Volume 1 • Issue 1 • March 2006

Energy Security Insights

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Nuclear power and energy security: Indian context

This issue of *Energy Security Insights* is timely in its coverage of nuclear developments in relation to India. President George W Bush has just departed from India after having inked a nuclear deal of historic significance to the future of energy in the world. Admittedly, the US Congress has yet to ratify this agreement but the likelihood of it having a positive outcome is very high for all the energy and environment arguments put forward in this issue. As is to be expected with a large, visible, and sensitive matter such as the nuclear cooperation agreement and its ramifications, there have been a number of negative and/or cautionary voices raised both in the US and India, and indeed in the rest of the world!

Undoubtedly, these notes of caution should be heeded to but the energy imperative of India is currently so critical that structuring of the deal can, and should, be viewed for its contributions to bringing the masses of India – one-sixth of the world population – out of their energy poverty situation. This essential driver of economic growth would make its impact not only on India but, through the ripple effects of globalization, maintain a momentum of climate-friendly global development. India today has 57% of its population unserved by electricity, and 90% of the cooking needs in the rural India are met through biomass. To sustain its targeted economic growth of 8%–10% till 2030, India would need a total electricity-generating capacity of 500–600 GW (gigawatts) as against its current capacity of 135 GW. With limits on the use of coal, both for domestic capacity as well as environmental reasons, and the uncertainties associated with the hydrocarbon market, increased access to nuclear capacity would definitely provide some relief.

However, India would be short-sighted to trade-off other energy options as a result of nuclear access. India needs to continue to work with the hydrocarbon-rich West Asian countries in a pact of mutually beneficial development that would necessarily be based on, but will have to go beyond, energy trade! As a natural partner for countries of this region, such cooperation would also go a long way in promoting stability in the region, providing an outlet to India's technical expertise to facilitate diversification of growth opportunities for the region, and much-needed investments into the country.

Leena Srivastava
TERI

Nuclear power: the new global interest

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It was 60 years ago that Dr Homi Bhabha, father of India's nuclear programme, stated that electricity from nuclear power plants would be produced at prices 'too cheap to meter'. For reasons that one can identify in hindsight, not only have we fallen short in producing substantial quantities of nuclear power but even the costs of energy produced have turned out to be much higher than originally anticipated. Improvements in project management and developments in technological capabilities in this country have certainly helped in bringing down the per unit costs of nuclear power capacity and the energy produced, particularly with the recent plants that have been constructed. In other countries, the experience has been mixed. In case of the US, technical problems, concerns about safety, and cost overruns have stalled the expansion of nuclear power capacity over the past three decades. In case of France, nuclear power has grown substantially to meet that country's needs for electricity and secure energy supply. Recent developments in the global energy market have, however, sparked a worldwide interest in nuclear energy, particularly over the past two years or so.

Two major factors have created this growing interest in nuclear energy in the recent years. First, growing concerns arising out of scientific evidence on climate change and its likely adverse impacts are pushing the developed countries to evaluate nuclear energy options far more seriously than they have done in the recent past. Some find the nuclear energy option as the only viable means to reduce the greenhouse gas emissions from power generation even during the first commitment period of the Kyoto Protocol, that is, by 2012. Another important reason has been the improved record of safety and overall performance of nuclear power technology round the world. However, the most important factor impelling countries towards greater use of nuclear energy, I believe, is the issue of energy security. With oil prices hovering in the region of 70 dollars per barrel and worldwide demand for oil increasing, concerns have risen to a new height on the stability of oil prices in future.

The global oil market is very sensitive to small changes even in perceptions about the future, leading to substantial increases in prices, which translate into major economic problems for oil importing countries. In recent weeks, problems in Nigeria, which raise some questions about the stability of oil exports from that nation, as well as current problems between the IAEA (International Atomic Energy Agency) with the Iranian government have raised further questions about supply of oil from that nation as well. These raise worries about exports at levels agreed upon by the OPEC (Organisation of Petroleum Exporting Countries) and resultant constraints in meeting increases in demand in future. Against this background, nuclear energy now appears an attractive option for a large number of countries. China's plans for a major increase in nuclear power generation provide a major source of assurance to the international community, particularly because globally, China has become the second-largest importer of oil after the US. An increase in nuclear power generation in China also provides some relief to those who are concerned about increased carbon dioxide emissions from larger quantities of coal that China would be compelled to burn for power generation to feed an ever-expanding economy in the years ahead. The status of nuclear plants under construction in different countries of the world is provided in Table 1.

Table 1 Nuclear plants under construction

Country	*Number*
China (planned)	30
India	8
Russia	4
China (current)	2
Ukraine	2
Taiwan	2
Argentina	1
Finland	1
Iran	1
Japan	1
Romania	1

Source International Atomic Energy Agency

If the agreement between president George W Bush of the US and prime minister Manmohan Singh of India comes into existence, India may see a significant surge in nuclear-power-generating capacity and a substantial increase in nuclear power generation in the coming years. As shown in Figure 1, India and China are currently producing a very small percentage of nuclear power in the total power that they generate.

Of course, a movement towards greater dependence on nuclear power must also carry with it questions on a secure supply of energy in future. Nuclear fuels are still scarce and not readily accessible to several countries of the world. There is, therefore, understandably, a scramble for resources in different parts of the globe so that those nations that are setting up large nuclear-generating capacities are in a position to access adequate supplies of nuclear fuels in future. However, in this regard, India has to contend with restrictions placed by the NSG (Nuclear Suppliers Group). Thus, the Bush–Manmohan Singh agreement acquires great importance not only for the supply of nuclear fuels but also for the future of nuclear energy developments in the country. Should India receive de facto recognition as a nuclear weapon state and should restrictions on the supply of nuclear fuels and equipment be removed, the country could become an attractive market for nuclear-power-generating equipment for countries such as the US, Japan, and several members of the European Union.

If the objective of the countries seeking major expansion in nuclear power is to reduce dependence on oil imports, then several structural shifts in their economic systems would become essential. For instance, given the reality that the bulk of oil imports are meant to supply road transport systems, a shift of this activity towards greater use of nuclear energy would pre-suppose a shift to electric traction, accompanied by a commensurate increase in the nuclear energy generated. Investments in nuclear energy per unit are significantly higher than in conventional electricity supply capacity because nuclear power requires capital costs per unit, which is significantly higher than the conventional coal-based power plants and marginally higher than investments in the IGCC (Integrated Gasification Combined Cycle) plants. The IEA (International Energy Agency) estimates capital cost per kilowatt of 800–1300 dollars for conventional coal, 1300–1600 dollars for coal gasification, and 1700–2150 dollars for nuclear power stations.

With growing constraints in mining and transportation of coal in India as well as prospects of higher coal prices, both internationally and domestically in future, a country such as India would find it attractive to substantially expand its nuclear power capacity. At the same time, coal-fired stations are likely to continue as the major form of new capacity for power generation. The IEA estimates coal-fired capacity additions during the period 2001–30 to exceed 1400 GW (gigawatts) worldwide. They estimate that half of these new plants will be established in China and India. Nuclear plant construction was estimated at 150 GW, concentrated largely in the Asian countries. However, these estimates are based on a 2003 publication by the IEA as part of their *World Energy Outlook*. Since then, increase in oil prices as well as geopolitical changes, particularly in the Middle East, have necessitated a second look at nuclear power possibilities. Natural-gas-based power plants, which have a substantially lower capital cost, would also look less attractive now, given the likely increase in natural gas prices worldwide. It is significant that the Dabhol power plant, which has been shut for five years now, is running into serious problems with the fuel supply because original prices of LNG (liquefied natural gas) to be supplied to the plant have now increased significantly since the

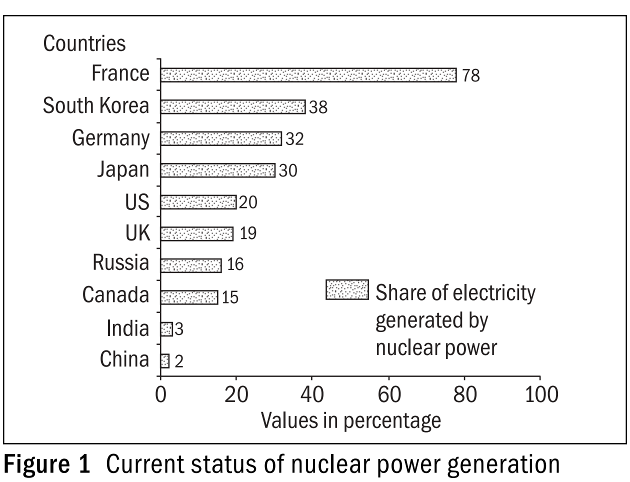

Figure 1 Current status of nuclear power generation
Source International Atomic Energy Agency

original agreement collapsed, and new arrangements are having to be put in place by the current owners of the plant who are sourcing new LNG supplies.

While technological choices and the source of energy used can be diversified through deliberate policy and proper pricing, these efforts are likely to remain unsuccessful unless major reforms are carried out in the power sector of the country. Essentially, any capital invested, which requires legitimate returns from power generation, would run into serious constraints if the electric utility industry remains financially weak and is unable to pay for the power purchased. The government has limits to the amount of investment it can sustain as a service to be provided without adequate financial returns. If the private sector or even public sector investments are to be attracted for nuclear or any other form of power generation, revenues will have to be ensured to pay for the power supplied. Hence, despite international agreements and infusion of private sector capital, nuclear power in this country can only grow to provide energy security if it is accompanied by substantial and rapid reforms in the power sector. Energy security, therefore, will grow only at a pace that is created by strong political steps to reform and restructure the power industry, which has remained largely stagnant in the country for over five decades. Energy security requires managed dependence on oil imports, but even more importantly, purposeful domestic reforms.

Securing our emerging energy needs: what nuclear energy can do*

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Present Indian scenario

In spite of being among the top five electricity-producing countries in the world, India has a very low per capita electricity consumption (about one-sixth of the world average). Only 55% of the households have access to electricity, and about one fifth of the villages are yet to be electrified. To meet the energy requirements of the economy, the power policy aims at ensuring power availability for all by 2012, electrification of all villages by 2009, and access to electricity for all households by 2012. These objectives would require capacity addition of 100 GW (gigawatts) and total investments of about 180 billion dollars till 2012. Long-term planning will involve ensuring availability of fuels, systems (for generation and distribution), and markets.

According to a study by Goldman Sachs, India has the potential to show fastest growth over the next 30–50 years and could achieve a growth rate higher than five per cent over the next 30 years if infrastructure development proceeds successfully. Given this, requirements in the electricity sector have been projected by the DAE (Department of Atomic Energy) as follows:

- Per capita electricity generation is expected to rise from 613 kWh (kilowatt-hours) in 2002 to about 5305 kWh in 2052 (Figure 1 [a]).
- Growth of electricity has been projected to be about 6.3% between 2002 and 2022, dropping to 4.9% between 2022 and 2032, 4.6% in the next decade, and 3.9% between 2042 and 2052.
- Installed power capacity is projected to grow from 138.73 GWe (gigawatt electric) in 2002 to 1344 GWe in 2052 (Figure 1 [b]).

India's energy resource base and role of nuclear energy

India will continue to be heavily dependent on coal and it will remain as the most important energy source as far as electricity-generating

*Summary of a talk given on 25 November 2005 at TERI, New Delhi.

potential is concerned. With technological progress and improvements on the commercial deployment front, nuclear energy can play an important role in the electricity sector. The potential for electricity generation from all available resources other than nuclear energy and coal is very meagre (Table 1). Nuclear

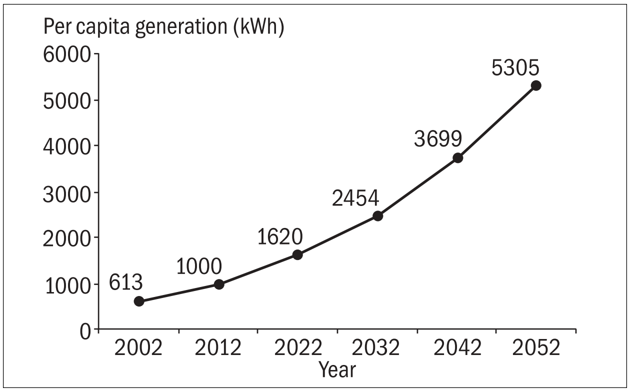

Figure 1 [a] Projected per capita electricity generation

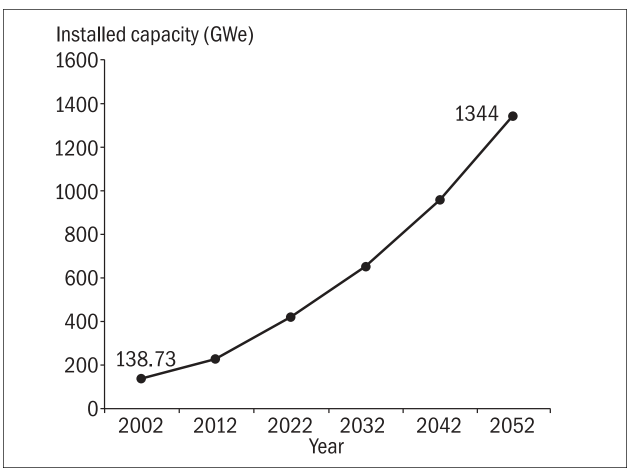

Figure 1 [b] Projected installed power capacity
Source Department of Atomic Energy

energy, particularly from the FBR (fast-breeder reactors) and thorium reactors, has a huge potential to augment this base. Nuclear power, by the DAE estimates, can contribute to about 20% share in the total electricity generation system by 2052 (Figure 2).

