



INDIA'S NUCLEAR PROGRAMME

The US-India agreement, called “Agreement for Co-operation Between the Government of India and the Government of the United States of America concerning Peaceful Uses of Nuclear Energy” has been done in view of the requirement for the US side under section 123 of its Atomic Energy Act 1954. Hence it is also popularly known as the 123 Agreement.

The Beginning: India’s indigenous nuclear programme was founded on a conviction, soon after independence, that this would be an important step towards realising her vision to attain self-reliance and technological independence. India’s first Prime Minister, Pandit Jawaharlal Nehru recognized early that nuclear technology offered a tremendous potential for economic development, especially for a developing country aspiring to leapfrog technology gaps brought about by long years of colonial exploitation. This thinking was reflected in the enactment of the **Atomic Energy Act of 1948**, within a year of our independence. All the initiatives taken by us since have been in consonance and in continuation of those early enunciations keeping national interests as paramount.

Three Stage Programme : The importance of nuclear energy, as a sustainable energy resource for our country, was recognised at the very inception of our atomic energy programme conceived more than four decades ago under the able guidance of Homi Jehangir Bhabha. A three-stage nuclear power programme, based on a closed nuclear fuel cycle, was then chalked then - which forms the bedrock of our nuclear policy. The three stages envisage:

- ❖ Natural uranium fuelled Pressurised Heavy Water Reactors
- ❖ (PHWRs),

- ❖ Fast Breeder Reactors (FBRs) utilising plutonium based fuel, and ,
- ❖ Advanced nuclear power systems for utilisation of thorium.

Thorium and uranium are the two naturally occurring elements which have the potential of being used as fuel in a nuclear power plant. India has reasonable deposits of natural uranium, while thorium deposits are quite vast.

Natural uranium consists of two isotopes, of which U235 which constitutes about 0.7% of natural uranium, can be easily fissioned in a nuclear reactor to produce energy. The balance is U238, a fertile material, which gets partially converted to fissile Pu239 on absorbing neutrons, during its residence in the nuclear reactor. On discharge from the reactor, spent fuel can be dealt with in two ways. The first one, termed 'open cycle', consists of treating the entire spent fuel as waste and disposing it as such. With this approach, only about 2% of the energy potential exploitable from uranium is utilized.

To avoid this colossal waste, a **closed fuel cycle** has to be pursued. It is possible to separate plutonium and uranium-238 from the spent fuel in a **reprocessing** plant and use these two valuable nuclear materials once again in a recycling mode. Besides recovering fissile material, reprocessing helps to sort out the wastes according to their activity levels and their decay period thereby **assisting waste disposal and minimizing environmental impact**.

Thorium, a fertile material, cannot be easily fissioned in a nuclear reactor to produce energy. However, like uranium-238, thorium also gets partially converted to a fissile material uranium-233, when used as a part of nuclear fuel mix. India has vast reserves of thorium and our resource profile calls for development of a closed cycle involving utilization of thorium. This was realized early by the planners and our nuclear programme is based on this option. In the world today, both the options are being followed. Countries which have stockpiled enough fissile material inventory are advocating open cycle option. **However, countries like France and Japan prefer a closed cycle as their long term energy security is closely tied up**

with following a closed cycle. Pursuit of the closed cycle option calls for setting up of reprocessing plants and breeder reactors. Because of the sensitive nature of the technology involved, self reliance is a must. Therefore, a comprehensive R & D programme has been set up to make us technologically independent.

On the basis of the above-mentioned strategy, **three stages of the Indian nuclear power programme** have been identified. In the first stage, natural uranium dioxide based fuel is used in heavy water moderated and cooled Pressurised Heavy Water Reactors (PHWRs). The indigenous resources can support about 10,000 MWe of installed capacity through the use of PHWRs. To kick start the nuclear power generation programme, the first two plants were of the boiling water reactor type and were based on imported technology. Subsequent plants are of PHWR type and as explained in the next section, we have, through our R&D efforts achieved complete self-reliance in this technology and this stage of the programme is now in the industrial domain. In addition, as an additional programme, we may go in for plants of VVER type using Russian technology in order to augment generation capacity in the country. Further to conserve fuel and to develop expertise which will be needed during subsequent stages, technology for the fabrication of mixed oxide (MOX) fuel has been developed and introduction of such fuel assemblies in the reactors at Tarapur has already commenced. With this India joins other countries like France and Japan which are using MOX fuel in nuclear power plants.

