27th Wilhelm von Pochhammer Memorial Lecture 2015

Towards Sustainable Green Energy Future

Anil Kakodkar

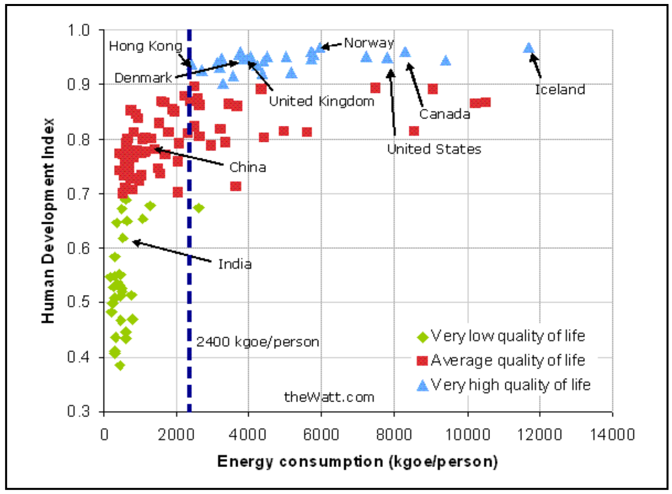
19th March 2015

Ronen Sen - Chairman for the Session

On my behalf and that of members of the Federation of Indo-German Societies, I welcome Dr. Anil Kakodkar, who will be delivering the 27th Wilhelm von Pochhammer Lecture this evening. After the lecture we will give the annual scholarship awards, organized jointly by our federation and the Hanns-Seidel-Stiftung.

Our speaker this evening, Dr. Kakodkar, needs no introduction to this audience. He is a very eminent reactor engineer and scientist who has made tremendous contributions to our atomic energy programme, our energy security, our industrial development and our higher education, and of course our national security. I have had the privilege of knowing him in different capacities over recent decades, including in his role as Director, BARC, and for a long time as Chairman of our Atomic Energy Commission. He played a pioneering role in setting up the research reactor Dhruv, and the heavy water pressurized power reactors which were standardized for serial production in entirely an indigenous effort. He has been, as you know, a strong proponent of advanced heavy water reactors using thorium, as part of the three stage atomic energy programme which was envisaged by Dr. Homi Bhabha. He has contributed very significantly to civilian nuclear programme as well our strategic nuclear programme. This included both Pokhran I and II nuclear tests, in 1974 and 1998 respectively, I am personally aware of his contributions in the building of our first nuclear powered submarine, recently commissioned as the INS Arihant, which we used to earlier refer to as the ATV or S-2 project. His services have been recognized by the nation and he has got numerous awards. To mention just a few, he has got different Padma awards, including the Padma Vibhushan award from the President of India. Without further ado, I request Dr. Anil Kakodkar to deliver his lecture, on the very important and topical theme: “Towards a Sustainable Green Energy Future”.

Dr. Anil Kakodkar – Speaker for the Session



Thank you Ambassador Ronen Sen, distinguished people sitting in front of me, Ambassador Lambah, Dr. Varadarajan, Dr. Kapoor , there are many other people whom I know, ladies and gentlemen. It is a great honour for me to be able to speak in front of all of you on this important occasion, the 27th Wilhelm von Pocchhamer lecture. What I am going to speak is in many ways to state the obvious. But I want to make a case for sustainable development in the context of the green energy future and of course being an Indian and coming from nuclear background, the two, the nuclear context and the Indian context would occupy larger part of whatever I am going to present.

I am conscious that the nuclear programmes in India and in Germany are on two different tracks right now. There are obviously reasons for that and I am not going to go into those reasons here. I am essentially going to restrict myself to the larger energy scene in the overall global context and focus on the long term Indian energy scene in broader terms. So let me begin.

We all know that several inputs are necessary to support development and energy is certainly one of the most important among them. A correlation between human development index (HDI) and the energy use in per capita terms in different countries is shown in the figure. Each point there on the graph represents a country. The top blue triangles literally in a horizontal line at the highest level of (HDI), represents the developed countries of the world. The red squares are the countries which are mid way between the development process. And then there are the light green rhombuses which represent the developing world. India belongs to this group. One can see the distinctive features for each one of these three domains. You add energy into the developing countries, and you would see fairly rapid improvement in HDI. On the other hand any addition of energy in the developed world would contribute little to HDI there. This clearly has to be an important factor along with economics and energy security considerations, in determining energy policies and energy mixes in different countries. As far as India is concerned, the hard fact is that we need lots of additional energy, larger than any other country in the world.

Let us look at some numbers. India today is around 17.5% of world population with just around 5% of world's electricity production. Our per capita electricity consumption is around a tenth of OECD countries and about half of the non-OECD countries. To reach a HDI comparable to the advanced countries, we need to produce 7.5 times more electricity as compared to what we have today. China already produces 5 times more electricity as compared to India with their per capita electricity consumption 4.5 times higher as compared to us. So in the context of the climate change debate, in the context of sustainable energy debate or whatever, I think India and China are two different cases. Very often we put them together and that actually neither addresses China's issues nor addresses India's issues. It is clear from these numbers that they must be seen differently.