India's nuclear power programme

India has followed a three-stage nuclear power programme, consisting of development of the following stages:
Stage 1 PHWRs (pressurized heavy water reactors),
Stage 2 FBRs, and
Stage 3 thorium-based reactors.

Table 1 India's energy resource base

Energy resource	*Amount*	*Electricity potential*[a] (GWe-year)
Coal	53.3 BT	10 660
Hydrocarbon	12 BT[b]	5 833
Uranium metal	61 000 T	
▪ In PHWR		328
▪ In fast breeders		42 231
Thorium-metal (in breeders)	225 000 T	155 502
Hydro	150 GWe	69 per year
Non-conventional renewable energy	100 GWe	33 per year

BT – billion tonnes; T – tonnes; GWe – gigawatt electric
PHWR – pressurized heavy water reactors
Note [a]Assuming all resources are used for generating electricity.
[b]Currently known resources (including coal-bed methane) are 3 BT. However, Ministry of Petroleum and Natural gas has set a target of locating at least 12 BT as per *Hydrocarbon Vision 2025*.

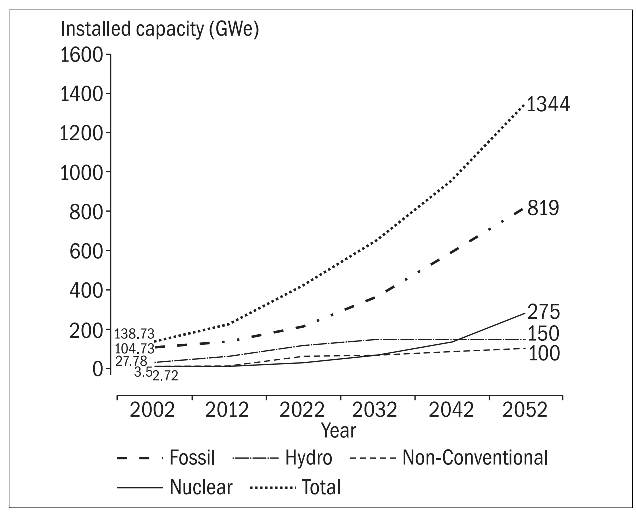

Figure 2 Projected installed power capacity by fuel
Source Department of Atomic Energy

India is endowed with modest uranium reserves, which can support 10 000 MWe (megawatt electric) of PHWR capacities. PHWR is the most efficient way of using natural uranium. India's first 540 MWe PHWR unit operating at Tarapur is doing remarkably well.

India is following the path of first concentrating on the FBRs along with the PHWRs and then going on to develop thorium-based reactors. Following this path will allow India to have fairly large electricity generation from domestic nuclear fuels. In order to proceed on to the next stage of the nuclear power programme, certain basic objectives need to be achieved. These include completing the 500 MWe PFBR (prototype fast-breeder reactor) now under construction at Kalpakkam, closing the fuel cycle with fast reactors and mastering all aspects of the fuel cycle technology, and incorporating feedback from the operating experience of PFBR in the future fast-breeder reactors.

There are various technologies that are being researched upon and would help India in meeting its nuclear energy needs. These include the following.

- AHWR (advanced heavy water reactor), which would derive two-thirds of its energy from thorium. Development of the AHWR has given India an opportunity to incorporate several passive safety features in the design of this reactor; for example, heat removal by natural circulation. These features are now being incorporated by other countries in the fourth-generation systems. It would also help India in gaining experience in large-scale handling of thorium.
- The ADS (accelerator-driven systems), which would support growth with thorium systems and require long-term R&D (research and development) efforts, is one area that has attracted several international groups to collaborate with India to use vast expert manpower resources.
- Steady-state super-conducting Tokamak has given India the technological capability to participate in ITER.[1]

Changing approach to nuclear energy technology in international arena

There has been a shift in the approach to nuclear energy in the industrialized world today. Until recently, open fuel cycle was a preferred option among most countries. However, closed fuel cycles are now being preferred, as they are more efficient from the point of view of energy sustainability and credible waste management. These are also more environmentally friendly as waste can be recycled back for use. There is now a convergence on the need to move towards closed fuel cycle as is obvious from various programmes initiated, such as INPRO (International Project on Innovative Nuclear Reactors and Fuel Cycles), GEN IV (Generation IV), and MNA (Multilateral Nuclear Approaches), etc. All along, India has based its strategies on closed fuel cycle and this should continue to be a formal part of India's national policy.

Investment in nuclear energy sector

With regard to investment in the nuclear energy sector, the initial R&D investment should be led by the government. The approach should be to follow the RD3 philosophy, that is, research, development, demonstration, and deployment. After the prototype demonstration, the first commercial unit can be financed on a 1:1 debt–equity basis and subsequently, one could move to 2:1 debt–equity ratio.

Costs of nuclear energy

Nuclear power stations have been set up at a capital cost of approximately 50 million rupees/MWe. The unit cost, inclusive of the cost of decommissioning, is about 2.50 rupees/unit for a freshly constructed nuclear power station and 2.65 rupees/unit for the Tarapur Power Station. Nuclear energy is far more competitive for power generation than the other energy sources. Capital cost of nuclear power plants is high but fuelling cost is low and so it is less subject to inflationary pressures. Moreover, nuclear fuel, being of high calorific value, can be easily transported and stored.

Fuel supply situation

On the fuel supply situation, reactors now operating and under construction will take the nuclear installed capacity to 7280 MWe. Installed capacity of about 20 000 MWe is expected to be achieved by 2020 through PHWRs, FBRs, and eight LWRs (light water reactors). Fuel supply for the PHWRs and FBRs will be based on the domestic sources but for

[1] To start with, ITER was an abbreviation for International Thermonuclear Experimental Reactor. However, it has now been decided to drop the full form and just retain the name ITER, which in Latin means 'the way'.

LWRs, fuel has to be imported. So far, fuel supply has been tied up for the two LWRs under construction at Kalpakkam. For the remaining reactors, so far, no tie-ups have been made.

Policy directions for future

Policy directions and strategies, which India should follow to meet its emerging nuclear energy needs, should include the following.

- The 540 MWe PHWR design should be scaled up to 700 MWe.
- Uranium exploration efforts should be stepped up.
- Metal-alloy-based fuels should be developed for FBR by 2020.
- The 500 MWe FBR should be completed on schedule and four similar units should be constructed before 2020.
- Research in the area of ADS and fusion systems should be stepped up to speedily exploit vast thorium resources.
- High temperature reactors and technologies should be developed to produce, store, transport, and use hydrogen.

Nuclear energy in India: key factors for growth

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Energy security is an important issue for a large country like India. It can only be provided by a policy that supports a diversified portfolio of energy sources. Nuclear energy is riding a wave of interest internationally, particularly in India, due to a combination of factors, including the rising prices of fossil fuels, limits to continued availability of fossil fuels, climate change issues, and other environmental concerns. It is in this context that we briefly discuss various nuclear technologies and fuels used in the nuclear energy programme in India.

We argue in this paper that growth of nuclear energy in India in the years ahead will be determined by several factors, including

- success in locating additional sources of uranium,
- success achieved in domestic R&D (research and development),
- opening up of civil nuclear cooperation with other countries, and
- success in the ITER (International Thermonuclear Experimental Reactor) project.

India's future energy mix and place of nuclear energy

The two key policy issues in planning for secure energy futures are (i) adopting a scenario-based approach and (ii) adopting an integrated energy framework and strategy. While the scenario-based approach can help identify all possible trajectories, an integrated energy framework can help in delineating the steps to be taken for development of various technology options. With a view to define the role to be played by the nuclear energy in the coming decades, the DAE (Department of Atomic Energy) developed a scenario about the possible growth of energy requirements in the country in the coming five decades and looked at all sources of energy to examine as to how the energy requirements could be met (Grover and Chandra 2004). The conclusion is that energy requirements of the country are so large that whatever maximum could be produced based on nuclear energy should be the target. Growth scenarios for the period up to 2031/32 have been made by the Planning Commission (Planning Commission 2005a) as well and their draft report is available on Internet.

The Planning Commission report gives two growth scenarios for power capacity till 2031/32, and projections by the DAE lie in between these two scenarios. With regard to nuclear, Planning Commission report says

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Nuclear, on the other hand, offers India the most potent means to long-term security. Promoting nuclear through its three-stage development process described in the main report is critical if India hopes to tap vast thorium resource and become truly energy independent beyond 2050 (Planning Commission 2005b).

Thus, considering the likely growth scenario and examining all sources of energy, one cannot escape the conclusion that nuclear energy has a very important role to play in India's growth. This role becomes all the more important if one considers the fact that nuclear power plants emit no greenhouse gases. However, despite the realization of importance of nuclear energy, there are certain constraints imposed by the domestic nuclear fuel resources. Considering these constraints, it is clear that fossil fuels will continue to have a dominant share for the next five decades and India will perhaps be consuming more coal than any other country in a few decades from now (Srinivasan, Grover, and Bhardwaj 2005). Therefore, it is desirable that all steps be undertaken to ensure that the nuclear sector plays a greater role in country's growth. This will entail making a detailed assessment of various issues involved and taking appropriate policy measures to address them. In the next section, we discuss nuclear technology choices in India, given both the concerns of fuel security and credible waste management.

Some fundamentals

Nuclear fission

To start with, it is necessary to understand certain fundamentals about nuclear technology. There are two different nuclear reactions viz., fission and fusion, which can be used to produce energy. So far, only nuclear fission has been used for production of energy on a commercial scale: certain heavy isotopes split into lighter nuclei and neutrons when bombarded with neutrons. During the process of splitting or fission, energy is also released, which is used to produce electricity. Uranium-235 is the only naturally occurring isotope that is fissile and can be used in nuclear reactors to produce energy by fusion. There are other naturally occurring nuclei that can be converted into fissile isotopes and then used for producing energy by the process of nuclear fission. Two fertile isotopes found in nature are uranium-238 and thorium-232 that can be converted to corresponding fissile isotopes plutonium-239 and uranium-233. The process of conversion of fertile isotopes into fissile isotopes is known as breeding. Neutrons produced by a fission reaction have high kinetic energy. In thermal reactors, they are first slowed down by a moderator and then cause fission by colliding with a fissile isotope. Fast reactors are designed in a way that the process of fission takes place when neutrons are at a high speed. The process of breeding occurs more efficiently in fast reactor systems.

Natural uranium consists of two isotopes viz., uranium-235 and uranium-238. As indicated above, while uranium-235 is a fissile material, uranium-238 is not. Almost all reactors now in commercial operation are thermal reactors and generate energy from fission of uranium-235, which constitutes only 0.7% of the natural uranium. Broadly, present-day commercial reactors can be classified into two categories: The first category uses natural uranium with heavy water moderator and the PHWRs (pressurized heavy water reactors) fall in this category. The second category uses uranium as fuel, which has been enriched in the isotope uranium-235 to about four per cent. Such reactors are called LWRs (light water reactors). In both cases, the net result is that less than one per cent of the total energy potential of the uranium ore is used. When uranium fuel is irradiated in the reactor, a fraction of uranium-238 gets converted to plutonium-239, a fissile material, which can be used as fuel. In an open cycle system, no attempt is made to increase the fraction of uranium-238 converted to plutonium-239, or to recover and recycle this plutonium. If one could follow an approach where most of the uranium-238 is converted to plutonium-239 and is used for energy generation, then the presently available uranium can provide energy for the entire world for several centuries. The predicted nuclear renaissance cannot be sustained by the continued use of open cycle concept. Only breeder reactors based on a closed cycle approach can theoretically use the full energy potential of uranium ore by multiple recycling and are being studied by all countries having interest in nuclear energy. The closed cycle approach, by which fertile material recovered from the spent fuel is recycled, also significantly reduces the radioactive waste per unit of energy produced. It also facilitates recovery of certain useful isotopes, such as cesium-137 and stronitium-90, from the fission products.

Besides uranium, another heavy metal occurring in nature is thorium-232. It cannot be used to fuel nuclear reactors as such and breeding is necessary to convert fertile thorium-232 into fissile uranium-233. Strategies based on closed fuel cycle are necessary, both for energy sustainability and for credible waste management (see Figure 1 for details).