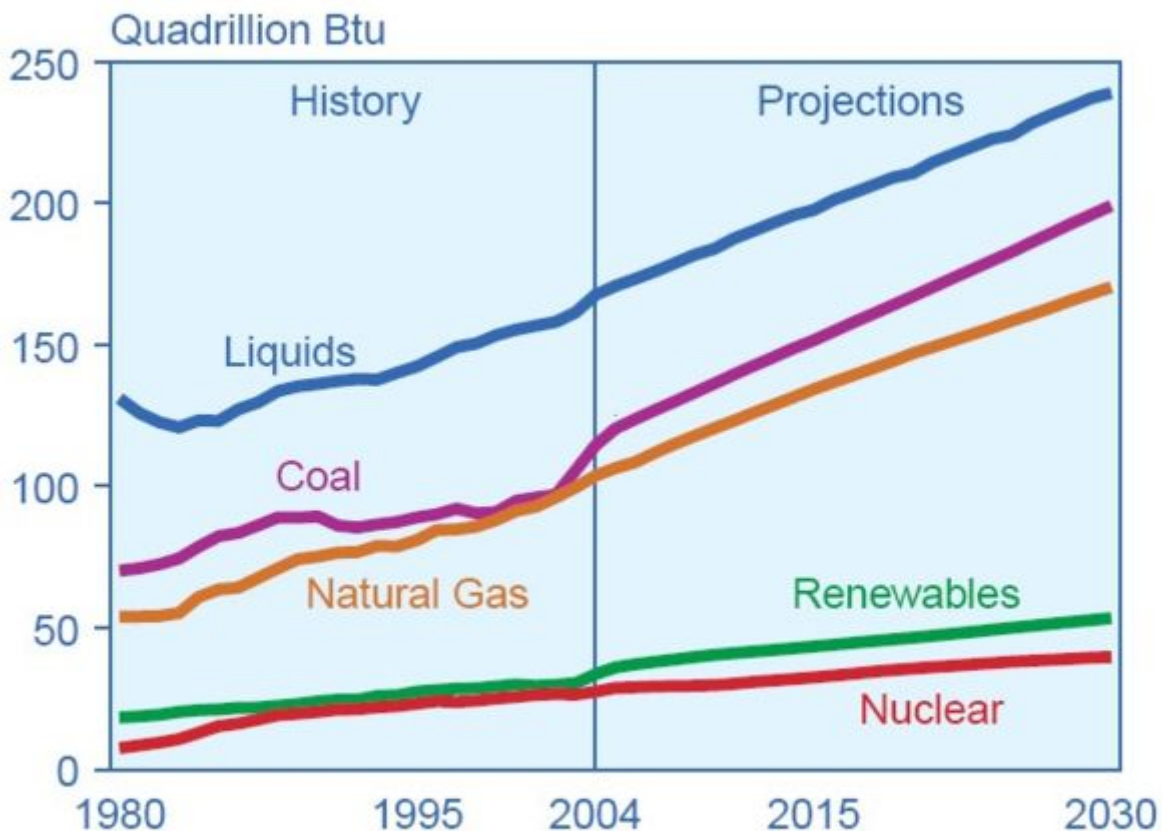
In the second stage, the **fissile plutonium contained in the spent fuel from the PHWR is separated in fuel reprocessing plants.** Plutonium serves as the main fissile element for fuelling the Fast Breeder Reactors (FBRs). Using FBRs an energy output of 350 GWe can technically be sustained using indigenously available uranium resources. In pursuit of second stage, a fast breeder test reactor has been set up and technology development for a 500 MWe prototype fast breeder reactor is in progress. In parallel, as a part of the second stage of our nuclear programme, it is proposed to use thorium based fuel, along with a small feed of plutonium based fuel in Advanced Heavy Water Reactors (AHWRs). The AHWR are expected to

shorten the period of reaching the stage of large-scale thorium utilization.

In the third stage, **dedicated breeder reactors based on uranium-233 and thorium are planned to be constructed.** These reactors would serve as the mainstay of the final, thorium utilization stage, of the Indian nuclear programme. The currently known Indian thorium reserves amount to 200,000 GWe-yr of the electrical energy and can easily meet the energy requirements during the next century and beyond.

India's nuclear programme , unlike that of many nations does not have a separation - of military and civil programmes . Thus, when the peaceful nuclear tests explosions of 1974 and 1998 were conducted, the belief that these were fueled by nuclear fuel supplied for civil nuclear energy led to sanctions being imposed against India - and denial of technology, fissile material and related support for our nuclear programme. Our first nuclear power plant at Tarapur built with US help and based on US uranium supplies was crippled without uranium supplies. It was a major set back to the 3 Stage programme as it imposed restrictions on imports of high-technology products, denied access to Uranium from the US and other countries , prohoibited transfer of nuclear technology – reactors, reprocessing etc ., imposed economic and financial sanctions – withdrawal of bilateral assistance and restricted support from Multilateral financial agencies- World bank , International Monetary fund.

Figure 4. World Marketed Energy Use by Fuel Type, 1980-2030



Sources: **History:** Energy Information Administration (EIA), *International Energy Annual 2004* (May-July 2006), web site www.eia.doe.gov/iea. **Projections:** EIA, *System for the Analysis of Global Energy Markets* (2007).

Green indicates countries building new reactors.
 Yellow indicates countries planning new reactors.
 Dark blue indicates countries with reactors, but no plans for expansion or phase-out.
 Pale blue indicates countries with reactors considering phase-out.
 Red indicates those which formerly had commercial reactors, but which have all been phased out.