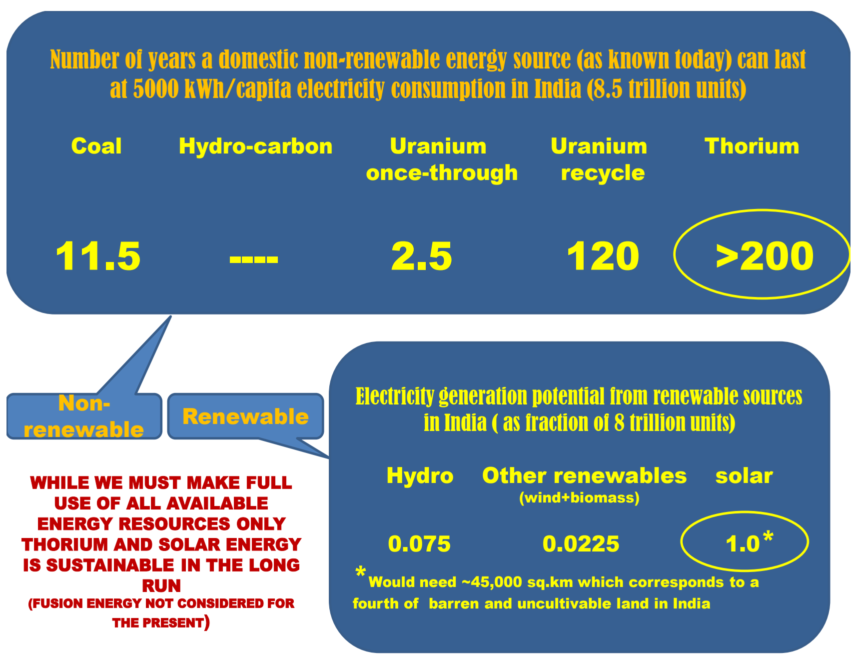
India's need for additional electrical energy to reach a HDI comparable to the advanced countries is thus much larger than any other country. In fact for electricity generation alone our additional needs would be around a third of the present day electricity produced worldwide. According to the integrated Energy Policy Report that was brought out by the Planning Commission some years back the total commercial primary energy supply which was around at 329 million tonnes of oil equivalent in 2003-2004 is expected to reach to something like three to four times that figure by the year 2032 and would still be rising. Two third of that augmented energy supply would need to be imported as against one third of the present energy supplies that are being imported. This in turn would mean that India's energy imports would go up by a factor of eight. Even after taking into account our rising economy, we can ill afford such an increase in energy import bill.

Then there is also a question about the impact of inflation in energy prices caused by such large and rising demands not only from India but also many other countries. Also there probably would be a much greater volatility in energy prices. So it is clear that to take care of sustainable energy supply for our country, we really need to focus on energy that we have on the

Indian land mass. That anyway should be our first preference and we should we should derive most of our energy needs from geographical area under our control.

Let us now look at the known energy resources within the country. We should look at these resources in the context of energy supplies necessary to support high HDI. For this purpose in India we should aim at around 5000 kWh per capita or a total generation of 8.5 trillion kWh. I have two tables on this figure, the one at the top is for the non-renewable energy sources and the other at the bottom is for the renewable energy sources. In case of non-renewables if you ask a question; how long a particular energy source would last at a rate of consumption of 5000 kWh per capita, you will find that most of the available energy sources are not sustainable. Even coal, which indeed is the most significant resource as of now, would barely be sufficient for just around ten years. Thorium however represents an energy source that is abundant. Since thorium by itself is not fissionable, one has to begin with uranium and then use thorium after converting it to fissionable material in nuclear reactors. Thus in the long run in terms of non-renewable energy sources we have only one choice and that is nuclear. You need to begin with uranium first to be able to make use of thorium later. So we should look at them together.

In the context of renewable energy sources, the question to be asked would be; what fraction of total energy requirement can be met by a particular source and one notices that everything other than solar energy would appear very small. You earmark something like 45000 square kilometres of land area, which corresponds to 1/4th of the barren uncultivable land in India, you can actually tap all the



energy that the country would need even at 5000 kWh per capita level of energy use. Thus it is very clear that we need to focus on nuclear and solar energy to meet our long term energy needs in a sustainable way. No need to depend on imports, the energy is available right on our land and luckily both of them do not emit carbon-di-oxide. So they do not cause climate change concerns.

Now can we live with one, why do we need both? And the answer to that is - we actually need both because first of all a country must have an energy mix. You can't put all eggs in the same basket. We would have only two, so we need to take recourse to both of them. Further, they have many complimentary features between them. Concentrated source versus diffused source, available 24x7 versus being intermittent etc. There are complimentary benefits to be derived by making use of both. In fact, looking at the continuously rising energy demand in the country, we need to tap all available energy sources as we progress towards increasing the share of solar and nuclear energy. What has happed in our country over past decades is however exactly the reverse. Tracking the share of different energy sources during the years 1971 to 2009 would show actual movement to be from low carbon to high carbon. Aggressive policy push, including on resource access, economics and technology fronts, to quickly enhance the share of nuclear and solar energy and aiming to reach 100% is thus necessary for our secure and sustainable green energy future. Luckily, this seems to be happening now as far as solar energy is concerned.

Leveraging indigenous knowledge systems in making technology choices as well as adaptation, deployment and ongoing development of appropriate technologies should be an integral part of policy making and implementation. Otherwise there is a danger of distortions being caused by aggressive vendor push. Deeper and comprehensive engagement with national knowledge systems also enriches the human resource development in new and upcoming areas.

With respect to solar energy while the present policy regime does seem to incentivise growth, we need to also focus on realising full domestic value chain within the country. In addition to greater contribution to GDP such an approach insulates us from vulnerabilities that can arise as a result of heavy dependence on imports. We are all aware of the shock that the Chinese created worldwide in the matter of rare earths. In case of photovoltaic materials and value added products, today's low prices are perhaps a result of a particular global dynamics. It can change and then the whole thing could well be subjected to a major shock. In order to smoothen that shock, the domestic value chain is of great importance and I think we need to focus on that.

With respect to solar energy we also need to focus on large capacity solar thermal plants. At large capacities (> a few hundred MWe) these plants would favourably compete with photovoltaic. They can run 24x7 since energy storage is simpler and cheaper. Most importantly, in the context of domestic value chain in my view, it is much easier, much simpler for India to quickly achieve 100% domestic value addition capability. While, it could be a little more difficult to realise 100% domestic value addition in case of the photovoltaic, we must quite frankly attempt that as well.