Nuclear fusion

Another phenomenon that can be utilized to produce energy is fusion, which powers the sun and stars, and is potentially an environmentally responsible and intrinsically safe source of essentially limitless energy. Fusion is a process in which light atoms fuse together to produce a heavier element along with the release of huge amounts of energy. Very high temperatures, above 100 million degrees Celsius, are required for fusion reaction to take place for energy production. Gas raised to such high temperatures becomes 'plasma' wherein electrons are completely separated from the atomic nuclei (ions). Fusion reaction between two isotopes of hydrogen – D (deuterium) and T(tritium) – provides the basis for development of a first-generation fusion reactor as other fusion reactions require even higher temperatures. Each D–T fusion reaction produces an alpha particle (that is, helium) and a high-energy neutron. Alpha particles maintain plasma at the desired high temperature by re-depositing energy in it. Neutrons escape from plasma and are slowed down in a 'blanket' surrounding the plasma. Within this blanket, lithium is transformed into tritium, which is used as fuel, and the heat generated by neutrons can be used to produce steam and thereby electricity.

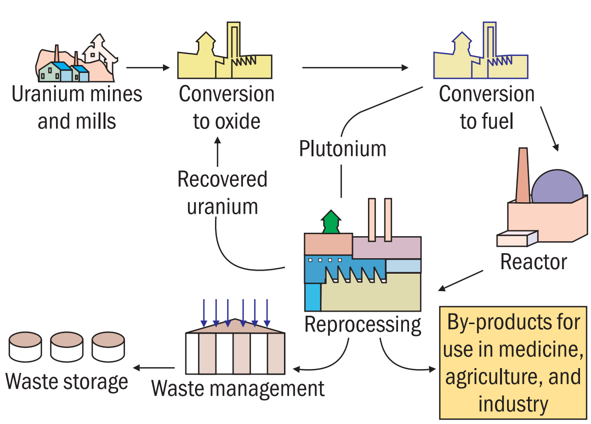

Figure 1 Indian nuclear fuel cycle

Planning for nuclear technology choices in India

India has modest reserves of uranium and plentiful reserves of thorium. While other developed nations realize the importance of breeder reactors and are pursuing R&D to realize similar objectives, India has planned its three-stage programme, which is based on pursuing a closed fuel cycle right at the inception of its nuclear programme in view of poor availability of uranium resources in the country and international embargo on civil nuclear commerce.

The nuclear power technology plan of the DAE is given in Table 1. It includes possible import of six reactors, in addition to the two at Kudankulam of 1000 MWe (megawatt electric) capacity each before 2020.

Looking beyond this plan, one can make the following three comments about the nuclear energy growth in India.

- Near-term growth will be determined by the success in locating additional uranium resources in the country based on intensification of efforts to explore uranium as planned by the DAE and opening up of international civil nuclear commerce with India.
- Medium-term growth will come from FBRs (fast-breeder reactors) and adoption of closed fuel cycle.
- Long-term growth will depend on the development of technologies for deployment of thorium and fusion technology.

Table 1 Nuclear power programme till 2020

Reactor type and capacities	*Capacity* (MWe)	*Cumulative capacity* (MWe)
Fifteen reactors at six sites under operation at Tarapur, Rawatbhata Kalpakkam, Narora, Kakrapar, and Kaiga	3 360	3 360
Five PHWRs under construction at Tarapur (1 x 540 MWe) Kaiga (2 x 220 MWe), and Rawatbhata (2 x 220 MWe)	1 420	4 780
Two LWRs under construction at Kudankulam (2 x 1000 MWe)	2 000	6 780
PFBR under construction at Kalpakkam	500	7 280
Projects planned till 2020: PHWRs (8 x 700 MWe), FBRs (4 x 500 MWe) LWRs (6 x 1000 MWe), AHWR (1 x 300 MWe)	13 900	21 180
Total by 2020		**21 180 MWe**

AHWR – advanced heavy water reactor; FBR – fast-breeder reactor; LWR – light water reactor; MWe – megawatt electric; PFBR – prototype fast-breeder reactor; PHWR – pressurized heavy water reactor

While growth aspects resulting from locating additional deposits of uranium in the country is an obvious fact, the remaining issues will be examined one by one.

Breeders and closed fuel cycle

In early days of nuclear energy when uranium prices were high, there was a worldwide interest in FBRs and several demonstration reactors were built. These include Dounreay DFR[1] (UK, 15 MWe, shut down in 1977), Phenix (France, 250 MWe), BN-350 (Kazakhstan, 90 MWe shut down in 1999), Dounreay PFR (UK, 250 MWe, shut down in 1994), Monju (Japan, 280 MWe), and FBTR (India, 40 MWt). Another demonstration CEFR (China, 25 MWe) is under construction. Full-scale industrial reactors include BN-600 (Russia, 600 MWe), Superphenix (France, 1200 MWe, shut down in 1998), PFBR (India, 500 MWe, under construction), and BN-800 (Russia, 800 MWe, under construction). Interest in fast reactors declined due to perceived proliferation concerns and availability of uranium at competitive prices. However, rising uranium prices and increasing energy demand have rekindled interest in FBRs with a closed fuel cycle.

Generation IV International Forum,[2] a US-led multi-nation initiative, has selected six reactor concepts for detailed study and these include concepts based on closed fuel cycle and fast reactors (Anonymous 2003). The selections are gas-cooled fast reactor, lead-cooled fast reactor, molten salt reactor, sodium-cooled fast reactor, supercritical water-cooled reactor (two options: open thermal and closed fast), and very-high-temperature gas-cooled reactor (open cycle). Thus, majority of the concepts are based on fast reactors and closed fuel cycle.

It is interesting to note that the US abandoned fuel reprocessing in the 1970s, considering its high cost and perceived

[1] DFR – Dounreay fast reactor, BN – stands for fast neutrons in the Russian language; PFR – prototype fast reactor; FBTR – fast-breeder test reactor; CEFR – Chinese experimental fast reactor; PFBR – prototype fast breeder-reactor.

[2] Design of nuclear reactors has evolved since the 1950s through evolutionary changes to improve safety and economics. Initial demonstration reactors could be classified as first-generation reactors. Based on operating experience with first-generation reactors, large-scale deployment of nuclear reactors took place and all these reactors are still in operation. These could be classified as second-generation reactors. Following accidents at Three-mile Island and Chernobyl, several evolutionary changes were made in the design of reactors to further improve safety. The EPR (European pressurized water reactor) now being built by the French company Framatome in Finland belongs to this category and is being called as the third-generation reactor. Other reactors such as the ABWR (advanced boiling water reactors) also belong to this category. Reactors now under design aim to make further significant improvements in safety by introducing passive safety features and are being called as the fourth-generation systems. This classification is not as yet very well accepted.

proliferation concerns. However, the US has just announced the Global Nuclear Energy Partnership (NucNet 2006), which has seven elements, one of them being 'DAE developing and deploying new nuclear recycling technologies', thereby reversing its policy on reprocessing.

A study carried out by the French utility EdF (Electricité de France) envisages industrial deployment of a first series of fast reactors by about 2040 (Carre 2005). The Russian viewpoint (Anonymous 2005) is that 'mass-scale construction of fast reactors shall not be delayed any longer' as reserves of both 'cheap and costly uranium will be exhausted between 2030 and 2050'. They advocate finishing development work for the next generation of fast reactors within a decade and start batch production of fast reactors by 2020. Nations are thus deciding the time frame for deployment of fast reactors depending upon their energy needs and uranium availability. India planned to go in for fast reactors in the second stage of its three-stage programme in view of modest domestic reserves of uranium. Though this was visualized five decades back (Bhabha 1954), its logic has become all the more important now in view of the burgeoning demand for energy. Grover and Chandra (2004) estimate that in about five decades from now, electricity requirements will be an order of magnitude higher than the present requirements, and known domestic fossil fuel resources would have been exhausted unless supplemented by new discoveries or breakthrough technologies.

Fast reactors can make a significant contribution to India's energy requirements but the rate of increase in fast reactor installed capacity has to follow a certain growth path as plutonium-239, the fuel for fast reactors, gets generated in nuclear reactors. Thus, the rate of new fast reactor capacity addition has to be determined by the rate at which plutonium can be bred. Breeding depends upon fast reactor design and chemical form of plutonium fuel. Metallic fuel gives much higher breeding ratio and the DAE is pursuing research in this direction. While the PFBR now under construction will use plutonium in oxide form, it is planned to use plutonium metal as fuel in fast reactors to be constructed after 2020. Considering India's energy requirements and the current state of research on this topic in the world, India has to pursue independent R&D and protect the intellectual property so developed.

Thorium technologies

The DAE has already irradiated thorium bundles in the PHWRs and set up a facility for reprocessing thorium. It has designed an AHWR (advanced heavy water reactor), which aims to derive two-thirds of its power from thorium. Implementation of the AHWR project and development of associated fuel cycle facilities will provide industrial-scale experience in the handling of thorium. There are certain other possibilities for thorium utilization, which include the ADS (accelerator-driven systems). ADS have two main components: an accelerator and a reactor. A reactor system using only thorium as fuel cannot become critical as thorium is not a fissile material. To make it critical, an external supply of neutrons is needed. A 'spallation' source can provide an external source of neutrons to achieve criticality in an otherwise sub-critical system. Protons, when accelerated to high energy in an accelerator and made to collide with a target of high atomic number element (such as lead, tungsten, uranium, etc.), cause detachment of a large number of neutrons from these nuclides in a process called spallation. Development of appropriate proton accelerators is the first step towards development of the ADS and efforts in this direction have already been launched worldwide as well as in India (Anonymous 2001).

Molten salt reactor first studied in the 1960s led to a proposal to set up 1 GWe (gigawatt electric) MSBR (molten salt breeder reactor) and molten salt reactors are one of the six systems retained by the *Generation IV International Forum* (David 2005). This could be another system to enable thorium utilization, but needs to be studied in detail before one can arrive at any conclusion.

Fusion

Based on the experiments conducted in various laboratories (Smith, Llewellyn, Todd, *et al.* 2005) around the world, scientists have convincingly concluded that fusion could be mastered to produce power. These experiments include the JET (Joint European Torus) of the EU and the TFTR (Tokamak Fusion Test Reactor) of the US. The ITER is the next step in fusion research towards achieving fusion-based power plant. The ITER programme was initiated in 1988 in collaboration with four parties: the US, the EU, Japan, and the Russian Federation (then USSR) under the auspices of the IAEA (International Atomic Energy Agency). The physics and engineering design of ITER was completed in 2001 and subsequently, three more parties viz., China, South Korea, and India have joined the ITER consortium. The design goal of ITER is to produce at least 500 MW of fusion power, with a plasma heating input of about 50 MW. The ITER will be located at Cadarache in south of France and aims to develop a plant for demonstrating generation of electricity based on fusion. Fusion technology is expected to make large-scale contribution in the second half of this century.

India joined the ITER as a full partner in December 2005 and this would involve contributing about nine per cent of the machine cost. Being a full partner, India will have access to this complex technology as and when it is ready for commercial deployment. In view of the potential of this technology, and the sizeable ongoing programme in fusion research at the Institute for Plasma Research, Gandhinagar, the decision of the Government of India to join the ITER programme is well advised.

It is difficult to predict the exact timeframe for deployment of the ADS and fusion reactors, but it is likely that both the technologies will be in deployment in the second half of this century. In any case, considering the large-scale energy needs of India and the world, R&D has to be pursued to deploy both the technologies.

Concluding remarks

Thus, to conclude, growth of nuclear energy in India in the years to come will be determined by several factors, including

- success in locating additional uranium resources in the country based on intensification of efforts to explore uranium as planned by the DAE;
- success achieved in domestic R&D
  - with regard to developing fast reactors with advanced fuels (having short doubling time, high burn up) and associated fuel cycle technologies to ensure multiple recycling of fuel,
  - development of technologies for utilization of thorium,
- opening up of civil nuclear cooperation with India; and
- success in the ITER project.

While opening up of the civil nuclear cooperation can lead to immediate gains, long-term outlook will be determined by ongoing R&D in the country. Policy framework has to seek a balance between short- , medium- , and long-term interests. A country of the size of India cannot plan its economy on the basis of large-scale import of energy resources or energy technology. While trade in energy technologies and fuel resources is welcome, indigenous development of energy technologies based on fuel resources available domestically or those which can be procured at competitive prices should be a priority for us.

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Nuclear power: no route to energy security

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After decades of poor performance, atomic energy seems to have received a second wind, especially after the joint statement of 18 July 2005 by the Indian prime minister Manmohan Singh and the US president George W Bush. Many pro-nuclear advocates now aver that a large-scale expansion of nuclear power is the only way to meet our electricity needs and ensure energy security. An examination of the history of atomic energy in India shows, however, that this is not a new claim. Since its inception, the DAE (Department of Atomic Energy) has been promoting nuclear power as the answer to our energy needs. As per the DAE's predictions, by 2000, there should have been 43 500 MW of nuclear-generation capacity in the country. But only 3310 MW (megawatts) has been realized, which is less than three per cent of the installed electricity generation capacity. Even by the DAE's projections, it will not become a significant fraction of India's electricity for the next few decades. And, as we argue below, nuclear power does not enhance our energy security.

