-1296	560	300-736	35-57
TCPES (Mtoe)*	329	1667-2077	-	972-1382	58-67

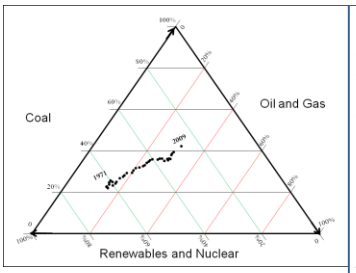
Source: Integrated Energy Policy
Mtoe- Million tones of oil equivalent, 1 toe equals 2.5 tonnes of coal or 900 cubic metres of natural gas / coal bed methane (CBM). * TCPES – Total Commercial Primary Energy supply including hydro, nuclear and renewables

We would need to import around 60% of primary energy supply by 2031-32.

Energy import bill increases much faster than economy.



India's primary energy needs are expected to grow around three folds by the year 2032. Around 60% of this would be required to be imported. This coupled with rising energy prices would mean a steep rise in energy import bill. As it is, energy costs in India are high creating issues about our competitiveness. With time this is likely to become a bigger challenge on account of rising prices in the world energy markets. Vulnerability to supply shocks and consequent economic and energy security risks are likely to be much more serious issues in years to come. We thus need to rapidly enhance domestic energy production as well as our ownership of traditional and new energy assets. At this stage we need to recognize that nuclear energy is already cost competitive today. The same is to an extent true with renewable energy and sooner or later all renewable energy forms are expected to reach parity with prevailing commercial prices. When these energy forms will actually be able to overtake fossil energy would depend on several factors. While we must be very aggressive in securing energy resources of all kinds, emphasis on renewable and nuclear energy resources would not only enable relatively cheaper energy production within the country but would also be consistent with the need to reduce our carbon foot print. For renewable and nuclear energy to play an effective role in this context, they must be able to produce in addition to electricity, thermal energy at different temperatures as well as meet the energy requirements of the transportation sector. Several technologies and technology products would need to be developed and their market entry facilitated overcoming barriers created by established technologies and products that depend on fossil energy. Transformation of renewable



Primary Energy Mix for India

Ref. Energy Technology Vision 2035 (Draft TIFAC Report)

- We need to enhance domestic energy production and ownership of energy assets to minimise energy import cost. (Both traditional as well as new resource types).
- We need greater thrust towards Renewables and Nuclear both to minimise imports as well as carbon dioxide emissions.
- We need greater thrust on transformation of renewable and nuclear energy into hydrogen and fluid hydrocarbons.
- Need to think of a policy shift to redeploy subsidy from natural hydrocarbons to renewable energy appliances and artificial hydro carbons/hydrogen from renewable/nuclear and bio-methane from waste.

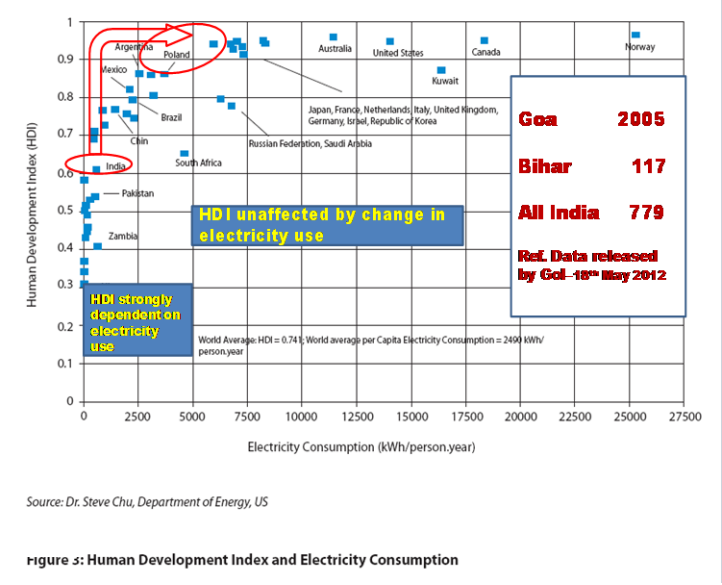
and nuclear energy into hydrogen and fluid hydrocarbons, end use devices running on hydrogen, electric/hydrogen mobility, solar pumps and lights, low cost energy storage for electricity and hydrogen etc. are some examples of new technologies that need to be quickly realized and deployed. We also need to think of a policy shift to progressively redeploy subsidy on fossil hydrocarbon products to renewable energy appliances, artificial hydro carbons/hydrogen produced using renewable/nuclear energy and methane produced from bio-degradable waste. For example, a staggering amount of waste is generated every day in every town and city, and the local bodies are grappling with logistics for its disposal. The government and individuals fail to see waste as a potential source of energy and agricultural input in the form of manure. NISARGRUNA developed by BARC is a robust biphasic bio-waste digester that offers a decentralized urban solid waste management solution through 100% recycle to produce 70-80% pure methane and organic manure. This gas could supplement cooking gas or even run engines. At places where domestic piped gas network is available, the gas company could discharge significant corporate social responsibility through liquidating waste and marketing gas as well as organic manure and at the same time create livelihood for people in the process.