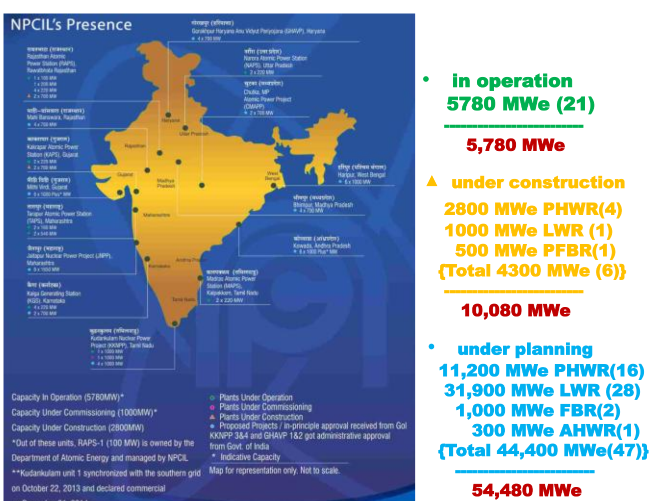
In addition to electricity production both centralised as well as distributed, we must also preferentially promote standalone solar agricultural pumps and solar lights for study of children in areas where there is strong dependence on kerosene for lighting. This would offset the subsidies that industrial electricity consumers pay for agricultural pumping or government pays for diesel and kerosene. A healthy consequence would be more competitive industrial production and better ground water management as well as preservation of soil quality.

I might mention here that a colleague from IIT Bombay, Prof. Solanki is implementing a million light programme for school students. He has already completed around 7½ or 8 lakhs of lights, all done in rural India in cottage industry mode. Thus the supply chain and ongoing support system gets created in rural areas contributing significantly to rural economy and livelihood. A student gets a small light for study purposes just for Rs.120 (remaining Rs. 380 coming from Govt. or corporate) and is not dependent on grid supply or kerosene. Prof. Solanki is now very confident that the programme can now be scaled up to make sure that no child in the country would be left without a light for study. On the basis of success he has achieved, it seems eminently possible to achieve such a goal within the next few years. So that is doable but that is another policy decision.

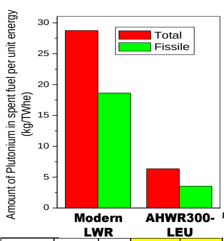
Let me now come to nuclear energy. The present Indian nuclear power programme is shown on the figure. You have 21 reactors in operation with a cumulative capacity of around 5700 megawatts. Six reactors are under construction. They are a mix of four PHWRs and a light water reactor as well as a prototype Fast Breeder Reactor. When completed (by 2016 as per present schedule), these together with operational reactors will take the total generation capacity in the country to around 10,000 megawatts. And then you have a large number of PHWRs, light water reactors, fast-breeder reactors and an advanced heavy water reactor in planning (some of them in advanced planning) stage. We hope that the nuclear power programme would soon see some significant momentum leading to increase in the share of nuclear energy in the country.

As is well known, we have a long term interest in thorium because as we saw earlier, India is well endowed with thorium. I am certain our three stage nuclear power programme would eventually take us to large scale use of thorium. Internationally, however, there has not been much interest in thorium in the past. This seems to be changing in recent times and the interest in thorium is in fact growing. It is growing for a variety of reasons. I will deal with this topic in some detail in a moment.

Nuclear energy which at one stage was contributing to something like 17% of total electricity production in the world has not grown the way it was expected to. Today, I would imagine its share is around 12-12 ½%. It has actually come down. This is because there are a number of barriers to the expected growth of nuclear power.



One of the major apprehensions relates to disposal of spent nuclear fuel. This actually is not a problem for a country like India as we have adopted a closed nuclear fuel cycle that recycles uranium and plutonium back for energy production. But there are many countries whose policies do not support recycle of spent nuclear fuel either on account of proliferation concerns or in case of countries with very small programme, for reasons of economic viability. United States has been the primary driver for policies against recycle of spent nuclear fuel. Technologically disposal solutions have in fact been worked out in the sense that you have repositories for geological disposal of spent nuclear fuel. However, over a period of time radioactivity decays and what remains are those species which have a long half-life. These are essentially actinides, the largest component being plutonium. A repository over a period of time could thus become a plutonium mine. A solution that was conceived to address proliferation concerns thus becomes a bigger proliferation concern over a period of time. In an attempt to correct the situation a 'perpetual' safeguards and physical protection system needs to be brought in with the repository at best becoming a facility for 'retrievable' disposal. So technically spent nuclear fuel cannot be disposed off in a manner that takes it out of any institutional control. As a matter of fact, at an international conference on the subject many years back in IAEA Vienna, as a Conference Chair, I openly stated that disposal of spent nuclear fuel as it is, is an unresolved issue and is unlikely to be resolved. Nobody dissented.

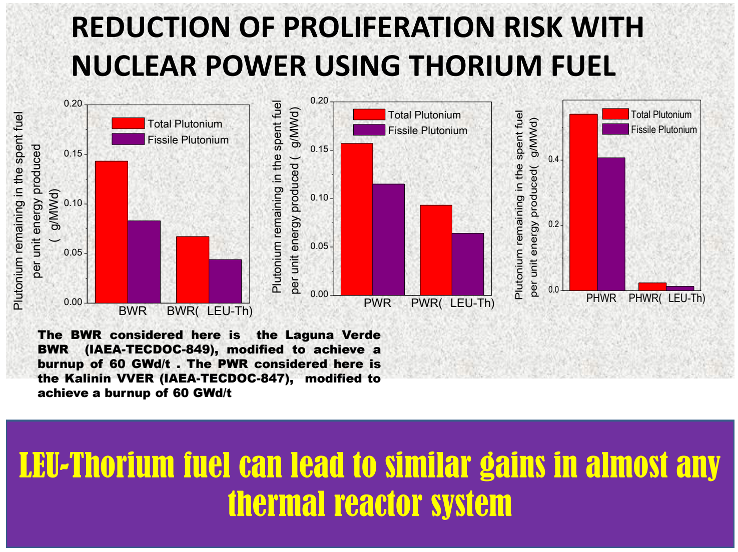


^{238}Pu	3.50	%	9.54	%
^{239}Pu	51.87	%	41.65	%
^{240}Pu	23.81	%	21.14	%
^{241}Pu	12.91	%	13.96	%
^{242}Pu	7.91	%	13.70	%
^{232}U	0.00	%	0.02	%
^{233}U	0.00	%	6.51	%
^{234}U	0.00	%	1.24	%
^{235}U	0.82	%	1.62	%
^{236}U	0.59	%	3.27	%
^{238}U	98.59	%	87.35	%