Energy security connotes the capacity to satisfy the energy needs of all sections of society without excessively compromising safety, the environment, or the well-being of future generations. This implies that electricity generation technologies should be economical, not run the risk of catastrophic accidents, be minimally polluting, and not leave long-lasting harmful legacies—nuclear power does not meet these criteria.

Economic and environmental costs

The DAE claims that nuclear power would be cheap and its costs compare very favourably with electricity from coal-fired thermal power plants. However, a comparison of the costs of the two using the standard discounted cash-flow methodology shows that nuclear power is competitive only for low discount rates (see Figure 1); for a wide range of realistic parameters, nuclear power is significantly more expensive (Ramana, D'Sa, and Reddy 2005). The discount rate is a measure of the value of capital, and given the multiple demands on capital for infrastructural projects, including for electricity generation, very low discount rates are not realistic. A larger proportion of nuclear

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capacity, therefore, implies that poorer sections of society cannot afford electricity, at least without greater subsidies, which would be detrimental to energy security.

Results shown in Figure 1 are based on costs of generating electricity at the Kaiga atomic power station and the RTPS (Raichur Thermal Power Station) VII: both base load plants of similar size and vintage in Karnataka. Coal for the RTPS VII is assumed to come from mines 1400 kilometres away. The largest component of the cost of producing electricity at nuclear reactors is the capital cost of the reactor, which includes construction cost (18 160 million rupees for Kaiga I and II, and 27 270 million rupees for Kaiga III and IV), and the costs of the initial loading of uranium fuel and heavy water used in reactor. The corresponding capital cost in case of the RTPS VII is 4910 million rupees (all of the capital costs mentioned do not include the interest during construction).

This economic comparison is largely based on assumptions favourable to nuclear power. In particular, cost of coal-generated electricity internalizes the cost of disposal of fly ash in an environmentally responsible fashion, but nuclear costs do not include cost of dealing with radioactive wastes. Despite more than half a century of intensive research, no one has found a way to render these wastes non-radioactive. This unsolved problem has caused many countries to reconsider the nuclear option. The DAE treats spent nuclear fuel by reprocessing it and segregating the waste into different categories on the basis of their radioactivity. Reprocessing also allows separation of plutonium, which, with further treatment, can be used as fuel in breeder reactors. Reprocessing, however, is expensive: as per our estimates, the cost of reprocessing each kilogram of spent fuel from the DAE's heavy water reactors is 20 000–30 000 rupees. The Nuclear Power Corporation does not include reprocessing costs in its tariff estimates; if included, it would increase the unit cost by 0.40 to 0.60 rupee.

Apart from the economic cost, because wastes stay radioactive for tens of thousands of years, they pose a potential health and environmental hazard to the future generations. This is clearly iniquitous as these generations would bear the consequences while we use the electricity generated by these reactors.

Finally, reactors are not the only source of pollution. Large quantities of radioactive and other toxic material are released into the biosphere at different stages of the nuclear fuel cycle. Thus, the nuclear fuel cycle is polluting, albeit in a way different from coal power.

Safety

Nuclear power also poses a risk to energy security because it is susceptible to catastrophic accidents. Chernobyl is the best-known instance of such a disaster. It resulted in several thousand deaths and contamination of tens of thousands of km^2 (square kilometres) of land with radioactive elements like cesium-137. Agriculture across large parts of Ukraine and Belarus had to be suspended, over a hundred thousand people were relocated, and the economy of Belarus was devastated. Such accidents can happen in other (non-reactor) facilities too. In 1957, a tank containing radioactive wastes from the Mayak reprocessing plant in the erstwhile Soviet Union exploded

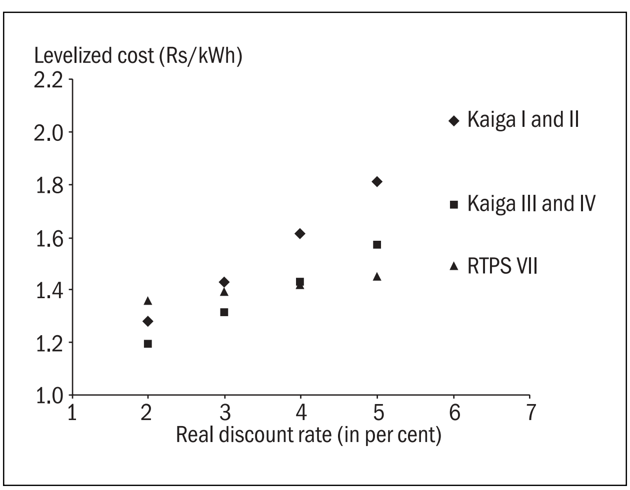

Figure 1 Levelized cost (the bare generation cost, which does not include other components of electricity tariff like interest payments and transmission and distribution charges) of Kaiga I & II (operating reactors), Kaiga III & IV (reactors under construction; projected costs), and Reichur Thermal Power Station VII (operating thermal plant) as a function of real discount rate[1]

[1]A measure of the value of capital after taking out the effects of inflation.

and contaminated 20 000 km^2 of land. India, still a largely agriculture-dependent economy, can simply not afford the risk of such disasters.

It is often stated that safety issues have been adequately addressed after the Chernobyl accident. However, basic features of nuclear reactors remain the same. It is a complex technology, involving large quantities of radioactive materials where events can spin out of control in a very short time. In studying the safety of nuclear reactors and other hazardous technologies, sociologists and organization theorists have come to the pessimistic conclusion that serious accidents are inevitable with such complex high-technology systems (Perrow 1984; Sagan 1993). The character of these systems makes accidents a 'normal' part of their operation, regardless of the intent of their operators and other authorities. In such technologies, many major accidents have seemingly insignificant origins. Because of the complexities involved, all possible accident modes cannot be predicted and operator errors are comprehensible only in the hindsight. Adding redundant safety mechanisms only increases the complexity of the system, allowing for unexpected interactions between subsystems and increasing new accident modes. All this means that it is not possible to ensure that reactors and other nuclear facilities will not have major accidents.

There is an experiential basis for concern about such accidents within India. Practically, all nuclear reactors and other facilities associated with the nuclear fuel cycle operated by the DAE have had accidents of varying severity (Chanda 1999; Rethinaraj 1999). A few examples are the unexplained power surge at the Kakrapar reactor in 2004, the 1993 fire at Narora, and the collapse of the containment at Kaiga in 1994. Because of the reasons mentioned in the earlier paragraph, many of these accidents could well have become the basis for a major radioactive release.

A further source of concern is that the AERB (Atomic Energy Regulatory Board), which is supposed to oversee safe operation of all civilian nuclear facilities, is not independent of the DAE. Further, as the former chairman of the AERB has observed, 'The AERB has very few qualified staff of its own, and about 95% of the technical personnel in AERB safety committees are officials of the DAE whose services are made available on a case-to-case basis for conducting reviews of their own installations. The perception is that such dependency could be easily exploited by the DAE management to influence the AERB's evaluations and decisions' (Gopalakrishnan 2002).

Uranium shortage and dependence on imports

The growth of nuclear capacity is contingent on the availability of fuel for reactors. Most of the nuclear reactors of DAE are fuelled using uranium from the Jaduguda region of Jharkand. These require over 400 tonnes of uranium annually. The current uranium production from Jaduguda has been estimated at less than 300 tonnes a year. The DAE has been continuing operations by using stockpiled uranium, which is likely to be exhausted by 2007.

Given this domestic resource crunch, the DAE will soon have to depend on imported uranium to run its reactors. This is one of the primary motivations for the Indo–US agreement. As an official stated in an interview on 26 July 2005 to the BBC, 'The truth is we were desperate. We have nuclear fuel to last only till the end of 2006. If this agreement had not come through, we might have as well closed down our nuclear reactors and by extension, our nuclear programme.' Just as power generation from natural gas and oil is dependent on importing these fuels, electricity from nuclear reactors will become increasingly import-dependent. Imports of uranium and other nuclear materials like heavy water have been subject to political considerations. The US, for example, refused to supply enriched uranium fuel for the Tarapur I and II reactors, following the 1974 nuclear test and the Nuclear Non-Proliferation Act passed by the US Congress in 1978. Therefore, if nuclear power is to expand significantly, electricity production could be subject to disruption by external events.

The alternative to importing uranium is to rely on breeder reactors fuelled by plutonium or uranium-233 derived from thorium. However, despite 50 years of ambitious plans, the DAE is yet to build a single industrial-scale breeder reactor. If and when they are built, because of greater safety requirements, they will likely be more expensive to build and operate than reactors so far constructed by the DAE. They will thus be capital-intensive, fuelled by materials produced through expensive reprocessing, and have higher maintenance costs, making electricity from these reactors very costly.

Poor economics and safety concerns have caused many western countries to abandon their breeder programmes. Even countries like France and Japan, where governments have long supported breeder programmes, are reconsidering their strategy. In France, a high level official commission examined the future of reprocessing (necessary for construction of breeder reactors), and found it more expensive than other options (Charpin, Benjamin, and Pellat 2000). Japan has not restarted the Monju breeder reactor, which was shut down in 1995 after a major sodium leak and a resultant fire; no new ones are under construction.

Conclusion

Nuclear establishment in India has long promised much; however, in spite of unstinted government support, delivered little. The DAE budgets have historically been high, at the cost of promoting other, more sustainable sources of power. In 2002/03, for example, the DAE was allocated 33 516.9 million rupees, dwarfing in comparison the 4735.6 million rupees allocated to the MNES (Ministry of Non-conventional Energy Sources), in charge of developing solar, wind, small hydro, and biomass-based power. Nevertheless, installed capacity of these sources was 4800 MW (as compared to 3310 MW of nuclear energy). While their contribution to actual electricity generated would be smaller because these are intermittent sources of power, they have much lower maintenance costs. Further, exploitation of most of these sources started in earnest only recently and there is ample scope for improvement.

Increased investment in renewable sources of energy is clearly desirable. Owing to the increased research and development investments and cumulative operational capacity, capital costs of several RETs (renewable energy technologies) have been declining. This trend is likely to continue because unlike mature technologies like these pertaining to coal and nuclear power, RET can improve considerably. These technologies are also amenable to the decentralized, community-based production and cause much less environmental damage than fossil fuels and nuclear energy. An increased reliance on the RETs and improvements in energy efficiency offer a basis for a robust energy strategy.

In light of the modest performance of nuclear power, in addition to the associated high costs and environmental and safety hazards, India should reconsider the nuclear option as it does not ensure true energy security.

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Access to nuclear technologies and materials under the Nuclear Non-proliferation Treaty and Nuclear Suppliers Group

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Introduction

In this energy-constrained world, it is often the politics and not the economics that defines access to energy resources. Growing energy demand of the Asian countries, and in particular, countries where conventional fuel choices are inadequate, are prompting them to look for newer energy options and supply sources, including nuclear energy. To attain the economic levels of western countries, and considering the nature of world oil politics, governments of many developing countries believe that nuclear energy could possibly become an indigenous source of power, which would enable their economies to develop rapidly and more securely, and usher in a new era of prosperity.

Development of nuclear energy in the 1960s and thereafter, and in particular, development of nuclear weapons, brought out the real danger that unrestricted and uncontrolled nuclear programme could have in the world. To avoid such a nightmare, in the 1960s and much later in the 1970s, the then nuclear-weapon countries decided to agree on the terms and conditions of access to nuclear technology and materials by other countries in the form of the nuclear NPT (Non-proliferation Treaty) and NSG (Nuclear Suppliers Group). This paper critically evaluates these two treaties in light of constraints imposed on access to technology and fuel choices.

The Nuclear Non-proliferation Treaty

Background

The NPT is second only to the United Nations Charter in the number of states that are party to it. It was signed in 1968 and entered into force in 1970. The treaty provided in Article X for a conference to be convened 25 years after its entry into force to decide whether the treaty should continue in force indefinitely, or be extended for an additional fixed period/periods. At the *NPT Review and Extension Conference* in May 1995, state parties to the treaty agreed without a vote on the treaty's indefinite extension, and decided that review conferences should continue to be held every five years.

One-hundred-and-eighty-eight states are party to the NPT; only India, Pakistan, and Israel are outside the treaty regime. Adherence to the treaty by 188 states, including five NWS (nuclear-weapon states), renders the treaty the most widely adhered to multilateral disarmament agreement. Since its entry into force, NPT has been the cornerstone of the global nuclear non-proliferation regime. The treaty is the only security agreement that permits two classes of members: states acknowledged to possess nuclear weapons and committed to negotiate their elimination, and states barred from acquiring them. As a disarmament and global cooperation mechanism, the NPT is a landmark international treaty whose purpose is to prevent the spread of nuclear weapons and weapon technology, to promote cooperation in the peaceful uses of nuclear energy, and to further the goal of achieving nuclear disarmament and general and complete disarmament.

The state-parties under the treaty are classified in to following two categories.