NISARGRUNA developed by BARC is a robust biphasic bio-waste digester that offers a decentralised urban solid waste management solution through 100% recycle to produce 70-80% pure methane and organic manure.

A staggering amount of waste is generated every day in every town and city, and the local bodies are grappling with logistics for its disposal. The government and individuals fail to see waste as a potential source of energy and agricultural input in the form of manure. At places where domestic piped gas network is available, the gas company could discharge significant corporate social responsibility through liquidating waste and marketing gas as well as organic manure. Create livelihood for people in the process.

Electricity

Electricity is a very convenient form of energy for both transportation and end use. Proportion of electricity in overall energy consumption is therefore expected to rise with time. As a matter of fact electricity use has become a barometer of level of development and quality of life. Human Development Index (HDI) rises sharply with increase in energy consumption up to around 5000kWh per capita. Beyond this level HDI reaches a maximum saturation level. We have to cover a lot of ground from the present level of around 800 kWh per capita to reach 5000 kWh per capita. Between now and the year 2032 the projected electricity requirements are expected to reach around 1000 GWe which would amount to a fivefold increase from present day generation capacity. With this the share of electricity in our total energy consumption may rise from 12% as at present to around 20%. When we reach these numbers, we would have reached around two third of the target of 5000kWh per capita.



Source: Dr. Steve Chu, Department of Energy, US

Figure 3: Human Development Index and Electricity Consumption

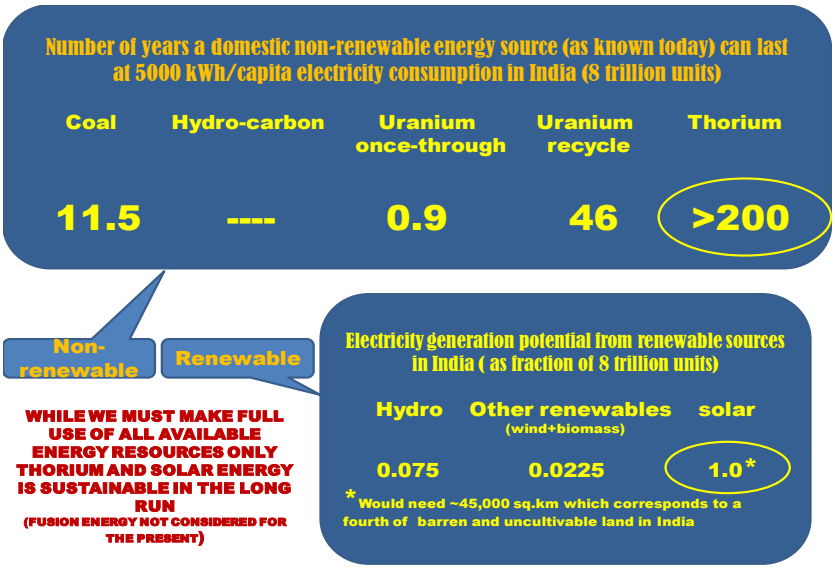
Securing energy for India's future is a major challenge

	World	OECD	Non-OECD (developing world)	India	India of our dream
Population (billion)	6.7	1.18	5.52	1.2	1.6 (stabilised)
Annual av. per capita Electricity (kWh)	~2800	~9000	~1600	~780	5000
Annual Electricity Generation (trillion kWh)	18.8	10.6	8.2	0.835	8.0
Carbon-di-oxide Emission (billion tons/yr)	30	13	17	1.8	?