Energy for growth: At that time, although the stage was set for India's accelerated economic growth, India's faced a major constraint - of shortage of Energy. For growth targets of 8 -10% to be achieved, an additional 20,000 Mw of nuclear electricity would be vital - a clean and efficient element in the energy mix. India began to seriously

consider this option and realised that the answer lay in engaging with the USA to conquer the restrictive regimes that had been imposed on her.

Our nuclear policy has been marked by restraint and transparency. India has maintained effective export controls on nuclear materials as well as related technologies even though we are neither a party to the NPT nor a member of the Nuclear Suppliers' Group. India is committed to non-proliferation and the maintaining of stringent export controls to ensure that there is no leakage of our indigenously developed know-how and technologies. In fact, India's conduct in this regard has been better than some countries party to the Nuclear Non proliferation Treaty. India has not violated any international agreements and its record on non-proliferation has been unblemished. Subsequent to the tests, the Government worked towards re-engaging with countries like US to end India's nuclear isolation, gain legitimacy as a country with advance nuclear technology and work towards greater international cooperation in areas of high technology and initiate measures to do away with technology denial regimes. Another challenge was of balancing and reconciling India's security imperatives for which her strategic nuclear programme is critical , with valid international concerns regarding the same .

India- US Agreement on bilateral civil nuclear co-operation

During PM's visit to the US in July 2005, the two countries – India and the US – carried forward an ongoing dialogue towards resumption of civilian nuclear co-operation - frozen since 1974. India agreed to give an assurance that nuclear supplies for civilian purposes would not be diverted to her strategic programme. Based on this concept, in March 2006, during the visit of President Bush to India, a Separation Plan was agreed upon by the two sides – according to which, India agreed to identify and place under IAEA safeguards 14 of her 22 thermal power reactors between 2006-14 in a phased manner. This would raise the total installed thermal power

capacity in Megawatts under safeguards from 19% at present to 65% by 2014.

In order to be able to enter into such a co-operation with India, the US Administration sought and obtained from the US Congress a legislative waiver from a stipulation in Section 123 of the the US Atomic Energy Act of 1954 requiring full scope safeguards as a condition for civil nuclear co-operation. The enabling legislation, called the Hyde Act was passed in the US Congress in December, 2006.

The ‘123’ Agreement

After 5 rounds of negotiations over the period, June 2006 to July 2007, negotiations for the 123 Agreement have been completed and the text of a bilateral co-operation Agreement agreed to on July 20, 2007. The final text of the **“Agreement for Co-operation Between the Government of India and the Government of the United States of America concerning Peaceful Uses of Nuclear Energy”** contains the following significant features:

The **final draft text** for the Agreement which is *“between two states possessing advanced nuclear technology, both parties having the same benefits and advantages”* **reflects** the understandings of July 2005 and March , 2006 and fulfils the commitments that Prime Minister had made in Parliament on August 17, 2007 in response to some concerns expressed in Parliament with regard to the understanding on civil nuclear co-operation with the USA. Moreover, the Agreement is **not at the cost of** the (i) autonomy of our strategic nuclear programme , (ii) indigenous III Stage Nuclear Programme and (iii) India’s R&D activities which will remain unhindered and unaffected .

Features

The Agreement further provides for full civil nuclear co-operation between India and the US - covering nuclear reactors and aspects of the associated nuclear fuel cycle including enrichment and reprocessing.

The Agreement explicitly provides that it will not affect the unsafeguarded facilities of either Party and that it shall be implemented in a manner so as not to hinder or otherwise interfere with any military nuclear facilities or nuclear material produced, acquired or developed by us independent of this agreement.

The Agreement provides for the development of a strategic reserve of nuclear fuel to guard against any disruption of supply over the lifetime of India's reactors. The Agreement contains a full reflection of the March 2, 2006 supply assurances, its linkage to safeguards in perpetuity and the provision for corrective measures that India may take to ensure uninterrupted operation of its civilian nuclear reactors in the event of disruption of foreign fuel supplies.

The Agreement accords consent to reprocess spent fuel deriving from processed US fuel. The agreement provides for the negotiation of arrangements and procedures for this within one year.

The Agreement provides for nuclear trade, transfer of nuclear material equipment, components and related technologies and for co-operation in nuclear fuel cycle activities.

The Agreement , as it is about civil nuclear co-operation. India's right to test in future, if it is necessary in India's national interest, does not get affected by this Agreement. There is no mention of testing in this Agreement. However, However, India, as a responsible nuclear state, would continue to observe its voluntary unilateral moratorium on testing and its policies of credible minimum deterrence and no first use.

India has obtained Cabinet approval for the final draft text for the agreement. As required by US Law, the US Government will take the Agreement to Congress for approval. As negotiated by us in the 123 Agreement, we will complete the negotiation of an India-specific IAEA safeguards agreement. United States, as committed, will work with NSG to adjust their guidelines to enable full civil nuclear energy cooperation and trade with India.