STRONGER PROLIFERATION RESISTANCE WITH AHWR 300-LEU

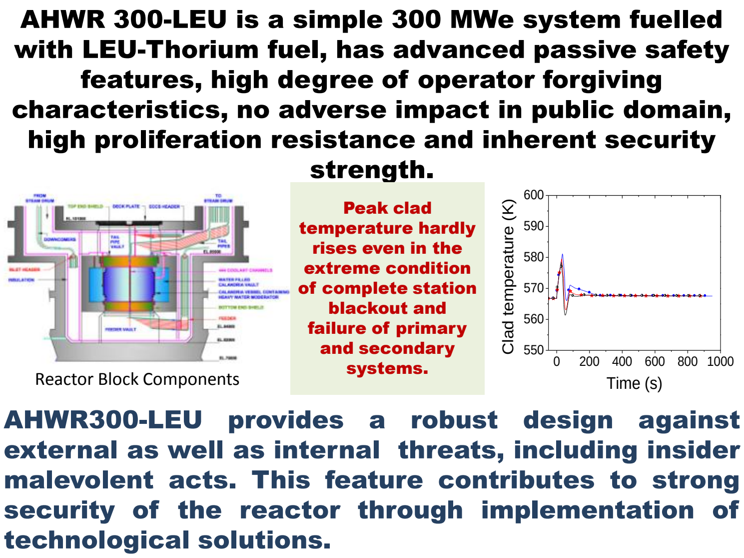
- ✓**Much lower Plutonium production.**
- ✓**Plutonium in spent fuel contains lower fissile fraction, much higher ^{238}Pu content which causes heat generation & Uranium in spent fuel contains significant ^{232}U content which leads to hard gamma emitters.**
- ✓**The composition of the fresh as well as the spent fuel of AHWR300-LEU makes the fuel cycle inherently proliferation resistant.**
- ✓**Uranium in spent fuel contains about 8% fissile isotopes, and hence is suitable for further energy production through reuse in other reactors. Further, it is also possible to reuse the Plutonium from spent fuel in fast reactors.**

Thorium can be of significant help in this context. If a country wants to adhere to the policy of once through use of nuclear fuel, the use of thorium-LEU (low enriched uranium) fuel would considerably eliminate the proliferation risk from the spent nuclear fuel so arising. This is because of the isotopic composition of plutonium and uranium in such spent nuclear fuel. Chemical separation of these elements would not lead to materials that are weapon useable in practical terms both on account of non-fissile content as well as high radiation as well as heat generation levels. On the other hand for countries that seek permanent and safe disposal could decide to recycle these materials since they have significant energy potential. So use of thorium can in principle soften the barriers to growth of nuclear power that relate to spent fuel disposal issue.



Globally there is a large spent nuclear fuel inventory, around 270,000 tonnes with around 12,000 tonnes getting added every year with no clear cut solution in sight. As we discussed earlier, direct permanent disposal of this material is an unacceptable security and safety risk. At the same time this inventory is a sufficiently large energy resource if recycled. Introduction of thorium in power reactors would not only alleviate further accumulation of this problem but could also address the legacy issue by way of safe disposition of plutonium.

Here is some data in support of the argument that I just made. The three bar charts, the first on the left is for boiling water reactor, the middle one is for pressurized water reactor and the right one is for pressurized heavy water reactor. The two bars, one in red and one in velvet are for the total plutonium and the fissile content in that respectively. Now there is a companion double bar there. Instead of low enriched uranium which we use in normal power reactors, if you use a mix of low enriched uranium and thorium (the proportions would of course be different for different reactor designs), you can notice that both the quantity of plutonium as well as the fissile content in the spent fuel is considerably reduced. In this context PHWRs seem particularly attractive. This is a reactor system in which we have global leadership. India can supply the smallest commercially competitive systems (220 MWe) in this category. PHWRs with thorium-LEU fuel offer an excellent opportunity for India to get in to export market and contribute to the growth of nuclear power worldwide especially in smaller countries.

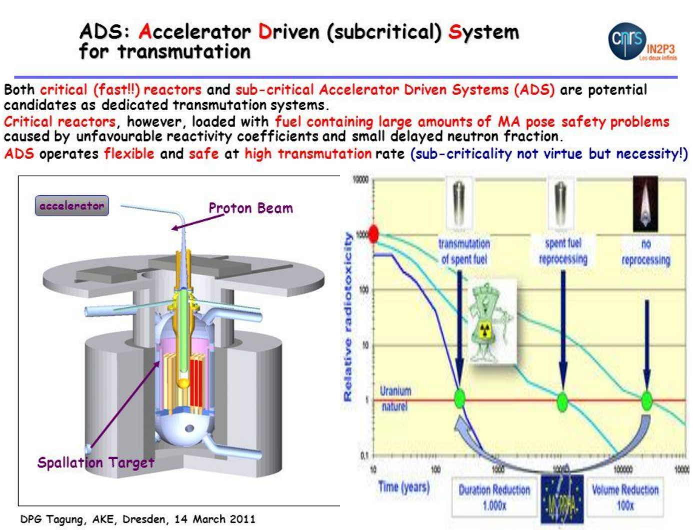


What about the energy to be derived from mined uranium or for that matter energy to be derived from fissile materials. You put these materials along with thorium, you can get as much energy or sometimes larger energy out of such a fuel simply because thorium has wonderful properties in terms of conversion to fissile material and generation of energy from the in-situ generated fissile material which is uranium 233.

What about accidents and what about terrorist activities? While conceptualising the advanced heavy water reactor (AHWR), while a key design objective has been to produce energy from thorium, the other equally important objective has been to eliminate any significant impact in the public domain even in case of an accident. The public trauma as a result of large scale displacement can thus be avoided. Adverse impact in public domain following an accident in a nuclear reactor is a result of escape of radioactivity across multiple barriers that are provided in a nuclear reactor. This thus occurs when there is a breach of barriers and there is a significant force to drive the radioactivity to distances beyond the plant boundary. The configuration if AHWR is has been designed in a manner that will make core heat-up very unlikely. This should prevent breach of barriers and resultant escape of radioactivity. For example, AHWR does not get into core heat up mode even in a situation where there is a complete station blackout (a technical jargon meaning failure of all external and plant power supplies, so there is no power for running station's safety systems) and on top of it you say that both the primary and secondary shutdown systems (normally there are two independent fully capable shut down systems) for some reason (say malevolent activities) have been decapacitated. This robustness has been realised by way of basic physical principles and innovative plant configuration. It is not based on active equipments or components and so the robust safety performance can be realised with a high level of reliability.