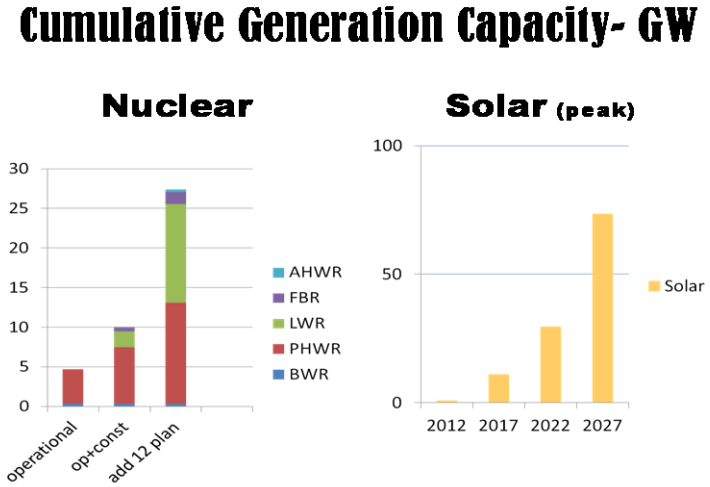
➢**India alone would need around 40% of present global electricity generation to be added to reach average 5000 kWh per capita electricity generation**

We need to recognize that 5000 kWh per capita would correspond to an annual electricity generation of 8 trillion kWh which would be more than

40% of global electricity generation today. Since more than 60% of our total energy need would need to be met by imports, it is clear that our electricity supply would also progressively become heavily dependent on imported fuel supply. A large population like India with its per capita energy use parameters reaching closer to industrialized countries is bound to become a major consumer of world energy resource. Heavy dependence on imported energy is clearly an unsustainable pathway for a large population like ours when earth resources are depleting and world would necessarily need to adopt low carbon strategies in order to address climate change issues.



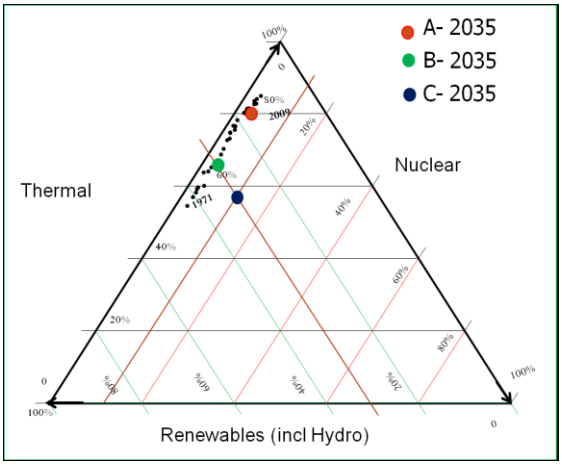
We therefore need to explore meeting our energy needs through domestic energy resources. A look at our domestic energy resources in the context of ability to support 5000 kWh per capita (this corresponds to 8000 trillion units annually) would suggest that we must necessarily focus our efforts on thorium and solar energy as these are the only two resources, as of now, that can support our energy needs in to future. Luckily our



efforts and national priorities are aimed at this objective. We need to make rapid progress in these areas to mitigate the energy crisis that is bound to set in the long run as discussed earlier.

Towards a lower CO_2 foot print

A group to look at energy vision for India up to the year 2035 as a part of Technology Vision 2035 exercise being pursued by TIFAC is currently working on different possible scenarios. It is clear that aggressive result oriented efforts are necessary to cut down dependence on fossil energy and as a consequence on imports.



Power Generation – Supply Mix scenarios for 2035 – Moderate Growth

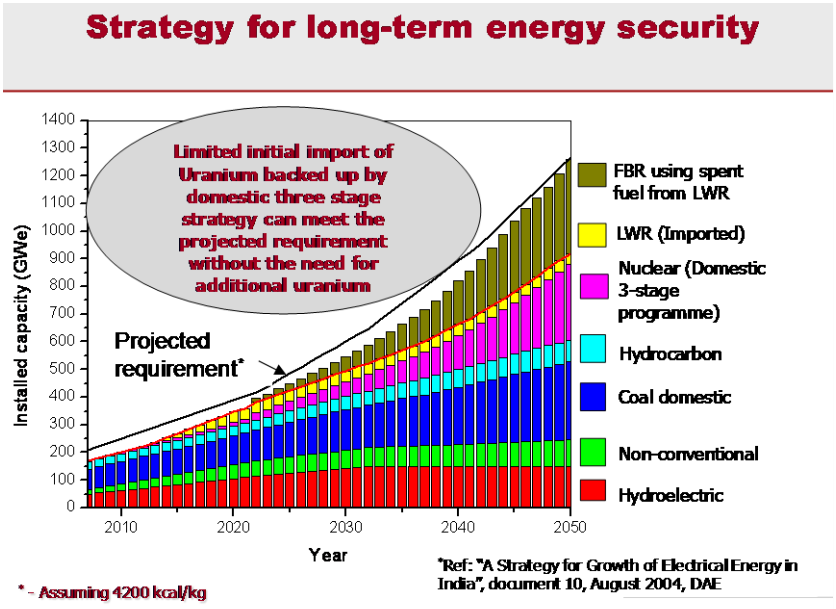
Ref. Energy Technology Vision 2035 (Draft TIFAC Report)