India has a long-standing commitment to the ideas of nuclear disarmament and our refusal to participate in any arms race, including a nuclear arms race. Our commitment to universal, non-discriminatory and total elimination of nuclear weapons remains undiminished. We stand for the strengthening of the non-proliferation regime as the infirmities in this regime have affected our security interests. We have been working together with the international community to advance our common objective of non-proliferation. We believe the Agreement is good for India, and good for the world.



Implication of the Agreement

- Nuclear energy will be a clean and cheap source of energy; nuclear science and technology has a high applicability in the field of medicine , in irradiation of food, helps in storage of food and also has several spin offs for the industry :
- The Agreement opens the door for India to civil nuclear cooperation as an equal partner with the USA and the rest of the world.

- It would help to address the problem of energy deficit that has emerged as one of the primary constraints on accelerating India's growth rate. As a result of the high rate of economic growth, demand for energy sources has been growing at a high rate. Presently, only 3% of India's energy needs are met from the nuclear sources. India plans to produce 20,000 MWe from the nuclear sector by 2020, an increase from the current 3,700 MWe.
- Increased share of nuclear power in the Indian energy mix will diminish the reliance on fossil fuels and reduce emissions from India. We envisage technology solutions to check growth of emissions (e.g. our membership of the Asia Pacific Clean Development Partnership) and the nuclear industry offers value in that respect.
- The participation of Indian scientists in global research projects is an intrinsic aspect of India's integration in the global economy. The Agreement would to an end technology denial regimes against India that have been in place for three decades and end India's nuclear isolation. It will open the doors for India to have civil nuclear cooperation as an equal partner with the USA and the rest of the world. It will enable us to meet the twin challenges of energy security and environmental sustainability. It will also have major spin-offs for the development of our industries, both public and private. At the same time, it will bring India the recognition it deserves thanks to the outstanding achievements of our scientists.

The future does lie in tapping nuclear energy. Countries such as France and the UK produce 85% and 52 % of their power from In the US and throughout Europe, investment in research and in the nuclear fuel cycle has continued, and some experts predict that electricity shortages, fossil fuel price increases, global warming from fossil fuel use, new technology such as passively safe plants, and national energy security will renew the demand for nuclear power plants.

Many countries remain active in developing nuclear power, including Japan, China and India, all actively developing both

fast and thermal technology, South Korea and the United States, developing thermal technology only, and South Africa and China, developing versions of the Pebble Bed Modular Reactor (PBMR). Finland and France actively pursue nuclear programs; Finland has a new European Pressurized Reactor under construction by Areva. Japan has an active nuclear construction program with new units brought on-line in 2005. As of the early 21st century, nuclear power is of particular interest to both China and India to serve our rapidly growing economies—both are developing fast breeder reactors. In the energy policy of the United Kingdom it is recognized that there is a likely future energy supply shortfall, which may have to be filled by either new nuclear plant construction or maintaining existing plants beyond their programmed lifetime.

Frequently asked questions about the India- US Agreement on civil nuclear co-operation:

o Does it affect our independent foreign policy?

There is no question of India ever compromising, in any manner, our independent foreign policy. The Agreement also clearly mentions this. The conduct of foreign policy determined solely by our national interests is our sovereign right. We shall retain our strategic autonomy.

o Does it mean India will have to sign CTBT/ FMCT?

The Agreement entails no obligations for India to sign CTBT/ FMCT. We, however, remain committed to a voluntary, unilateral moratorium on nuclear testing. We are also committed to negotiate a Fissile Material Cut-off Treaty (FMCT) in the Conference on Disarmament. India is willing to join only a non-discriminatory, multilaterally negotiated, and internationally verifiable FMCT subject to it meeting our national security interests.

o What happens to India's stand on Iran?

The 123 Agreement is about cooperation for peaceful uses of nuclear energy. It has no reference to any extraneous issue.

- **Is it linked to any other issue, such as purchase by India, of aircrafts.**

The Agreement is not linked to any extraneous commitment or obligation on India's part.

- **Have PM's commitment to Parliament been fulfilled?**

Commitments made by Prime Minister to Parliament, including in his statement to Rajya Sabha on August 17, 2006, have been fully adhered to.