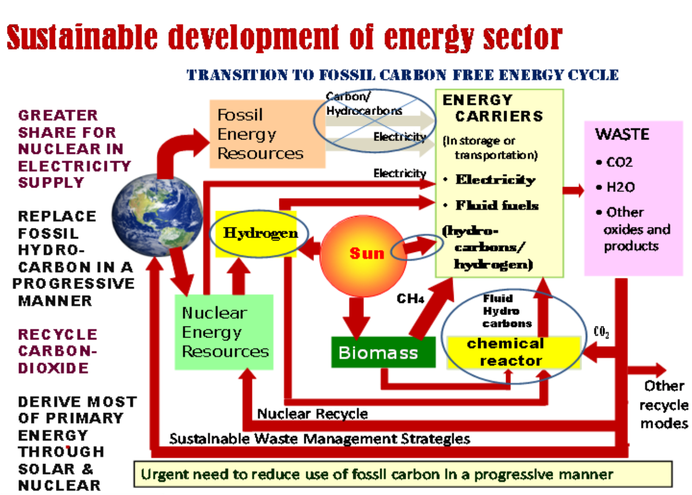
There is increasing interest internationally in use of thorium for energy production. One does see a number of ventures appearing on the horizon. Knowing India's sustained interest in thorium, many of them have started aggressive marketing efforts here. All of them need to be made aware of our closed fuel cycle policy and our need to pursue nuclear reactor and fuel recycle together. Looking at the present state of development, we need to tell them that instead of attempting to market thorium technology here, they should go elsewhere and try their luck there. May be we can also help them. All said and done, thorium does have a huge potential to address world energy problem and India has a great opportunity here.

I want to discuss the spent fuel problem a little further. When you reprocess the spent nuclear fuel, you of course separate out uranium, plutonium and recycle them in a reactor for energy production. There are still other higher actinides, which are in much smaller quantities but need disposal methodologies that are safe over very long periods since their radioactivity takes that long to decay. Similarly there are fission products like cesium and stronsium which generate a lot of heat restricting the storage density. Now, you can separate these species and either transmute them to species that have much lower half-life or deploy them to other economic uses. You can in fact produce some energy in the process as some of the higher actinides could undergo fission. Cesium can replace cobalt making radiation processing of food and other products significantly cheaper. Two things are happening here. Number one, by the process of separation you further reduce the quantity to be disposed off and by the process of transmuting the species you are actually hastening the decay. Further, with reduced heat generation in the disposal product, the requirement of storage space gets reduced. This technology is more or less within our reach now. For example, in BARC they have already demonstrated almost semi-industrial scale separation of higher actinides as well as cesium. Cesium has been immobilised in glass to produce radiation source pencils for use



in an irradiator. Worldwide, including in India, work is going on towards development of accelerated driven systems which are excellent platforms for transmuting higher actinides and other products. As the curve on the bottom right would show, the duration for radiotoxicity in waste to decay to a level comparable with a uranium mine decreases by a factor of a thousand to a few hundred years and the volume of waste to be disposed decreases by a factor of hundred. Further the storage density of the repository can now be much higher due to reduced heat load. The closed nuclear fuel cycle policy and related development is thus taking us closer to a regime where the high level radioactive waste is virtually reduced to a level of what has been existing in nature (uranium mine) within a time period comparable to the period over which institutional control can be maintained. At the moment we have laboratory scale research to back such a strategy. It has to be escalated to industrial scale development. I have no doubt that this would happen in less than a decade. It will certainly happen in India in less than a decade.

I now wish to turn attention to long term aspects of thorium technology development. The 300 MWe AHWR is a system to enable large scale experience with thorium at an early date. On account of its robust safety features realised within the framework of already proven technologies, it should receive wider acceptance as compared to its counterparts. I understand that the approval process for setting up of an AHWR is on the way. While AHWR is a good platform to address the energy needs in many countries, the domestic Indian program would need to follow the three stage track with thermal reactor, the fast reactor and thorium based reactors because that is the only way you can really exploit thorium potential on a large scale within the constraints of available uranium. It is also clear that the third stage thorium reactor would be of a different design. As I perceive, that is where the three stage programme track and the thorium technology development track would perhaps converge.



Just a couple of points beyond electricity. So far I talked about nuclear energy as a means of generating electricity. Electricity however is not the only form of energy that we need. We also need, for example, fluid fuels for running the transportation systems. At a time when we want to keep the carbon footprint low, we need to be able to produce such fluid fuels using the nuclear energy or solar energy as primary energy sources. This requires energy at high temperatures and efficient technologies to split water and produce hydrogen at competitive costs. That is one channel of technology development in which a lot of work is happening. Then there is a possibility of using hydrogen along with biomass to produce hydrocarbon substitutes (Dimethyl Ether as diesel substitute for example). This would be necessary to make full use of the existing infrastructure (existing fleet of cars and other vehicles). Over a period of time vehicle that use hydrogen or electricity would be available and the whole economy can shift to hydrogen or electric mobility. This way you can make a transition from fossil energy to non-fossil energy not just in the context of electricity but also in the context of other sectors of energy use. There is work going on in different parts of the world in this regard. India also is pursuing such development. I am aware that ONGC is supporting this activity in a big way. Clearly this effort needs to be significantly accelerated.