- **A -- High Coal**
- **B -- High Renewables**
- **C -- B + High Nuclear**

Solar energy is by its very nature a diffused energy source. Therefore to gather solar energy at a level sufficient to meet our national energy needs, we would need approximately 45,000 sq. kM of land area. This corresponds to around a fourth of barren uncultivable land that we have in India. While there would be natural motivation to use available land closer to load centers for collection of solar energy, we must remain conscious of conflicting demands on land for habitat, agriculture, grazing, industry, infrastructure and most importantly forests. Thus for large scale generation of solar energy; while making use of sun light collection areas wherever there are opportunities without getting into conflict with other competing land uses (such as roof tops, water reservoirs and canals etc.), should be resorted to the maximum extent feasible; focusing on barren uncultivable areas (desserts, mountain areas without tree cover and other barren/uncultivable areas) away

from population areas should be our approach. Most of such areas where there is adequate solar insolation are also likely to be water stressed. Ability to minimize dependence on water should thus be an important criterion for technology choices.

Since solar energy source is not available on 24x7 basis, significant investment on storage of energy to take care of mismatch between the profiles of power generation and demand across the grid would be necessary. Development of cost effective energy storage technologies therefore assume importance. For large capacity plants apart from better benefit of economy of scale, solar thermal technology may also offer relatively higher benefits as a result of cheaper energy storage. It should be even possible to configure direct conversion of sunlight into electricity at a high temperature and convert reminder energy through thermodynamic conversion route in a cogeneration mode enabling significantly higher overall conversion efficiency. On a decentralised level, solar power generation in standalone mode as also two way grid connected mode could supplement investment in energy generation in a significant way. In rural areas solar generating units could significantly supplement rural electrification program through setting up village micro grids where electricity has not yet reached. Even in places where grid has reached but power is not available for long durations, there may be a case for solar units. Under the JNNSM solar energy deployment is making rapid progress and we soon expect solar



energy to achieve grid parity.

On nuclear energy front, our uranium resources are very modest while there are vast thorium resources. Since thorium does not contain any fissile element, start of a nuclear program has to be necessarily based on uranium being the only naturally occurring element that contains a fissile isotope. Progressively one can grow the capacity to irradiate thorium to convert it to fissile species to enable large scale use of thorium. This would require fast breeder reactors that breed more fuel than what they consume. This is the rationale for our three stage technology development program which we have sufficiently mastered and are moving forward on its deployment. In terms of power generation capacity development, limitations on uranium availability however have posed restraints on growth.

Uranium imports were not possible till recently. With opening of international civil nuclear co-operation, we can now access external uranium to augment the growth of nuclear energy in the country. As compared to importing other energy forms which has to be recurring, a limited import of uranium initially and expanding capacity generation through three stage program deployment strategy can meet the projected energy requirements for catering to electricity generation needs without the necessity of additional imports.

For rapid deployment of nuclear power however, we need to prepare people by addressing their concerns and expand the supply chain within the country by creating greater confidence in the industry even as we carry forward development of necessary technologies.

National R&D efforts

It is necessary to ensure strong national R&D capabilities related to technologies for different energy sectors important in our context. Such capabilities are necessary even when technology is accessed from outside, to prevent loss of competitiveness as a result of obsolescence or to be able to address repair and maintenance issues without having to pay excessive opportunity costs. Investment in R&D can thus be seen as a strategy to protect investments made. There are other motivations for in house R&D and technological capability as well. Implementation of any technology brought in from elsewhere would need adaptation to Indian conditions and special challenges that they may pose. One needs to be able to identify these special challenges, work out appropriate solutions and establish their adequacy. Without adequate R&D background one may get diverted on a path that is not the most appropriate path for India or at times end up in failures. There are a number of examples of this having taken place in past. Taking R&D capability to a level that enables entire technology package to be evolved within the country is something we should aspire for. Just as this has been done in some areas like atomic energy and space, I see no reason why this cannot be realized across the board. A large country like India with large number of young and knowledgeable people once they are challenged, motivated and enabled can certainly deliver on this expectation. We however need to make necessary policy and structural corrections for this to happen.