- **What happens to our independent 3 stage nuclear power programme?**

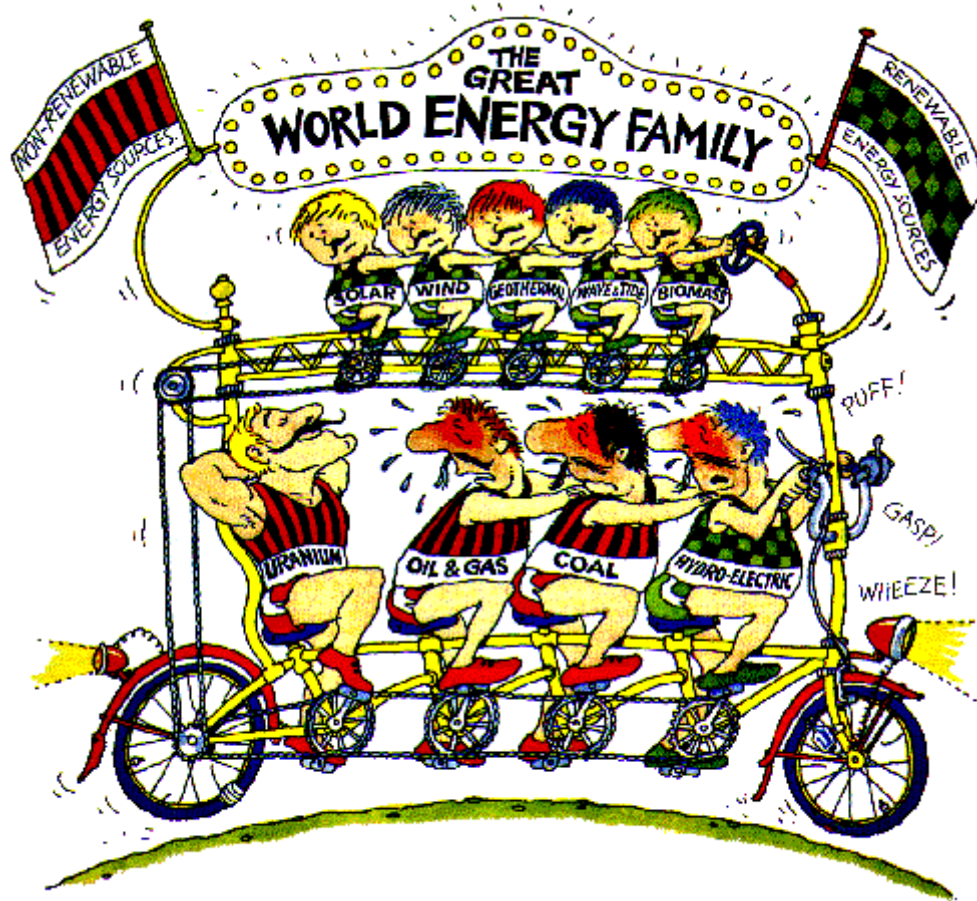
India's indigenous three stage nuclear programme does not get affected by this agreement. Its full autonomy has been preserved.

- **Does the agreement mean India has to give up its nuclear weapons programme.**

The agreement does not affect India's nuclear weapons programme in any way. However, India, as a responsible nuclear state, would continue to observe its voluntary moratorium on testing and its policies of credible minimum deterrence and no first use.

Advantages of nuclear Power

About half a million years ago human beings learned to make fire. By collecting and burning wood they were able to warm themselves, cook food and manufacture primitive implements. Thousands of years later the Egyptians discovered the principle of the sail. Later still came the invention of the water wheel. All these activities utilise various forms of energy - biological, chemical, solar and hydraulic.



Population

Together with this increasing energy consumption, it has been possible for the world to sustain an ever increasing population. At present, however, 77% of world energy production is consumed by the 28% of the world's population living in the industrialised countries. Put another way, almost three quarters of the world's population - mostly in the under-developed countries - uses less than a quarter of all the energy produced.

An even more rapid population growth is foreseen in the near future, with the world's population increasing from the present 5500 million to about 8500 million over the next thirty years before any levelling off can be expected, to give about 10 billion by 2050. Ninety per cent of population growth will be in the developing countries, which already have more than three quarters of the world's people.

Such a population increase will have a dramatic impact on energy demand, almost tripling it by 2050, even if the developed countries adopt more effective energy conservation policies so that their energy consumption does not increase at all over that period.

Energy can be considered in two categories - primary and secondary.

Primary energy is energy in the form of natural resources, such as wood, coal, oil, natural gas, natural uranium, wind, hydro power, and sunlight. Secondary energy is the more useable forms to which primary energy may be converted, such as electricity and petrol.

Primary energy can be renewable or non-renewable:

Renewable energy sources include solar, wind and wave energy, biomass (wood or crops such as sugar), geothermal energy and hydro power.

Non-renewable energy sources include the fossil fuels - coal, oil and natural gas, which together provide 80% of our energy today, plus uranium.

The availability of energy

There is no shortage of primary energy. The sun pours on to our planet each day many times more energy than we need. We see this energy in a variety of forms, ranging from solar radiation, through wind and waves, to trees and vegetation which convert the sun's rays into plant biomass. In addition there is an enormous amount of energy in the materials of the earth's crust. The challenge has been to convert these almost boundless resources into useable forms of energy.

Coal was the first fossil fuel to be widely used industrially and to increase people's standard of living.

Oil is a convenient source of energy. Because of its easy availability and low price, it played an important role in the economic development of many countries during the past century. At present, oil remains the major source of primary energy for some countries.

Today **natural gas** is widely used alongside coal and oil, as a very versatile fuel.

As demand for fossil fuels grows, we are using the technological base they have provided to increase our use of **renewable** energy sources.

But the question of "**Why Uranium?**" puts the focus on energy sources which are suitable for electricity generation. Electricity demand is growing twice as fast as overall energy demand in all parts of the world. And electricity generation accounts for 40% of total primary energy.