Time to conclude now. How do we see the energy world of future. Today we have our energy coming from fossil carbon and hydrocarbons which run our energy systems including generation of electricity. Tomorrow we should be able to derive electricity and hydrogen from both nuclear and solar, two major primary energy sources which could meet the long term requirements of this country or for that matter the world as a whole. In the interim, we can also use hydrogen along with biomass to produce a variety of hydrocarbon substitutes to facilitate transition from present day end use logistics to the new framework necessary for hydrogen/electric systems. Methane directly produced from biodegradable waste and excess agricultural residue could also be a partial alternative of significant value. Here, I would like to sight the French programme. Many people talk about the planned reduction in share of nuclear electricity in France. What they are planning is to dedicate a specified number of their nuclear reactors to produce hydrogen. They have also planned biomass production in a regenerative mode and meet the entire fuel needs of the French transportation fleet by producing non-fossil hydrocarbon substitutes using hydrogen and biomass. I strongly believe that, given our acute situation with respect to our energy needs particularly in the long term, we must have a master plan for our energy independence and implement it in a mission mode. Sooner we do this, better it would be for our survival in today's competitive and greedy world.

And with that I thank you all for a very patient hearing. You would notice all these elements are well within the Indian capability and we can actually move along with the rest of the world or for that matter with the more advanced countries in the world and address our long term energy future.

Chairman

I think we have some time for questions and answers. I would request you to restrict yourself to one question so that others over here can also get the opportunity to do that. Second, please restrict your questions as far as possible to the topics which were covered, which is a pretty broad range of issues ranging from basic needs of our people to energy security, from nuclear proliferation to environment protection, from safety to economic viability of long term programmes. Please also keep the questions as brief as possible. And a mike will be brought to you so that you can be audible to everyone.

A participant

You mentioned that with AHWR reactors there is no chance of a meltdown. There is no core heating. So it means nothing like Fukushima can happen there, right? And then you said within ten years these might be commercially available.

Speaker

Well, AHWR should be there even earlier because I think this design is all ready for implementation.

A participant

Okay. I mean the only question then would be the capital required to put up all these plants. Technologically there should be no problem.

Speaker – That is right.

A participant

Respected Sir, what is expected of the Indo-US nuclear deal? How does it fit into our country's energy requirement as you have projected. For example, is it absolutely essential to mature or materialise such deals? How will it basically affect our energy requirements?

Speaker

I was almost expecting this question. The point is the following. We started with the three stage programme right in the beginning. The whole reason was that we are a uranium deficient country and we should be able to fully exploit our thorium resources. Going through the three stage programme means that you will have to deploy heavy water reactors followed by fast reactors followed by thorium reactors. With uranium that we have we could set up around 10,000MWe capacity which is nothing compared to the national needs. The question is how fast we are able to implement the three stage nuclear power development programme. Even after recognising that our implementation rate must improve, taking 10,000 MWe capacity to several hundred thousand megawatts can happen only on the basis of fast reactors. That being a matter of technology gestation period would be a rate limiting factor. Our first prototype commercial fast breeder reactor is just getting ready at Kalpakkam. Then there is the question of putting more fast reactors and only when we have installed a fairly large fast reactor capacity could we implement large scale deployment of thorium.

As far as technology development or preparing for the future is concerned, I think the country has done a lot. The energy needs of this country are however growing much faster and as economy grows the needs are also growing more rapidly. A time has come for nuclear energy to contribute substantially to these growing energy needs. That needs additional uranium from outside. And if we want to have access to additional uranium from outside, you have to get over the Nuclear Supplier Group's embargo and nothing in the world moves without United States. So that was the rationale for development of international civil nuclear co-operation.

Sooner the agreements with different countries are operationalised, the faster will be the growth of nuclear power capacity addition. Domestic nuclear power programme is any way going on independently. That also needs to be accelerated, but that is another matter.

A participant

What about the recent Japanese experiments of beaming energy by microwave which could open the door to energy catching stations in space that would then beam it down to earth. Is India thinking of that in view of its own satellite programme, space programme?

Speaker

There has been conceptual level work on that in India also. Dr. Kalam had talked about the self-breathing engine, a vehicle which could take components and build a solar station up in space and then beam that energy down through microwave. These are conceptual studies. Certainly we should watch for such developments.

A participant

Dr. Kakokdar is too modest. He has developed thorium based reactors. This is entirely original in the world and we have an abundance of thorium. Therefore we should congratulate him on this main contribution.

The second, unlike earlier times about 80% energy in agriculture is no longer animal or human labour, it is entirely by mechanisation and electrical power and therefore subsidy is given. It is going to be a serious problem. Now we are saying the power consumption should be reduced through better efficiency. Energy conservation will increase the availability of energy for other uses and therefore our economy will grow. We have to also look at the possibility of energy system running on ocean and what could we do with ocean waves. There are a number of possibilities but the politicians have to agree and that long term energy calculations have to be done. But that is another responsibility of Dr. Kakodkar.

Speaker

Thank you. I think that is an observation which everybody would agree.

A participant

I am Professor Abbi from IIT Delhi. In order to garner support for nuclear energy there is a need for informed public opinion. In view of the confidentiality attached to the atomic energy programme, there has been an information deficit in the public domain which not only made it difficult for debates for knowing about modern technology developments but also hampered the nuclear physics educational programmes in the country. Could you comment on these concerns.

Speaker

I do share the view that the public perception is important. With atomic energy, there is obviously a strategic connotation. So when somebody wants to know, for example, material balance, obviously there is a problem. So sensitive information related to the strategic programme is not shared in public domain. From national security considerations, there is obviously some part of atomic energy which is inaccessible to the public. But as far as nuclear power is concerned, I think the entire thing is open to public. Nuclear Power Corporation has to work like any other company under the Companies Act. Under the Companies Act there are some mandatory disclosures which are binding on NPCIL as well. They have become quite aggressive in terms of the public awareness campaigns. There are lots of public debates as well as discourses. But I agree with you, more needs to be done.

A participant

Thank you very much Sir for presenting us the overall concept of the development of nuclear energy in India with the thorium cycle. I think you pointed to the fact that the concepts have been there since the 1950s, you developed this out of the scarcity of the uranium availability within India and the concept as I said is with us since let's say half a century. And I think realistically at this point in time the limitations of this concept have become very obvious because the actual role out of nuclear energy in India is actually far less than the rollout of renewable energy, especially wind and solar right now. And I think particularly the wind energy sector has expanded several times that of the nuclear sector. I don't know what the exact production figures are. And even in the nuclear sector, the large nuclear power plants which are largely planned with imported technology, which as far as I understand are not a part of this integrated concept involving the breeder reactors, thorium cycle and so on. So I am wondering, is this concept that has been there in India over the last fifty years, is this really still in the same way relevant as the country saw it for decades. Isn't it actually that the realities of current power needs point to of course expansion of coal, as sad as that is, expansion of renewables, as good as that is, perhaps not fast enough, perhaps with its own difficulties and then even involving imported nuclear technology. But isn't the classical idea, how to develop the nuclear cycle including thorium in India, isn't it somehow stuck? That is my impression. How far is the Kalpakkam reactor actually ready, how far is the rollout of this entire concept at the current state?