- NWS consisting of the United States, Russia, China, France, and the United Kingdom
- NNWS (non-nuclear-weapon states)

The basic objective of the treaty is to prevent nuclear proliferation. Classifications of countries are meant to eliminate nuclear weapons in a time-bound manner. This is done by persuading (1) the

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existing NWS to disarm, (2) the NNWS states to refrain from acquiring nuclear weapons, and (3) providing access to technologies and materials to the NNWS for peaceful use under the IAEA (International Atomic Energy Agency) safeguards.

Most important to the NPT is the concession of the NNWS to refrain from acquiring nuclear weapons and in exchange, the NWS agree to make progress on nuclear disarmament and provide unrestricted access to nuclear energy for non-military uses.[1] The treaty establishes a safeguard system under the responsibility of the IAEA to further the goal of non-proliferation and as a confidence-building measure between state parties.[2] Safeguards are used to verify compliance with the treaty through inspections conducted by the IAEA.[3] Safeguards do not apply to the NWS. Article IX defines an NWS as one that has manufactured and exploded a nuclear weapon or other nuclear explosive devices prior to 1 January 1967, that is, the United States, the Soviet Union (now Russia), the United Kingdom, (these three from the beginning), and France and China (became NWS two decades later). The set of five NWS parties to the NPT are the same set of permanent members of the Security Council. For India, Israel, and Pakistan, all known to or suspected to possess nuclear weapons, joining the treaty as the NNWS would require that they dismantle their nuclear weapons and place their nuclear materials under international safeguards.[4] South Africa followed this path to accession in 1991. The NPT thus seeks to inhibit the spread of nuclear weapons by promoting peaceful uses of nuclear energy.

Access to nuclear technology and resources

The NWS and NNWS under the NPT regime are obliged not to acquire nuclear weapons or to transfer nuclear weapons and other nuclear explosive devices or their technologies to any NNWS. Article I of the treaty provides that the NWS agree not to help the NNWS develop or acquire nuclear weapons, and under A.II, the NNWS permanently forswear the pursuit of such weapons.

Article III provides that the NNWS parties undertake not to acquire or produce nuclear weapons, nuclear explosive devices, or divert acquired technology for the weapon programme. They are also required to accept safeguards to detect the diversion of nuclear material for peaceful purposes such as power generation to the production of nuclear weapons or other nuclear explosive devices. This article establishes safeguards for transfer of fissionable materials between the NWS and NNWS. This must be done in accordance with an individual safeguard agreement between each NNWS party and the IAEA.[5] To verify these commitments and ensure that nuclear materials are not being diverted for weapon purposes, Article III tasks the IAEA with the inspection and verification of NNWS' nuclear facilities. Under this agreement, all nuclear material in peaceful civil facility under the jurisdiction of the state must be declared to the IAEA whose inspectors have routine access to the facility for periodic monitoring and inspection. States transferring nuclear technology, material, or equipment that could be of some relevance in a weapon development programme make the acceptance of safeguards a condition for such transfer. For important installations, most suppliers impose an even more stringent condition of 'full-scope' or 'comprehensive safeguards' in that the recipient country accepts the IAEA safeguards over all its relevant nuclear activities. Safeguards are, thus, in most situations, a verification process imposed by the nuclear technology suppliers under the NSG guidelines. They require a guarantee that their exports will not contribute to nuclear weapon development.

[1] NPT Articles 2, 4, and 6

[2] Article 3

[3] Ibid

[4] India, Israel, and Pakistan that have never signed and ratified NPT (Non-proliferation Treaty), could thus technically be classified into a third category of states not party to the NPT.

[5] India has consented for such International Atomic Energy Agency safeguard inspection for only six of its reactors – RAPs-1 and 2, TAPs-1 and 2, and Kudamkulam 1 and 2 – as they have imported nuclear facilities.

As far as rights of the NNWS under the NPT regime are concerned, Article IV (treaty provision expanded in the Box 1) acknowledges the 'inalienable right' of the NNWS to research, develop, and use nuclear energy for non-weapon purposes. It also supports the 'fullest possible exchange' of such nuclear-related information and technology between the NWS and NNWS. Article V, now effectively obsolete, permits the NNWS access to the NWS research and development on the benefits of nuclear explosions conducted for peaceful purposes. Article V of the NPT, concerning peaceful nuclear explosions, has been overtaken by Article VIII of the CTBT (Comprehensive Nuclear Test Ban Treaty), which prohibits such explosions, as the perceived utility of peaceful nuclear explosions has diminished over time, and with the new CTBT regime in place, relevance of this clause has lost its value. It is now the CTBT that places restrictions on all nuclear explosions. The five NWS are signatories of the CTBT.

Thus, Article IV acknowledges state parties to provide for transfer of information and technology to assist countries in their civilian nuclear programmes under the Article III safeguards and makes the IAEA the main multilateral channel for expansion of application of nuclear energy for peaceful purposes. It is under these provisions that India, though not party to the NPT, but a volunteer to accept the IAEA safeguards and verification of its declared civilian nuclear facilities, could access nuclear technologies and fuel from the United States. The NPT itself does not bar signatories from providing civilian nuclear energy to non-signatories. But the American Congress went beyond the NPT by enacting Nuclear Non-proliferation Act of 1978 (NNPA, PL 95-242), which imposed tough new requirements for the US nuclear exports to NNWS, which involved full-scope safeguards and termination of exports if such a state detonates a nuclear explosive device or engages in activities related to acquiring or manufacturing nuclear weapons, among other things. To make the Indo–US nuclear cooperation work, the relevant export licensing requirements of the US need to be amended as also the NSG guidelines regarding nuclear export controls (detailed explanation in the next section).

Nuclear Suppliers Group

Background

The NPT granted NNWS access to nuclear material and technology for peaceful purposes as long as they committed to not developing nuclear weapons. Recognizing that materials and technologies used in peaceful nuclear programmes could be used to develop weapons as well, several NPT nuclear supplier states sought to determine in relation to the treaty, what specific equipment and materials could be shared with NNWS and under what conditions. These supplier states formed the Zangger Committee in 1971, to reach common understandings on how to implement Article

Box 1 NPT **Article IV**

1 Nothing in this treaty shall be interpreted as affecting the 'inalienable right' of all parties to the treaty to develop research, production, and use of nuclear energy for peaceful purposes without discrimination and in conformity with Articles I and II of this treaty.

2 All parties to the treaty undertake to facilitate, and have the right to participate in the fullest possible exchange of equipment, materials, and scientific and technological information for peaceful uses of nuclear energy. Parties to the treaty in a position to do so shall also cooperate in contributing alone or together with the other states or international organizations to the further development of applications of nuclear energy for peaceful purposes, especially in territories of non-nuclear-weapon states party to the treaty, with due consideration for the needs of the developing areas of the world.

III.2[6] of the NPT. This is in view to facilitate interpretation of the obligations arising from that article to institute the IAEA safeguards before being allowed imports of certain items that could be directly used to pursue nuclear weapons. These items were collectively referred to as the 'trigger list.'[7] The trigger list governs export, direct or indirect, of those items to the NNWS that are not party to the NPT. The Zangger understandings established three conditions for supply: a non-explosive-use assurance, an IAEA safeguards requirement, and a re-transfer provision that requires the receiving state to apply the same conditions when re-exporting these items.[8]

In response to India's explosion of a nuclear device in 1974, several Zangger Committee members joined with France, which was not a member of the NPT at that time, to establish in 1975 the NSG to further regulate nuclear-related exports. The NSG is a group of nuclear supplier countries, which seeks to contribute to non-proliferation of nuclear weapons through implementation of guidelines for nuclear exports and nuclear-related exports. Each participating government implements the NSG guidelines in accordance with its national laws and practices. Decisions on export applications are taken at the national level, in accordance with the national export-licensing requirements. The NSG added technologies for control to the original Zangger Committee's 'trigger list'. This became Part I of the NSG Guidelines. In addition, NSG members agreed to apply their trade restrictions to all states, not just those outside the NPT.

NSG comprises 44 nuclear supplier states,[9] including China, Russia, and the United States that have voluntarily agreed to coordinate their export controls governing transfers of civilian nuclear material and nuclear-related equipment and technology to NNWS.

Operating guidelines

The NSG Guidelines first published in 1978 comprise two parts, each of which was created in response to a significant proliferation event (see footnotes 10 and 11 below) that highlighted shortcomings in the then existing export control systems (as detailed in Box 2). Both Part 1 and 2 of the NSG Guidelines aim to ensure that nuclear trade for peaceful purposes does not contribute to the proliferation of nuclear weapons or explosive devices while not hindering such trade.

The Part I Guidelines govern exports of nuclear materials and equipment, which require the application of IAEA safeguards at the recipient facility. The Part 1 nuclear control list is the 'trigger list' because export of such items 'triggers' the requirement for the IAEA safeguards.[10]

The Part II Guidelines govern export of nuclear-related dual-use equipment and material. The NSG Guidelines also control technology related to both nuclear and nuclear-related dual-use exports. Part II basically identifies dual-use goods, which are non-nuclear items with legitimate civilian applications that can also be used to develop weapons.[11]

The NSG Guidelines introduce a degree of order and predictability among suppliers, and

[6] Article III.2 of the NPT states that
Each state party to the treaty undertakes not to provide
(a) source or special fissionable material or
(b) equipment or material, especially designed or prepared for processing, use, or production of special fissionable material to any non-nuclear-weapon state for peaceful purposes, unless the source or special fissionable material shall be subject to the safeguards required by this Article.'

[7] IAEA document INFCIRC/209.

[8] International Atomic Energy Agency, Communication of 10 May 2005 received from the Government of Sweden on behalf of participating governments of the Nuclear Suppliers Group, Information Circular, INFCIRC/539/Rev.3 (30 May 2005).

[9] Argentina, Australia, Austria, Belarus, Belgium, Brazil, Bulgaria, Canada, China, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Japan, Kazakhstan, Latvia, Lithuania, Luxembourg, Malta, Netherlands, New Zealand, Norway, Poland, Portugal, Romania, Russia, Slovakia, Slovenia, South Africa, South Korea, Spain, Sweden, Switzerland, Turkey, Ukraine, the United Kingdom, and the United States.

[10] Part I responded to India's diversion of nuclear imports for supposedly peaceful purposes to conduct a nuclear explosion in 1974 and is published in 1978.

[11] NSG members adopted Part II in 1992 after discovering how close Iraq came to realizing its nuclear weapon ambitions by illicitly employing dual-use imports in a covert nuclear weapon programme before the 1991 Persian Gulf War.

Box 2 NSG Guidelines

Guidelines for nuclear transfers (INFCIRC/254, Part I)
The first set of NSG Guidelines governs the export of items that are especially designed or prepared for nuclear use. These include (i) nuclear material, (ii) nuclear reactors and equipment therefore, (iii) non-nuclear material for reactors, (iv) plant and equipment for reprocessing, enrichment, and conversion of nuclear material and for fuel fabrication and heavy water production; and (v) technology associated with each of the above items.

Guidelines for transfers of nuclear-related dual-use equipment, materials, software and related technology (INFCIRC/254, Part II)
The second set of NSG Guidelines governs the export of nuclear-related dual-use items and technologies, that is, items that can make a major contribution to an unsafeguarded nuclear fuel cycle or nuclear explosive activity, but which have non-nuclear uses as well, for example in industry.

harmonize standards and interpretations of suppliers' undertakings with the aim of ensuring that the normal process commercial competition does not lead to outcomes that further proliferate nuclear weapons. Consultations among NSG participants are also designed to ensure that any possible impediments to the international nuclear trade and cooperation are kept to a minimum. Thus, to be eligible for importing Part I items from an NSG member, states must have comprehensive IAEA safeguards, covering all their nuclear activities and facilities. Thus, for the transfer of Part I items to an NNWS, the controls require full-scope safeguards of the IAEA on all nuclear activities of the recipient country. In case of Part II goods, the IAEA safeguards are only required for specific nuclear activity or facility that the import is destined for.

Access to nuclear materials under the Nuclear Suppliers Group

As described earlier, NSG participants implement NSG Guidelines in accordance with its national laws and practices. At the national level, decisions on export applications are made in accordance with the national export-licensing requirements. This is the prerogative and right of all states for all export decisions in any field of commercial activity and is also in line with the text of Article III.2 of the NPT, which refers to 'each state party', and thus emphasizes the sovereign obligation of any party to the treaty to exercise proper export controls. In context of access to the US technologies by India, this restriction along with application of the US domestic law[12] restrains the US from doing nuclear trade and exchange till date with a NNWS that is not party to the NPT. The NSG countries meet regularly to exchange information on issues of nuclear proliferation concern and how these impact the national export control policy and practice. However, it is important to remember that NSG does not have a mechanism for limiting supply or for coordination of marketing arrangements, and does not take decisions on licence applications as a group. Again, to make the Indo–US nuclear cooperation work, the US government will need to amend its domestic law and also take the NSG members into confidence before any physical transfer takes place.