Some of the key technology and policy thrusts that we should focus our attention on are:

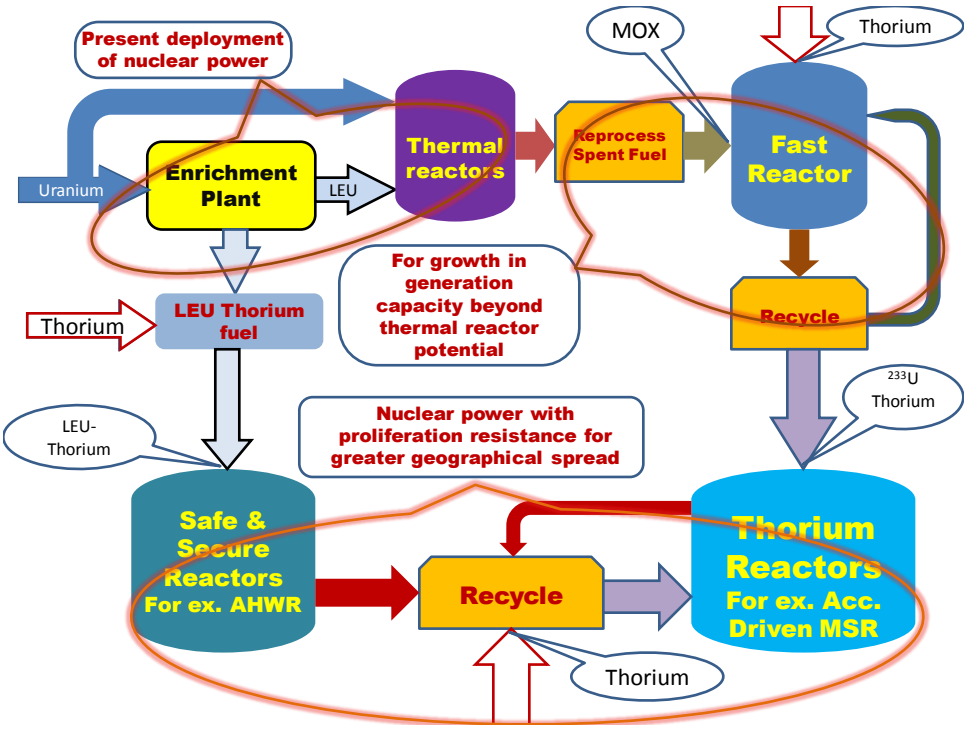
- New energy technologies
  - For energy production

- Solar
- Nuclear

  - For hydrogen production, storage/transportation and utilisation
  - For synthesis of fluid hydrocarbons

- Energy technology up gradations
- Clean coal technologies (with Indian coal)
- Special attention to India specific problems
- Hybrids with Solar thermal for power generation and air conditioning/refrigeration
- Gradual replacement of subsidy on kerosene and power supply for agriculture pumping with incentives for solar lights and solar pumps respectively
- Energy efficient building architecture with integrated renewable energy, water harvesting and waste recycle systems
- Mobility
  - Electric
  - Hydrogen

Reaching a Global leadership



We should also recognize that pursuing our independent R&D consistent with national objectives has the potential to put us in a relatively advantageous position from a long term perspective. This would be a strong possibility at least in areas where challenges that we face today are also the challenges likely to be faced by other countries tomorrow. Our interest in development of technologies for energy from thorium presents a good example in this context. There are already signs of greater interest in thorium in several business entities abroad. We thus have the opportunity to lead the global effort in thorium related development.

Similarly we have the opportunity to lead the global effort in making transition from fossil electricity to non-fossil electricity as also the transition from fossil hydrocarbon to non-fossil fluid energy carriers. We must recognize that our priority on these objectives should be far greater than other countries, given our precarious fuel availability situation. We must therefore move forward and lead these developments rather than wait for other countries to develop the requisite technologies which they may not pursue in the time frame relevant to us and when they do it may be too late for us.