Speaker

Well, that will require a little longer answer but I will give it. Before that, let me say that I think India's energy needs are such that we must make use of all energy sources. Although I was talking in the context of a time period several decades from now and the kind of expected resource position expected at that time, today coal is the main energy source for us and we must make full use to meet our energy needs. For that matter we also must make full use of any other available energy source because I think our development requires as much energy as we possibly can get. Let me say that upfront.

But having said that, let us recognise that today we have an installed nuclear generation capacity of around 5700 megawatts. This capacity is delivering electricity at 80-85% plus capacity factor. You compare with any other global benchmark and these power reactors are running at a capacity factor comparable or better. This is number one. I am also a champion of renewable energy. In fact I was first chairman of the Solar Energy Corporation. I accepted that because certainly solar energy is an important option. Wind, it has done much better. It is actually the leading renewable energy today. In order to compare nuclear with wind or solar, we need to recognise the intermittent nature of wind or solar energy. 5700 megawatt of nuclear power capacity is equivalent to five times as large a capacity in wind or solar. Both need to grow. The point I am talking about is that around 2050 - 2070 time frame if the entire supply will be based on renewable energy, I think there are serious issues. We have to look at renewable and nuclear together because there is no third option. Now let us look at what is happening in nuclear in that context. Today the domestic reactors which are under construction are of 700 megawatts capacity and there are 4 such units under advanced stage of construction. More such reactors are being planned. The Kalpakkam fast breeder reactor which you mentioned is around 95% complete. When completed, which should happen late this year or early next year, I would imagine that India would be operating the second largest commercial fast breeder reactor in the world.

And then of course there is already a plan, I showed you, there are two more fast breeder reactors in the pipeline. So while the capacity addition in fast reactors won't go as fast as thermal reactor capacity addition, but it would also grow. It is important that we reach a stage of maturity in this technology as early as possible. Presently however we need to depend on thermal reactor capacity addition for speedy nuclear capacity addition. This is where large imported power reactors running on imported uranium are necessary. I however do not agree with you that imported power reactor means no three stage programme. Because then you are in the same trap as countries like United States where you have to live with an unresolved spent fuel disposal problem. India right from day one has adopted the policy of recycle. And so I am sure there will be a time when Indian technology would have advanced enough to even reprocess the spent fuel arising from imported reactors under IAEA safeguards and recycle the fuel materials back in fast reactors. So while we have a domestic programme completely insulated from international controls because you can't do development when an inspector or a policeman is breathing down your neck, the technology so developed would also be applied to the spent fuel of imported origin following the three stage programme logic including the use of thorium at a later stage. So I think the two would go hand in hand.

A participant (Mr. D V Kapur)

The canvas is so vast that there could be many questions. I have one observation, one little doubt and one suggestion. You rightly mentioned in one table at an earlier stage about our consumption, it is linked to economic development indicators. We have about 900 may be a little more and China has today 4000. But it is important to recall is that not very long ago in late 70s, 1977 or so we were at par with China. And we failed in our power programme, plan after plan, we planned for 30,000 megawatts, we commissioned 15000 megawatts, sometimes 50%, sometimes less than 50%. Till all these forty years that has been the story. Had we been fulfilling according to plan, this 900 figure would have been about 2000, world of difference. That, purely in my own analysis, is failure of project management which doesn't exist in this country. I mean every politician when he comes to a conference he says our failures are execution but why execution failure. That is the project management. And unless, whether we go in for nuclear programme, this programme, that programme, in all cases, if that gap which is not being talked at all, is not fulfilled, not made up, we will not be able to achieve our required desired results.

Secondly, I fully agree with you the need for expanding solar programme. There is a lot of scope also. But let us not give the feeling that renewables will be able to totally solve the problem. Although you said that it requires a mix but there is a feeling as if that can solve total problems. And there my doubt is in case of solar, that is the land required. You see what is happening on the land law, the issue is prices of the land and solar requires a lot of land. We don't have deserts or Gujarat type of areas where land is of no value. They cannot become the power station for the whole country. Perhaps some solution may have to be found through the rural side by making a hybrid of without battery solar plus hydrogen base co-generation and those can be small scale and they will also not require too much of land. But those are innovative type of things which we have to evolve for our type of requirement, they are not being discussed.

And the third where I said suggestion, you at one stage said also that you are still the champion of coal. What to do? There is no choice. If we have to develop, we have got to for some decades depend a lot on coal. Coal, the problem is, which is under criticism, is about pollution, carbon. Now carbon capturing from boilers which is theoretically possible and it has been achieved also, that requires a lot of research - that research is not being advocated. And if that is done, if you capture carbon from the boiler effluent, that can be converted to methane. It not only makes the boiler pollution free, it solves your hydrocarbon problem also. So that is an area of research which must be advocated. I don't know world over, but there are some places where it is happening.

Speaker

Thank you. I share what you said but let me add my own take on this. First, with respect to solar, I think you can have a lot of variants and I think all of them are important. Rooftop in urban areas, micro-grid or the hybrids of the kind you mentioned in villages, they are all important. But when you are talking about for example, the current target of hundred thousand megawatts by 2020, and I don't know how that would be possible. But let us say that you have that target, if you want to achieve such large targets, you have to necessarily think in terms of large power blocks. That obviously as you said will require large tracts of land. I think it is unthinkable that you can set up such plants close to human settlements or for that matter close to wherever there is a human economic activity, agriculture or whatever. India is the second densest country in the world. Thus I think you need to focus on land which is available in our deserts or land which is available in our mountains and that too mountains where there is no environment conflict. If there is a lush green mountain, obviously you can't do that. You thus need to identify the so-called barren uncultivable land that is away from a potential, the human and land use conflict, not just today but also long term in future. So I think we need to necessarily focus on such lands and that necessarily means a completely different challenge. At the simplest level that challenge is you have all generation at one place and use far away and you have unidirectional flow of power and it has its own problems. But I think we need to address that problem. The second issue is with regard to storage. This is where a significant solar thermal component should help since cost of thermal storage is much lower. We should of course minimise consumptive use of water which is likely to be in short supply in such areas. All this means development of appropriate solutions under Indian conditions that need to be pushed aggressively.