To put the choices into perspective, let us look briefly at the potential and limitations of each source of electric power, beginning with 'renewables'.

Hydro-electric generating facilities have the attraction of providing electricity without polluting the atmosphere. Their 'fuel' is falling water, which can occur naturally, but more often has to be engineered by the construction of large dams with lakes behind them. Its advantages have long been appreciated and today hydro power provides 19% of the world's total electricity. In many countries most of the suitable dam sites have already been used, thus limiting any further major development of this source.

Solar energy in particular has considerable logical and popular appeal. However, for electricity generation solar power has limited potential, as it is too diffuse and too intermittent. First, solar input is interrupted by night and by cloud cover, which means that solar electric generation capacity can typically only be used to about 15% of its capacity. Also, there is a low intensity of incoming radiation and converting this to high-grade

electricity is still relatively inefficient (12 - 16%), though this has been the subject of much research over several decades.

On a small scale (and at relatively high cost) it is possible to store electricity. On a large scale any solar electric capacity has to be worked in with other sources of electricity with full back-up. While it is true that sunlight itself is free, the capital costs of conversion, maintenance and storage are extremely high. The main role of solar energy in the future will be that of direct heating.

Other renewable energy sources also have shortcomings which limit their ability to play a greatly increased role in meeting electricity needs:

Wind, like the sun, is 'free' and is increasingly harnessed for electricity. Over 5000 megawatts capacity is now installed around the world. However, similar storage and back-up issues arise as for solar. It is not always available when needed, and some means is required to store energy or provide substitute capacity for windless periods.

Geothermal energy comes from natural heat below the earth's surface. Where hot underground steam can be tapped and brought to the surface it may be used to generate electricity. Such geothermal sources have potential in certain parts of the world. Some 6000 MWe of capacity is operating. There are also prospects in other areas for pumping water underground to very hot regions of the earth's crust and using the steam thus produced for electricity generation.

Biomass. Most forests and agricultural crops are technically capable of being converted into some form of energy, even if the primary purpose of the crop is to provide food. The 'energy farm' concept where crops are produced solely for energy production is also receiving consideration. Such farms however would compete with other crops for water, fertiliser and land use, thus requiring us to choose between fuel and food. In short, while biomass already provides a useful and growing source of

energy for rural communities in third world countries, and organic waste and water plants can be used to produce 'biogas', it is only likely to play a very small role overall.

For the remainder of this century, the only energy resources available for economic large scale electricity generation are therefore likely to be oil, gas, coal and nuclear.

Oil has generally become too expensive to use for electricity and it has the great advantage of being a portable fuel suitable for transport. Wherever possible it is conserved for special uses, such as transport and in the petrochemical industry.

Gas has been seen in the same way as oil, as being too valuable to squander for uses such as electricity generation. But after the oil price shocks of the 1970s, increased exploration efforts revealed huge deposits of natural gas in many parts of the world and today these are extensively used for power stations. The main virtue of gas however is that it can be reticulated safely and cheaply to domestic and industrial users and burned there to provide heat. It is also a valuable chemical feedstock.

Coal dominated the production of electricity until it was displaced to some extent by cheap oil in the 1950s. Coal still produces 42% of all electricity worldwide, while uranium produces 17%. In OECD countries the figures are closer together: 40% and 23% respectively.

Uranium is also abundant and the best deposits are unevenly distributed. Some eighty percent of it occurs in six countries. World mine production is about 50,000 tonnes of uranium oxide concentrate per year. Practically all of it is used for electricity.

Energy Conversion:

Typical Heat Values of Various Fuels

Brown coal	9.7 MJ/kg
Firewood	16 MJ/kg
Black coal	24-30 MJ/kg
Natural Gas	39 MJ/m ³

Crude Oil	45-46 MJ/kg
Uranium - in light water reactor	500,000 MJ/kg

(MJ = megajoules)

Which should be used?

World reserves of coal are, in theory, large enough to produce the electricity we shall need for several hundreds of years. However, it is likely that more and more of the coal mined in the future will be converted into the more valuable liquid fuels and so will not be available for electricity generation. There are also environmental and other problems associated with the increased mining and burning of coal.

World coal production is about 3.5 billion tonnes per year, most of it being used for electricity.

The difference in the heat value of uranium compared with coal and other fuels is important (though both are used at about 33% thermal efficiency in the power station). A one million kilowatt (1,000 MWe) power station consumes about 2.3 million tonnes of black coal each year, or about 25 tonnes of uranium (UO₂) enriched to about 3-4%. The latter requires the mining of 45-90,000 tonnes of typical uranium ore.

Wastes

The enormous difference in the quantities of fuel used also directly affects the quantities of waste that remain after the electricity has been generated.