In 1992, the NSG added full-scope IAEA safeguards as a condition of nuclear supply to the NNWS, and established nuclear-related dual-use guidelines and a control list. In 1995, the NSG added controls on nuclear technology for items on the trigger list. The requirement that no transfer of trigger list items to the NNWS takes place unless the recipient state has full-scope safeguards on all its nuclear activities, is particularly pertinent because it establishes a uniform standard of supply that is based on IAEA's international verification system. In 1997, IAEA strengthened its safeguards system to improve the agency's ability to exercise its verification role. Under the NSG operating procedure, contacts and briefings take place with non-participating countries. This is in addition to the outreach activities conducted with potential NSG participants. NSG's dialogue with non-NSG

[12] Nuclear Non-proliferation Act of 1978

member-countries is part of its 'outreach' programme that seeks to engage in consultations with non-member countries on domestic export controls on nuclear goods, resulting in proliferation concerns. The visit of the NSG team to India in 2004 and again in April 2005 is a part of this process.

The flexibility is that states can choose to adhere to the guidelines without being obliged to participate in the NSG.[13] At the May 2004 plenary meeting, NSG members adopted a 'catch-all' mechanism, which authorizes members to block any export suspected to be destined to a nuclear weapon programme even if export does not appear on one of the control lists.

The NSG regime is voluntary. NSG members may ultimately export what they wish. For instance, Russia transferred nuclear fuel to India in January 2001 even though 32 of the 34 NSG members earlier declared that the shipment would contradict Russia's NSG commitments. Members are supposed to report their export denials to each other so that potential proliferators cannot approach several suppliers with the same request and get different responses. NSG states are expected to refrain from making exports identical or similar to those denied by other members. All NSG decisions are made by consensus.

India–US agreement on civilian nuclear cooperation under the Non-proliferation Treaty and Nuclear Suppliers Group

India is neither a party to the NPT nor a member of the NSG unlike the United States. In fact, as discussed above, NSG is the successor to the Zangger Committee, and was initiated at the behest of the United States, immediately after India's nuclear explosion in 1974. As per the present NPT provisions, India could belong to the NNWS. NPT never visualized a country with nuclear weapon being out of treaty mechanism. India being both, that is, non-recognized nuclear weapon state and not being a party to NPT falls outside the NPT framework and could be classified differently. This will be the classification which the India-US civil nuclear cooperation will bestow India into the world civil nuclear energy cooperation. Definition of an NWS for the purpose of NSG is the same as that in the NPT; namely, that which has exploded a nuclear device before 1 January 1967. From NSG's perspective, therefore, India, Pakistan, and Israel are the NNWS.

The NPT and NSG both, without full-scope safeguards, bar state parties to transfer technology and material to non-state parties. With regard to India, except Tarapur and Rajasthan reactors, and related facilities that are under facility-specific safeguards, India's entire nuclear-fuel cycle has been indigenous, autonomous, and free from foreign inspections and thus has not accepted the full IAEA safeguards. It is in this context that India and the US have agreed to collaborate in civilian uses of nuclear energy. What does the India–US joint strategic agreement mean and how does the civilian nuclear cooperation work in context of the present international regime?

As per the text of the statement,[14] the US would

- work to achieve full civil nuclear energy cooperation with India as it realizes its goals of promoting nuclear power and achieving energy security,
- seek agreement from Congress to adjust the US laws and policies,
- work with friends and allies to adjust international regimes to enable full civil nuclear energy cooperation and trade with India, including but not limited to expeditious consideration of fuel supplies for safeguarded nuclear reactors at Tarapur, and
- encourage its partners to also consider India's request expeditiously to join ITER (International Thermonuclear Experimental Reactor) and a willingness to contribute.[15]

[13] NSG (Nuclear Suppliers Group) gives status of 'unilateral NSG adherents'. Both Israel on 1 July 2004 and Pakistan on 23 September 2004 have made their export laws in conformity with the NSG Guidelines and have communicated their domestic export laws to the IAEA: the IAEA circular INFCIRC/632 and INFCIRC/636, respectively. This is the first step towards the NSG's recognition of their non-proliferation credentials.

[14] Text of India–US joint statement (July 2005) available at http://www.dae.gov.in/jtstmt.htm.

[15] In December 2005, India became full party to ITER Project. See, Joint Press Release *Twelfth ITER Negotiation Meeting*, Jeju, Korea, 6 December 2005. Details available at <http://www.iter.org/N_12_Joint_Press_Release.htm>.

And in turn, India would[16]

- identify and separate civilian and military nuclear facilities and programmes in a phased manner and file a declaration regarding its civilian facilities with the IAEA,
- take a decision to place voluntarily its civilian nuclear facilities under the IAEA safeguards,
- sign and adhere to an additional protocol with respect to the civilian nuclear facilities,
- continue India's unilateral moratorium on nuclear testing,
- work with the US for conclusion of a multilateral FMCT (Fissile Material Cut off Treaty),
- refrain from transfer of enrichment and reprocessing technologies to states that do not have them and support international efforts to limit their spread,
- ensure that necessary steps have been undertaken to secure nuclear materials and technology through comprehensive export control legislation as well as through harmonization and adherence to the MTCR (Missile Technology Control Regime) and the NSG Guidelines.

The US recognition of India as a 'responsible state with advanced nuclear technologies' has given India the status of a de facto NWS outside the NPT. This along with the civil nuclear cooperation agreement with binding commitments on both the parties, will increase the integration of India into the global nuclear game. India, on its part, agreed 'to assume the same responsibilities and practices and acquire the same benefits and advantages of other leading countries with advanced nuclear technologies.' This would require India to align her laws and regulations with the IAEA safeguard agreements and NSG guidelines.

As a first step, the Indian enactment of 'The Weapons of Mass Destruction and Their Delivery Systems (Prohibition of Unlawful Activities) Bill, 2005'[17] fulfils India's obligations under the United Nations Security Council Resolution 1540 of 28 April 2004. This is considered a step closer to the NPT parameters. One of the key requirements of the Security Council Resolution is that export controls and other legislative measures to prevent proliferation-related activities under such a law should be effective against 'non-state actors' and agents of terrorism as well. Another important step that would be required by India is to agree to meet the Guidelines, Part I of the NSG, which refer to control on transfer of 'trigger list', and Part II Guidelines, which refer to nuclear-related dual-use items. Part I attracts full-scope safeguards of the IAEA on 'all peaceful nuclear activities' of an NNWS in the sense of the NPT and Part II attracts islanded safeguards on transferred equipment or material. That is, from the point of this commitment, India needs to separate its civilian and military nuclear facilities for impending the IAEA safeguards and inspections. India's impeccable record on non-proliferation creates a strong case to convince the NSG in relaxing its rules. This is evident from the fact that though India is not party to NPT and NSG, its domestic export controls have not been less stringent than the guidelines of the NPT, NSG, and MTCR.

The US, on its part, to make this agreement work, needs to convince the NSG members to make suitable regulatory adjustments as the decision is based on consensus and would require the US Congress to amend its domestic legislation on export and licencing to allow the transfer of technologies and materials. This shift in policy will allow several NSG countries to collaborate with India in the civilian nuclear programmes.

Conclusion

The NPT and NSG clearly provide for transfer of nuclear technologies and materials for peaceful nuclear applications. But between the 1970s and 2000s, the world has changed its geo-political character. Moreover, the 21st century saw dramatic advances in nuclear physics, which made some of the provisions redundant. Adding to it, inequality developed in interpretation of its

[16] Supra 13

[17] Bill No. 70 of 2005

The Preamble of the Bill also describes India as nuclear weapon state

'Whereas India is determined to safeguard its national security as a Nuclear Weapon State' provisions, non-implementation of treaty commitments by the NWS, and the indefinite extension of the treaty without any serious compliance with regard to the nuclear disarmament obligations by the NWS added more pessimism to the entire process. Though with great limitations, NSG, a creation of more informal arrangements, played a major role in persuading the nuclear supplier countries to the commitments of non-proliferation of weapons but in the mean time, it committed itself to have peaceful uses of nuclear energy programme through the non-binding guidelines.

To have a credible nuclear energy programme that addresses proliferation, and security and access to peaceful civilian nuclear energy programme, the present NPT regime needs far-reaching changes. The developing countries, with genuine aspirations of progress, would require an energy source that is largely indigenous and adequate towards achievement of economic and social development that the countries in the West had the benefit of. The current world nuclear energy inequity needs to end.

Table 1 provides a time line of nuclear activities from 1957 to 2006.

Year	*Event*
1957	Setting up of IAEA (International Atomic Energy Agency)
1970	NPT (Nuclear Non-Proliferation Treaty) entered into force
1971	Formation of Zangger Committee
1974	First nuclear explosion by India
1975	Creation of NSG (Nuclear Suppliers Group)
1978	Adoption of Part I NSG Guideline
1992	Adoption of Part II NSG Guideline
1995	Indefinite extension of NPT Review Committee
1996	Adoption of the CTBT (Comprehensive Nuclear-Test Ban Treaty)
1998	Second nuclear explosion by India
2001	Russian transfer of nuclear fuel
2005	India-US Joint Strategic Agreement
2005	India joined ITER (International Thermonuclear Experimental Reactor) Project
2006	India-US nuclear deal signed

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Looking beyond the nuclear deal

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The Hindu

Though there are manifest difficulties in negotiating the recent India–US agreement on the civilian nuclear cooperation through the twin thickets of the US legislative process and the NSG (Nuclear Suppliers Group), it is reasonable to assume that the Indian nuclear energy industry is likely to avail of imported fuel and equipment in the not too distant future.

That such an eventuality is at all possible is due, primarily, to three reasons. First, the growing economic and strategic significance of India in a world that is in transition from one system of order to another. For the US, which intends to weather this transition with its hegemonic power intact if not augmented, nuclear cooperation with India forms the bedrock of a wider set of strategic interactions aimed at harnessing the Indian strategic capabilities. Indeed, strategic factors have over-determined the American approach to the Indian nuclear question to such an extent that India's nuclear weapons are probably considered an asset for the US rather than a liability in the global balance. This has enabled realists in the American policy planning system to overcome the non-proliferation theologians and push for the mainstreaming of India's nuclear capabilities even if this means accepting many conditions laid down by the Indian nuclear scientists, such as excluding the fast breeder programme from the purview of international safeguards for the time being.

Second, the rise of India and China is exerting tremendous pressure on the international hydrocarbon market as far as the US and western oil majors are concerned. This is not so much due to the current levels of demand – indeed, it is a fallacy that demand growth in these two countries is an important, let alone pivotal, cause of the recent upwards trend in the international oil prices – as to the hedging strategies that China and India have embarked upon. These strategies are aimed at securing a major upstream presence through equity oil acquisitions as well as establishment of new transportation infrastructure, such as transcontinental and trans-regional pipelines. India, in particular, is seriously examining prospects of a strategic natural gas pipeline from Iran via Pakistan. If completed, such a project

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would fill a major gap in the emerging Asian energy architecture and open the possibility for generalized outflow of Central Asian and Caspian oil and gas southwards towards the Persian Gulf and hence to Asia, rather than exclusively westwards via the US-promoted pipelines like Baku-Tbilisi-Ceyhan.

Third, the US nuclear reactor construction industry has been in doldrums since 1976 and is looking towards China and India as a major source of new demand. Although the Indian nuclear establishment would be more comfortable sourcing reactors from Russia or France, it is highly unlikely that lifting of the embargo on civil nuclear cooperation with India at the urging and initiative of the US will not result in some contracts going to the American companies. The US would also be looking forward to leveraging the nuclear agreement to secure a greater share of the growing Indian arms market.

The fact that none of these three reasons sound particularly appetizing – indeed all reasons suggest that the offer of civil nuclear cooperation comes with a collateral price tag in some other area – is by itself not a sufficient ground to reject or oppose such a historic deal, which offers the Indian nuclear industry a chance to end more than 30 years of isolation. But they do suggest the policy areas where utmost caution is required.

If unreasonable expectations of the US – on the strategic front, energy security front, and trade front – are met fully or even partially, many of the gains stemming from resumption of civil nuclear cooperation will be lost. This newsletter is perhaps not the best forum to address the first and third fronts but energy security is a question that demands utmost clarity and it is to this subject that I will now turn.

Simply put, India must reject the notion that there can be any trade-off between the prospects of greater civil nuclear cooperation and those of cooperative hydrocarbon ventures of the kind the country is looking at with Iran, Pakistan, and even China. That the US is looking at these two as a trade-off should be amply evident both from the timing of US Secretary of State Condoleezza Rice's initial offer of an energy dialogue in March 2005 as well as from the pronouncements made since then by her, by the US ambassador to India David Mulford, and by the sundry officials and legislators in the US. The US president George W Bush's remarks in Islamabad on 4 March 2006 that the US has a problem not with the Iran pipeline but with Iran's nuclear ambitions is not a shift in line as some have suggested but a cleverer reformulation of the same objection.