With respect to carbon capture, in the figure that I projected, I in fact had shown, one route is to recycle carbon-di-oxide. This should be a matter of intense research. This is happening elsewhere in the world. We need to mobilise our research resources and infrastructure to intensify domestic research in this area.

A participant

I would like to come back to the question of solar energy. Years ago when one said, the uninformed or little informed question, India has so much sunshine, why is there not more solar energy? The answer used to be, that is very expensive to develop and to produce. Could you perhaps comment a little bit on the economic aspects of these sources of energy. Secondly, could you perhaps also comment on the pollution aspect of both nuclear and solar energy because we have already a pollution problem in Delhi, so how will this develop?

Speaker

Well, on the cost, solar energy is very close to grid parity today. There is of course at this moment around 30% subsidy but it is coming down and I think it is very close to grid parity. But you are absolutely right. If you had asked this question maybe ten years ago, I think the answer was solar is expensive, very expensive. So that answer was right at that time but today things are different. But as I said, today solar is cheaper not because we are manufacturing at that low cost, it is because it is available in international market at that price. The market price today for solar energy is actually artificial in my view. One need not be under the illusion that these prices will remain low forever. Even so, I think it will be reasonable to say that solar energy is pretty close to grid parity.

On nuclear, nuclear is already competitive with the grid for may be thirty/forty years in India. I am not saying that this is so all over the world. It is country specific, but in India, it is competitive. We have been making heavy water reactors that are competing well. However when one is talking about imported power plants, imported power plants where a good part of manufacture has taken place abroad, I am not too sure whether those will be competitive. The country has enough manufacturing base and, there must be 100% domestic manufacture for the power plants of foreign technology. And if you do that they would also be commercially competitive.

With respect to pollution, both solar and nuclear are very clean energy sources and for that matter if you don't have pollution, from the same solar installation, you would actually produce more energy. The solar installations at times suffer because a lot of sun rays are scattered because of particulate pollution. Nuclear and solar both are free from particulates, carbon-di-oxide and oxides of sulphur and nitrogen. Nuclear means everybody will talk about radiation, I will argue that it is negligible, it is lower than the variation in natural radiation from place to place where we have lived for generations with no harmful effect. In case of solar if you are talking about photovoltaics, particularly the silicon based photovoltaic, production of silicon has an environmental angle for which technological solutions exist. Thus both solar and nuclear are clean energy sources.

Chairman

Thank you, Dr Kakodkar. We bring this question and answer session to a close now. Now I will request Mr. Anand Singh Bawa, the honorary secretary, to announce the scholarship awards.

The scholarship awards were instituted when Ambassador Lambah took the initiative to institute these. He has done this consistently wherever he has gone, whether it was setting up a chair on India studies in UC Berkeley in the '80s and elsewhere. It is of great benefit to us.

Mr. Anand Singh Bawa

Dr. Kakodkar, friends, in 2007 as many of you know the Federation of Indo-German Societies in India and Hanns-Seidel-Stiftung had instituted a scholarship programme for German speaking research scholars to spend six months to a year at a German university to facilitate and advance the M.Phil and PhD studies. The programme was started with researchers from the Centre of German Studies at Jawaharlal Nehru University and the Department of Germanic and Romance Studies at the University of Delhi. The award includes return tickets to the university town in Germany, medical insurance and a monthly stipend. Six months for M.Phils and one year for PhD scholars. Further the Hanns-Seidel-Stiftung invites these scholars to various programmes to interact with scholars from other parts of the world who are also conducting their research in Germany. This year we have three scholars, M.Phil and PhD who will be going to Germany under the programme. May I now announce their names.

M.Phil. We have two scholars, first one we announce is Suman Singh. She is a scholar from the Department of Germanic and Romance Studies at University of Delhi under the supervision of Professor Shaswati Majumdar. She will conduct her research at the Bergische University of Wuppertal. The topic for her M.Phil dissertation is – Narrative Strategies and Social Criticism in German Horror Fiction. Her work will focus on contemporary texts but will necessarily have to engage with the historical development of the genre.

The second M.Phil scholarship is awarded to Satya Prakash, a scholar at the Department of Germanic and Romance Studies at the University of Delhi under the supervision of Dr. Jyoti Sabharwal. He also will conduct his research also at the Bergische University of Wuppertal. The topic for his M.Phil dissertation is – The City as a centre of social change and continuity and Zunge Zeigen and Kalikatha via Bypass. Zunge Zeigen was written by Gunter Grass between 1987 and 1998, during his stay in Calcutta. Kalikatha via Bypass was written by Alka Saraogi, in Hindi, in 2000. Both have presented their perception of the city of Calcutta, however, from different perspectives. The emphasis of the research is on the representation of Calcutta in the context of social change and continuity to the two literary works.

We have one PhD scholar, Sunil Sharma. He is a scholar at the Centre of German Studies, Jawaharlal Nehru University under the supervision of Mr. Ram Chandra Gupta. He will conduct his research at Ludwig Maximilians-University of Munich. The title of his research is "Conceptual metaphors in German and Hindi phraseologisms", which falls under the subject of cognitive linguistics, cognitive science and everyday psychology. Earlier he has been a recipient of our scholarship as an M.Phil scholar.

Chairman

Thank you. Once again thanks to Dr. Kakodkar for his very erudite but at the same time eloquent lecture on complex and inter-linked subjects in terms which can be understood by a lay man. I thank him once again for his illuminating address and to all of you for your attendance and participation. But before he leaves I would like to present to Dr. Kakodkar some volumes of our earlier publications from the society. I now bring this meeting to a close. Thank you.