The 25 tonnes or so of spent fuel taken each year from a 1000 MWe nuclear reactor is highly radioactive and gives off a great deal of heat. Much is reprocessed so that 97% of this is recycled. The remaining 3%, about 700 kg, is high-level radioactive waste which is potentially hazardous and needs to be isolated from the environment for a very long time. However, the small quantity makes the task readily manageable. Even where the spent fuel is not reprocessed, the yearly

amount of 25 tonnes is modest compared with the quantities of waste from a similar sized coal-fired power station.

A 1,000-MWe coal-fired power station produces about seven million tonnes of carbon dioxide each year, plus perhaps 200,000 tonnes of sulfur dioxide which remains a major source of atmospheric pollution. Other waste products from the burning of coal include large quantities of fly ash (typically 200,000 tonnes per year), containing toxic metals, including arsenic, cadmium and mercury, organic carcinogens and mutagens (substances that can cause cancer and genetic changes) as well as naturally-occurring radioactive substances.

If not fully contained, these routine wastes can cause environmental and health damage even at great distances from the site of the power station. For example, acid rain caused by the release of sulfur dioxide has crossed national boundaries and caused severe damage to lakes, rivers and forests in Canada, Scandinavia and elsewhere.

Any means of producing electricity involves some wastes and environmental hazard.

The nuclear industry is unique in that it is the only energy-producing industry that has taken full responsibility for the disposal of all its wastes and meets the full cost of doing so. Nuclear energy today saves the emission of about 2.3 billion tonnes of carbon dioxide each year (compared with over 7 billion tonnes per year emitted from fossil fuel electricity generation).

Economics

The difference in fuel requirements between coal fired and nuclear power stations also affects their economics. The cost of fuel for a nuclear power station is very much less than for an equivalent coal fired power station, usually sufficient to offset the much higher capital cost of constructing a nuclear reactor. Consequently, in practical terms, electricity from nuclear reactors in many regions is competitive with electricity produced from coal, even after providing for management and disposal of radioactive wastes and the decommissioning of reactors.

OECD projections show nuclear energy cheaper than coal in most parts of the developed world (except UK, western USA and parts of Canada). It is also cheaper than gas in many areas.

Electricity generation - the future fuel mix

For most countries the questions that need to be answered are: What are our likely electricity requirements? What forms of generation are available to us? Which combination will provide our needs with maximum security and the least harm to our population and environment?

The debate about whether to build nuclear energy reactors is again in full swing. It is necessary, as we become more aware about the magnitude of the climate change through the global warming phenomenon.

Most scientists agree that we are seeing the effects of global warming already and that the imminent future looks dire. We must reduce the emissions that cause global warming. Therefore alternative energy must be employed.

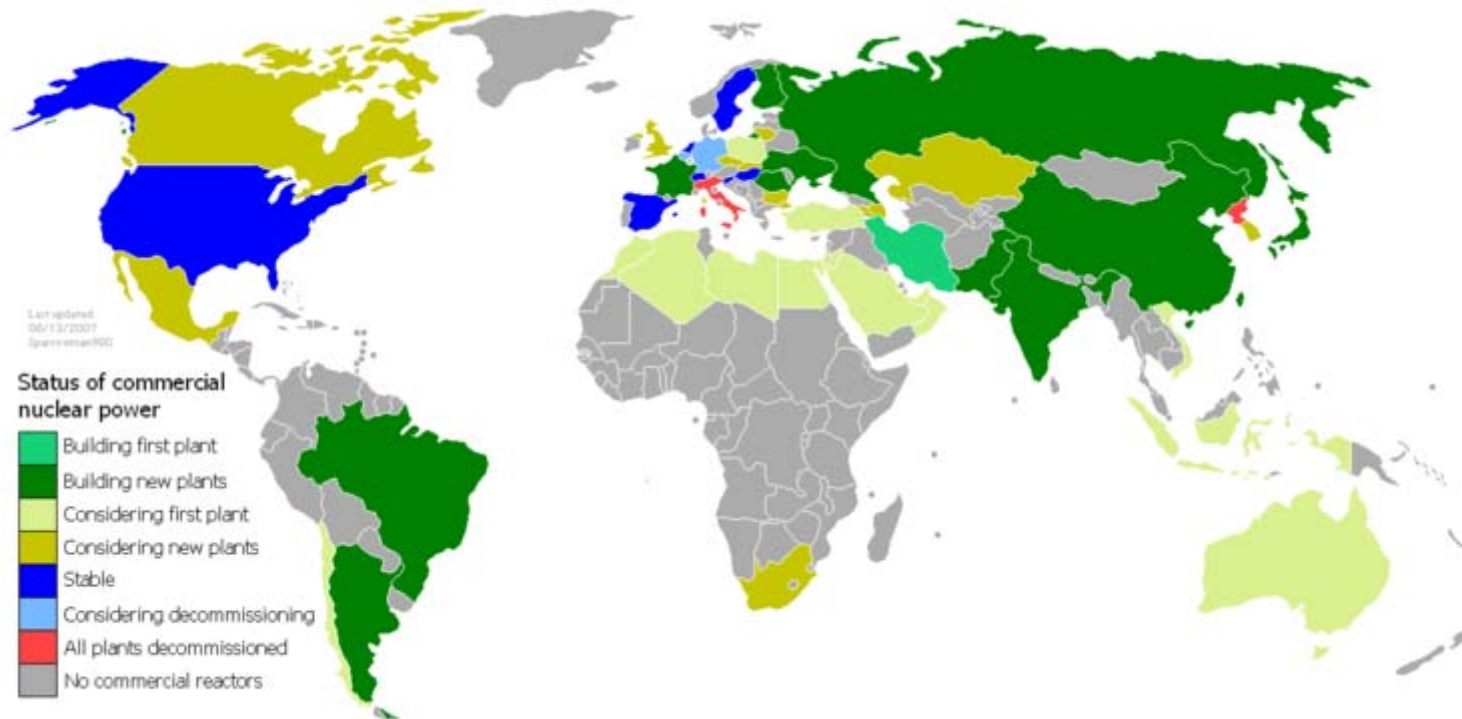
Some think this means a wholesale adoption of nuclear energy, some see no advantages of nuclear energy, some believe in a mix of nuclear energy with renewable energy.