Oil and, particularly, natural gas will continue to be an important part of the Indian energy mix in the short and medium term, and nuclear power can be seen as a substitute only in the long term. Up until the middle of this century then, finding and securing new sources of hydrocarbons will have to be a key aspect of India's quest for energy security. Given the enormous reserves of natural gas in Iran, that country is a natural partner for India and multiple forms of transport infrastructure – including pipelines and LNG (liquefied natural gas) tankers – will be needed between the two countries. The presence of Pakistan is not a problem but an opportunity for India because involving Islamabad in a trilateral or even multilateral energy grid is an excellent way of raising the level of economic interaction between the two neighbours who have traditionally been at loggerheads with one another. Ever since prime minister Manmohan Singh came under fire for suggesting in an interview to the *Washington Post* in July 2005 that the Iran pipeline might never take off, his government has been careful to reiterate its commitment to the project, provided it is found to be financially viable. While financial viability is important, particularly when comparing alternative modes of transportation or indeed imports, there should be no underestimation of political benefits that the pipeline might also bring. These benefits will accrue in three distinct and mutually reinforcing ways. First, India and Pakistan will experience the burden of mutual dependency for the first time in decades. Second, Iran will get to develop a stable and secure export market for its natural gas. Third, the Iran–Pakistan–India pipeline might become a catalyst for a wider network of pipelines criss-crossing the Asian heartland and connecting areas of supply with areas of demand in a manner unmediated by the outside influence.

Though a recent convert to the cause of pipelines, India has begun to compensate for its earlier lack of interest with an ambitious proposal for an Asian gas grid that would take these two connections – Iran–India and Kazakhstan–China – and extend them in a way that links Asia's major energy-producing and -consuming regions to one another. At the meeting in New Delhi in November 2005 of principal north and central Asian energy-producing and -consuming countries, India unveiled an ambitious 22.4-billion-dollar pan-Asian gas grid and oil-security pipeline system. The grid has four principal elements. The first would extend the existing Baku–Tbilisi–Ceyhan pipeline system – originally conceived by the US as a means of shipping central Asian hydrocarbons westwards – down to the Red Sea via Syria, Jordan, and Saudi Arabia, allowing Caspian crudes to be exported easily to the Indian Ocean littoral. Second is the famous Iran–Pakistan–India pipeline, with the possibility of two additional sourcing spurs, one from the Caspian–Turkmenistan region to Iran, the other from Turkmenistan via Afghanistan. The third element would be a pipeline system connecting eastern India to Myanmar and south-western China with one connection running from Sittwe on the Burmese Bay of Bengal coast to Mizoram, Manipur, and Assam into China, eventually connecting up to the West–East China gas pipeline near Shaanxi, the other from Yangon to Kunming. The fourth element would involve the laying of pipelines that would connect the Sakhalin deposits in Russia to Japan, China, and South Korea.

Pipelines aim to deliver gas, crude, or products between discrete points but this does not mean they have to be a zero-sum game. The underlying economic logic of a grid is that capital costs can be more easily absorbed and amortized and energy supplies calibrated to match demand variations in the consuming countries without too much effort. But there is a political logic as well. As the Asian grid will create mutual dependencies, giving countries a stake in the political and economic stability of one another, it will hasten the process of regional integration. If at all Asia is to make progress towards creating an Asian counterpart to the IEA (International Energy Agency) and developing a regional market for energy with its own price markers, construction of physical infrastructure such as pipelines is essential.

While the Iran–India energy link is crucial to the emergence of any Asian gas grid, Sino-Indian collaboration will likely be the platform on which any wider energy architecture in Asia will emerge. The two countries have travelled some distance in reaching an agreement in January 2006 for the joint bidding of oil and gas assets in third-world countries but there are many more areas for cooperation that can and should be explored. India, in particular, must not lose interest in this aspect of energy security now that the nuclear deal with the US looks increasingly likely to come through.

Above all, India and China need to keep in mind the big picture: evolution of an Asian market for crude and products with long-term supply contracts and stable prices, and, eventually, an Asian Energy Union. As Mani Shankar Aiyar, who was India's petroleum and natural gas minister until 30 January 2006, pointed out in a recent lecture to the Chinese energy specialists in Beijing, the European Union started life as a coal and steel union before growing eventually into a full-fledged economic and political community. Could energy play the same role in Asia, with India and China serving as sheet anchors in the way France and Germany did in Europe? With India and China committed to building strategic petroleum reserves, South Korea offering to work on an 'Inter-Asia Oil and Gas Transportation System', and Iran planning its own hydrocarbon bourse, such an idea is no longer far-fetched.

Linked to an Asian oil market is the billion-euro question of non-dollar denominated energy trade. Asian countries collectively hold more than two trillion dollars worth of foreign reserves, the overwhelming share of which is in dollar-denominated instruments. Prudential norms suggest that diversification of the Asian reserve portfolio is overdue. In China, the SAFE (State Administration of Foreign Exchange) has signalled its intention to explore the more 'efficient use' of the country's forex reserves and in India, commentators like S Venkitramanan have suggested the Reserve Bank of India start thinking along similar lines. One way to sustain this shift would be to consider yen- or euro-based trading in energy. The economic dynamism of Asia for the foreseeable future suggests that what is needed is a strategic rather than a tactical change in composition of reserves. Huge and unsustainable deficits being run by the US are undermining the 'oil standard' that has been central to the hegemony of both the dollar and Washington for more than three decades. Relying exclusively on the dollar for energy trade will hurt Asia's producers and consumers alike in the long run and there is need for a shift in some other direction.

To conclude, India's quest for energy security cannot be considered in a unidimensional manner in which sectors and timeframes are collapsed in an unrealistic manner. The Indian economy will require both hydrocarbons as well as nuclear power, not to speak of other sources of conventional and non-conventional energy. The biggest mistake that policy planners can commit is to consider one source as a trade-off for another, especially given the differing timeframes. As a stand-alone deal, the nuclear cooperation agreement with the US has much to commend it. But its costs will start adding up if, as a consequence, we turn away from the Iran pipeline and from the wider agenda of an Asian energy grid and energy market.

Accessing opportunities in a changing global nuclear order

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India has, for a large number of years, been the target of a global nuclear technology blockade or denial regime, given its decision not to sign the Nuclear NPT (Non-proliferation Treaty). Operationally, this means that India has been out of the technical and commercial loop on peaceful uses of energy, which otherwise, the NPT member states were eligible for; but its obverse is that it has encouraged India to develop an impressive indigenous capability. Despite this, it is evident that there is a fuel, safety, and a technical constraint, in terms of meeting India's power needs through the nuclear route in its larger plan to secure energy needs.

India has a limited resource availability of uranium, to the tune of about 70 000 tonnes; but it has one of the largest resources of thorium in the world, amounting to 360 000 tonnes. Therefore, India chose to adopt a programme in which the fuel cycle maximizes energy yield of the nuclear-energy-producing ores. The programme involves three stages, described as follows:

- *Stage I* Construction of natural-uranium-based pressurized heavy water moderated and cooled reactors; spent fuel from these reactors can be reprocessed to obtain plutonium
- *Stage II* Construction of FBRs (fast-breeder reactors) fuelled by plutonium produced in Stage I; these reactors are also to breed U-233 from thorium
- *Stage III* Power reactors using U-233/thorium as fuel

India is currently in the second phase where the FBRs are to be commissioned. India's uranium resource base can only support 10 000 MW (megawatts) of power generation through the PHWR (pressurized heavy water reactor) route, which is Stage I of India's nuclear programme.

Inadequate fuel in Stage I would not only affect the nuclear contribution towards alleviating the energy deficit but also the three-stage nuclear programme. In Stage II, the FBR route will require plutonium derived from Stage I. This has technological implications. If the FBRs are fuelled by using metallic fuel, the rate of plutonium generation is twice as fast as the MOX (mixed oxide) route, which will generate the required fuel for rapid growth of the FBRs. India currently has the experience and capability to use only MOX-derived fuels and it needs to invest in the development of metallic-fuel-based reactors. Therefore, it currently needs international cooperation to meet its fuel requirements in Stage II so that the FBRs become self-sustaining. The third issue relates to safety aspects of reactors and India's needs for some form of cooperation on safety issues. But given the nature of nuclear technology, collaboration on safety issues does involve sharing of the reactor technology and, hence, is difficult under the NPT regime and the NSG (Nuclear Suppliers Group) Guidelines.

The current search for ways of increasing India's room to manoeuvre in the international nuclear order has to be seen in the context of fuel, safety, and technological constraints towards expanding the scope and potential of nuclear energy to address India's energy concerns. This re-engagement that India seeks is at an appropriate time, given that the global nuclear order is poised to change, driven by concerns with a fossil-fuel-induced climate change, shortages of oil and gas, emerging geopolitics of oil, and the need for alternative energy fuels and sources. There is a growing and emerging interest in new bilateral and multilateral nuclear arrangements by countries such as France, Russia, and the US, including the UK and China, which also have a keen interest in wanting to obtain a share of the rapidly growing nuclear energy market. The confluence of strategic and commercial interests is fitting for India to use strategically to its advantage to meet the needs of its three-stage nuclear programme. Over the past year, there have been new overtures from Canada, France, Russia, and the US to re-examine nuclear energy collaborations. These vary in form and content but the spirit of wanting to engage with India's nuclear programme for strategic and commercial reasons cannot be denied.

The Indo–US joint statement of 18 July 2005 issued by the US president George W Bush and the Indian prime minister Manmohan Singh promised efforts by the Bush administration to pass a legislation, which would allow the US to provide full civilian nuclear technology cooperation to India. India's pressing energy needs and its non-proliferation record present a great test case to enable this re-entry into an otherwise closed international order. The joint statement is perceived as giving India due recognition in the global nuclear order, acknowledging the existence of its strategic programme while being invited to be a partner in the international civil nuclear energy cooperation. This opportunity was being offered in exchange for India placing its civilian facilities under the IAEA (International Atomic Energy Agency) safeguards and ring-fencing these from its weapons programme. In the domestic debate that followed, this original statement became embroiled in worries that there was an effort to cap the strategic programme. In his speech to the Parliament on 28 February 2005, prime minister Manmohan Singh did refer to an initial separation plan identifying 65% of its installed nuclear capacity as civilian by the end of the plan. This civilian domain would be under the IAEA safeguards. But he did state that the indigenous fast breeder programme would not be put under safeguards. This was in fact the way it was when the India–US nuclear deal was agreed upon between the US President and the prime minster of India on 2 March 2006. The deal accepts a separation plan that will place 14 of India's nuclear reactors under international safeguards in a phased manner by 2014 while eight remain outside of these for defence purposes. See Map 1 for location of various atomic energy establishments in India. Further, it has been conveyed that India will not accept safeguards on the PFBR (prototype fast breeder reactor) and the FBTR (fast breeder test reactor), which are located at Kalpakkam[1]. The US government on its part reaffirmed its assurance to create

[1] Details available at <http://www.dae.gov.in/press/suopm0703.htm>, last accessed on 8 March 2006.

necessary conditions for India to obtain full, uninterrupted, and continual access to fuel supplies from the international fuel market for the safegaurded reactors. Again to make the agreement workable for the life term of nuclear reactors, the US is prepared to undertake measures such as incorporation of agreement provisions under Section 123 of the US Atomic Energy Act, work with IAEA for an India-specific fuel supply arrangement, help develop a strategic nuclear fuel reserve, and work with Russia, France, and UK to commit fuel supply without any disruption.[2] This would end the blockade and give a large impetus to the nuclear energy programme, thereby increasing India's energy options for future.

The Indo–Canadian joint statement of 26 September 2005 ends many years of non-cooperation with Canada as it suspended all nuclear cooperation after the 1974 nuclear tests and formally ended its nuclear relations with India in May 1976. The announcement includes the following measures.[3]

- Agreement by both governments to develop a mutually beneficial bilateral framework; support by both governments for scientific and technical contacts on a broader range of civilian nuclear issues within the public domain; and agreement by Canada to allow the supply of nuclear-related dual-use items to the Indian civilian nuclear facilities under the IAEA safeguards, in accordance with the requirements of the NSG's dual-use guidelines.
- Agreement by both governments to pursue further opportunities for development of peaceful uses of nuclear energy, both bilaterally and through the appropriate international forums, consistent with their international commitments.

Russia provided assistance with two 1000-MW light-weight reactors for the Kudankulam nuclear power plant in Tamil Nadu in 2000, despite considerable international pressure to suspend it, given its commitments as a member of the NSG. The question of how to expand cooperation between Russia and India in the civilian nuclear energy, however, figured prominently in the summit between the Indian prime minister and Russian president Putin on 6 December 2005, probably as a direct result of the opportunity that the Indo–US deal creates. The decision to cooperate was placed on a firm footing in March 2006, when enhanced civil nuclear cooperation figured prominently in talks between the prime ministers of Russia and India. This went a step further when Moscow agreed to supply uranium to the safeguarded reactor at Tarapur Atomic Power Station.

On 20 February 2006, India and France signed a declaration on Development of Nuclear Energy for Peaceful Purposes, following up on a joint statement issued by the president of France and the prime minister of India in September 2005.[4] This was to work towards adjustment of international civil nuclear cooperation framework with respect to India.

In December 2005, India joined the ITER (International Thermonuclear Experimental Reactor) project as a full member. The ITER nuclear fusion project promises to provide clean and safe energy in future. The consortium of ITER involves six other partners: China, South Korea, Japan, Russia, the EU, and the US. Involvement of India is considered to be beneficial to all parties, given the development in the domestic nuclear, scientific, and technological capabilities.

While international debate on India's inclusion in the global nuclear order is still tentative, domestic debate rages between those who believe that these deals (especially the Indo–US deal) may cause India to lose some of its independence in the nuclear choice-making, cap its strategic programme, as well as lock India into greater imported nuclear fuel

[2] Implementation of the India–US Joint Statement of 18 July 2005: India's Separation Plan tabled in Parliament on 7 March 2006.

[3] Details available at <http://w01.international.gc.ca/MinPub/Publication.asp?Language=E&publication_id=383095> and <http://meaindia.nic.in/parliament/ls/2005/11/30ls08.htm>, last accessed on 28 February 2006.

[4] Details available at <http://meaindia.nic.in/speech/2006/02/19jdol.htm>, last accessed on 28 February 2006.

dependency over time, and those who argue that it will lead to a greater energy security due to greater access to fuel and technology, and perhaps even a toning down of the weapon programme, which, it is argued, is large enough.

It is in this context that the GNEP (Global Nuclear Energy Partnership) needs to be viewed. This is a US-led initiative to enable expansion of nuclear energy for electricity generation. It seeks to address several policy objectives: (i) climate change concerns, (ii) new fuel sources, (iii) non-proliferation, and (iv) reduction of radioactive waste. The last is linked to the fact that partnership envisages the provision of fuel sources – fresh and those recovered from used fuels – by nuclear-capable states to those less capable but who agree to use the fuel for power generation only. There is sufficient, highly enriched uranium available from the international nuclear arsenal, which were dismantled in the early 1990s. Recovery of fuel from used nuclear fuel will reduce waste and the need for waste depositories. GNEP is being seen as a way of meeting all the above policy objectives. The issue that bothers those in the 'not so capable' group (and it is not clear if India is being classed in this group) is that it might create a new dependency on imported nuclear fuel, which could at a later stage, have all of the attendant geopolitical risks. Separation lines between the beneficial and non-beneficial uses of nuclear power are perceived as thin, and parties are wary of transgressions or impositions. It is clear that any international initiative (as in oil and gas) on the nuclear energy trade front needs to have some confidence-building measures woven into it if it is to take off in a way that would make all parties comfortable.

Glossary of terms in nuclear energy

Advanced gas-cooled reactor

It is the second generation of British gas-cooled nuclear reactors using graphite as the neutron moderator and carbon dioxide as coolant.

BWR (boiling water reactor)
It is a light water reactor used in some nuclear power stations. In a BWR, steam is produced in the reactor core and goes directly to the steam turbine.

Burn-up
Measure of thermal energy released by nuclear fuel relative to its mass, typically GWd/tU (gigawatt days per tonne of uranium).

CANDU
Canadian deuterium uranium reactor, moderated and (usually) cooled by heavy water.

Chain reaction
A reaction that stimulates its own repetition, in particular, where neutrons originating from nuclear fission cause an ongoing series of fission reactions.

Core
The central part of a nuclear reactor containing fuel elements and moderator.

Critical mass
The smallest mass of fissile material that will support a self-sustaining chain reaction under specified conditions.

Criticality
Condition of being able to sustain a nuclear chain reaction.

CTBT (Comprehensive Nuclear Test Ban Treaty)
This treaty bans nuclear explosions in all environments for military or civilian purposes. It was adopted by the UN General Assembly on 10 September 1996. According to the recent developments (as of 17 March 2006), there are

176 member states to the treaty with total ratifications of 132. The latest signatory state to the treaty is Lebanon and the latest ratifying state is Vietnam as of 17 March 2006. Additionally, it is yet to be ratified by Colombia, China, Egypt, Indonesia, Iran, Israel, and the US, and signed and ratified by India, Pakistan, and Korea, which is required for the treaty to enter into force.

Decay
Disintegration of atomic nuclei resulting in emission of alpha or beta particles (usually with gamma radiation).

Decommissioning
Removal of a facility (for example, reactor) from service, also the subsequent actions of safe storage, dismantling, and making the site available for unrestricted use.

Depleted uranium
Uranium having less than 0.7% of natural U-235. As a by-product of enrichment in the fuel cycle, it generally has 0.25%–0.30% U-235, the rest being U-238; can be blended with highly enriched uranium (for example, from weapons) to make reactor fuel.

Deuterium
'Heavy hydrogen' is a stable isotope of hydrogen having one proton and one neutron in the nucleus. It has the same chemical properties as hydrogen but physical properties may differ.

Fast breeder reactor/fast neutron reactor
A type of fast neutron reactor that produces more fissile material than it consumes using uranium-238 as substrate. Alternative fast and thermal breeder reactors are also possible using thorium. A fast neutron reactor, commonly called fast reactor, uses no moderator but instead relies on fast neutrons to sustain its chain reaction with the use of high-grade fuel such as enriched uranium or plutonium as fuel. Once the reaction has been provided for the initial start-up, the reactor produces its own fuel and the surplus can be used to sustain other breeders. A fast neutron reactor or simply a fast reactor is a category of nuclear reactor in which the fission chain reaction is sustained by fast neutrons. Such a reactor needs no neutron moderator, but must use fuel that is relatively rich in fissile material.

Heavy water
Water containing an elevated concentration of molecules with deuterium (heavy hydrogen) atoms.

Heavy water reactor
A reactor, which uses heavy water as its moderator; for example, Canadian CANDU.

High-level wastes
Extremely radioactive fission products and transuranic elements (usually other than plutonium) in spent nuclear fuel. They may be separated by reprocessing the spent fuel, or the spent fuel containing them may be regarded as high-level waste.

Highly (or high)-enriched uranium
It is uranium enriched to at least 20% U-235 (which in weapons is about 90% U-235).

ITER (International Thermonuclear Experimental Reactor)
It is an international tokamak (magnetic confinement fusion) experiment, planned to be built in France and has been designed to show the scientific and technological feasibility of a full-scale nuclear fusion power reactor. It has been built upon research conducted on devices, such as TFTR, JET, JT-60, and T-15, and will be considerably larger than any of them. The programme is anticipated to last for 30 years – 10 years for construction and 20 years of operation – and costs approximately 10 billion euros. After many years of deliberation, the participants announced in June 2005 that the ITER will be built in Cadarache, France. The consortium of ITER involves seven other partners: China, South Korea, Japan, Russia, the EU, the US, and India.

Light water
Ordinary water as distinct from heavy water.

LWR (light water reactor)
A common nuclear reactor cooled and usually moderated by ordinary water.

MOX (mixed oxide fuel)
Reactor fuel, which consists of both uranium and plutonium oxides, usually about five per cent plutonium, which is the main fissile component.

Moderator
A material such as light, heavy water, or graphite used in a reactor to slow down fast neutrons by collision with lighter nuclei.

Natural uranium
Uranium with an isotopic composition as found in nature, containing 99.3% U-238, 0.7% U-235, and a trace of U-234; can be used as fuel in heavy-water-moderated reactors.

Neutron
The uncharged particle, which remains in the nucleus of an atom is called a neutron.

NPT (Nuclear Non-proliferation Treaty)
It obligates five acknowledged nuclear weapon states (USA, France, Russia, UK and China) not to transfer nuclear weapons, nuclear explosive devices, or their technology to the non-nuclear weapon states. The treaty entered into force on 5 March 1970.

NSG (Nuclear Suppliers Group)
A multi-national body concerned with reducing nuclear proliferation by controlling the export and re-transfer of materials that may be applicable to nuclear weapon development and to improving safeguards and protection on the existing material. It was founded in 1975 in response to the Indian nuclear test of the previous year.

Nuclear fission
It is a process by which the nucleus of an atom splits into two or more smaller nuclei as fission products, and some by-product particles. The by-products include free neutrons, photons usually in the form of gamma rays, and other nuclear fragments such as beta particles and alpha particles. It is an exothermic reaction and can release substantial amounts of useful energy both as gamma rays and as kinetic energy of the fragments.

Nuclear fusion
The process by which atoms of elements fuse together to produce another element along with the release of huge amount of energy and neutrons. Neutrons released in the process can be re-utilized in breaking atoms of the element with further release of nuclear energy. Two isotopes of hydrogen (tritium, deuterium) fuse together to produce helium and release neutron and huge amounts of energy.

Nuclear reactor
It is a device in which nuclear chain reactions are initiated, controlled, and sustained at a steady rate. Nuclear reactors are used for many purposes. The most significant current use of nuclear reactor is for the generation of electrical power.

PHWR (pressurized heavy water reactor)
It is a nuclear power reactor that uses unenriched natural uranium as its fuel and heavy water as a moderator (deuterium oxide [D_2O]). While heavy water is expensive, the reactor can operate without expensive fuel enrichment facilities which balances the costs. The fuel elements are located in the pressure tubes, which are located in a steel vessel (called the calandria) and the heavy water circulates through the pressure tubes and is prevented from boiling.

Proton
The positively charged particle, which remains in the nucleus of an atom is called a proton.

PWR (pressurized water reactor)
It is a nuclear power reactor that uses ordinary light water as coolant and for neutron moderation. In a PWR, the primary coolant loop is pressurized so that water does not achieve bulk-boiling and heat exchangers called steam generators are used to transmit heat to a secondary coolant, which is allowed to boil to produce steam either for warship propulsion or for electricity generation. In having this secondary loop, the PWR differs from the BWR (boiling water reactor), in which the primary coolant is allowed to boil in the reactor core and drive a turbine directly.

Pool-type reactor
It is a type of nuclear reactor that has a core immersed in an open pool of water. The reactor core, consisting of fuel elements and the control rods, is situated in an open water pool. Water acts as a moderator, cooling agent, and radiation shield. The layer of water above the reactor core shields radiation completely so that operators may work above the reactor in total safety. This design has two major advantages: the reactor is easily accessible and the whole primary cooling system, that is, pool water, is under normal pressure.

Pu-239: Plutonium
It is a fissile element which on undergoing nuclear fission generates huge amounts of nuclear energy and is, therefore, used in making nuclear bombs.

Radioactivity
It is a nuclear phenomenon by which atoms of radioactive elements undergo decay by forming new elements with the emanation of alpha, beta, and gamma rays. It is unaffected by temperature, pressure, chemical and physical changes.

Re-processing
Chemical treatment of spent reactor fuel to separate uranium and plutonium from the small quantity of fission product waste products and transuranic elements, leaving a much reduced quantity of high-level waste.

U-235: Enriched uranium
It is a radioactive element which on undergoing nuclear fission gives two more uranium elements and large number of neutron to sustain the nuclear reaction.

Vitrification
It is a process of converting a material into a glass-like amorphous solid which is free of any crystalline structure, either by the quick removal or addition of heat, or by mixing with an additive. Solidification of a vitreous solid occurs at the glass transition temperature. In case of nuclear energy, vitrification process is used in incorporation of high-level wastes into borosilicate glass and is designed to immobilize radionuclides for waste disposal.

WMD (weapons of mass destruction)
These generally include nuclear, biological, chemical, and increasingly, radiological weapons. The term first arose in 1937 in reference to the mass destruction of Guernica, Spain, by aerial bombardment. Following the bombing of Hiroshima and Nagasaki, and progressing through the Cold War, the term came to refer more to non-conventional weapons using nuclear energy.

Zircaloy
It is a group of zirconium alloys. One of the main uses of zircalloys is in nuclear technology where it is frequently used as cladding of fuel rods in nuclear reactors. The alloying elements of zircaloy are tin, niobium, chromium, iron, nickel and hafnium.

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Map 1 Atomic energy establishments in India
Source <www.dae.gov.in/publ/indmap.htm>

The Centre for Research on Energy Security

CeRES (Centre for Research on Energy Security) was set up on 31 May 2005. The Centre will conduct research and provide analysis, information, and direction on issues related to energy security in India. It will track global energy demands, supply, prices, and technological research/breakthroughs – both in the present and for the future – and analyse their implications for global as well as India's energy security, and in relation to the energy needs of the poor. It will engage in international, regional, and national dialogues on energy security issues, form strategic partnerships with various countries, and take initiatives that would be in India's and the region's long-term energy interest. *Energy Security Insights* is a quarterly bulletin of CeRES that seeks to establish a multi-stakeholder dialogue on these issues.

The introductory issue that focused on oil and energy security issues is available at <http://www.teriin.org/div/esi01.pdf>.

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Printed and published by Dr R K Pachauri on behalf of The Energy and Resources Institute, Darbari Seth Block, IHC Complex, Lodhi Road, New Delhi – 110 003 and printed by him at Grand Prix and published at New Delhi.