Nuclear energy provides between 11% and 18% of world electricity needs.

By mid 1997, there were 32 countries of varying size, political persuasion and degree of industrial development, which included nuclear power in their energy mix and were operating nuclear reactors. Over 17% of the world's electricity is being produced by over 440 reactors, with 30 more under construction. Belgium, China, France, Hungary, India, Japan, Russia, Switzerland, UK and USA are just some of the countries with major nuclear energy programs.

In 1996 there was as much electricity produced from nuclear energy than from all sources worldwide in 1960 (2300 billion kilowatt-hours).

No country would want to be too dependent on a single energy source. For many it is therefore not a question of coal or nuclear for their main supply of electricity, but a combination of both, with as much help as possible from hydro power and other renewable sources.



So what are advantages of nuclear energy?

Fissile atoms contain vast amounts of energy

Nuclear fission, the splitting of a heavy atom's nucleus, releases great amounts of energy. For example the energy it releases is 10 million times greater than is released by the burning of an atom of fossil fuel. Besides it would take many hectares of land covered with solar collectors, wind farms or hydro-electric dams to equal this power.

No greenhouse gases are released by nuclear power plants.

According to some, even when accounting for the fossil fuel used in mining uranium, processing it, building and decommissioning of the nuclear plant, the picture remains good from this perspective. Less

than one-hundredth of carbon dioxide gas is produced by nuclear power plants compared to coal or gas-fired energy plants. This means nuclear energy also emits less greenhouse gas than renewable energy sources such as hydro, wind, solar and biomass.

Cost

The major costings in building nuclear power plants are usually those of construction and operating the nuclear plant as well as that of waste disposal and cost of decommissioning the plant. The cost of the end product, energy is subject to variables such as type of reactor, cost-over runs in construction and decommissioning, and loan interest rates.

Availability of uranium

Uranium is obtained from open-cut mines and is not expensive to mine. World reserves are estimated to last anywhere between 6 to 150 years, to even hundreds of centuries, depending on who is the commentator, and depending on the type of reactor they have in mind.

Present reactors only use some 1% of the energy available in uranium but in future fast breeder reactors could recycle spent fuel rods at a 99% efficiency rate. The potency and quantity of radio active waste material from such reactors is much less than that of current thermal reactors.

Other advantages include,

- **Nuclear fuel is inexpensive**
- **Waste is highly compact, unlike carbon dioxide**

The compact fuel is easy to transport

Further advantages of nuclear energy?

Among the **further advantages of nuclear energy** against the backdrop of climate change, is that we are forced to look at ourselves.

What have we done to get us here? Any promise of unlimited energy, nuclear or otherwise, is deceptive in a world that exists because of tensions, limitations, dependency and vulnerability.

We may have to adjust to that reality and use less energy than we actually think we need. You and I will need to review our priorities. Inevitably we will need to use more of the energies of relationship and genuine care for each other and our environments to be a success at that.

The main cause of global warming is the increased emission of so called greenhouse gases , in particular carbon dioxide (chemical symbol CO₂). These greenhouse gases have an average lifetime in the atmosphere of 50 to 200 years. This means that even if we stopped the emission of greenhouse gases completely tomorrow, global warming would still continue.

In other words: It is impossible to stop global warming, it is only possible to mitigate its effects through a drastic reduction of the emission of CO₂.

Can nuclear power plants mitigate the effects of global warming?

Nuclear energy is used to generate electrical power. Therefore it is only possible to reduce the emission of CO₂ if nuclear power plants are used instead of other, CO₂ emitting technologies. This is in particular the case for electrical generation plants

fuelled by coal, oil or gas. The CO₂ emission can indeed be reduced, if electrical power plants driven by fossil fuels are being replaced by nuclear power plants. However the application of nuclear power unfortunately is highly problematic, therefore the problem of CO₂ emissions must not be looked at independently of all other risks and problems. See our text about pros and cons of nuclear power for a summary of the advantages and disadvantages.

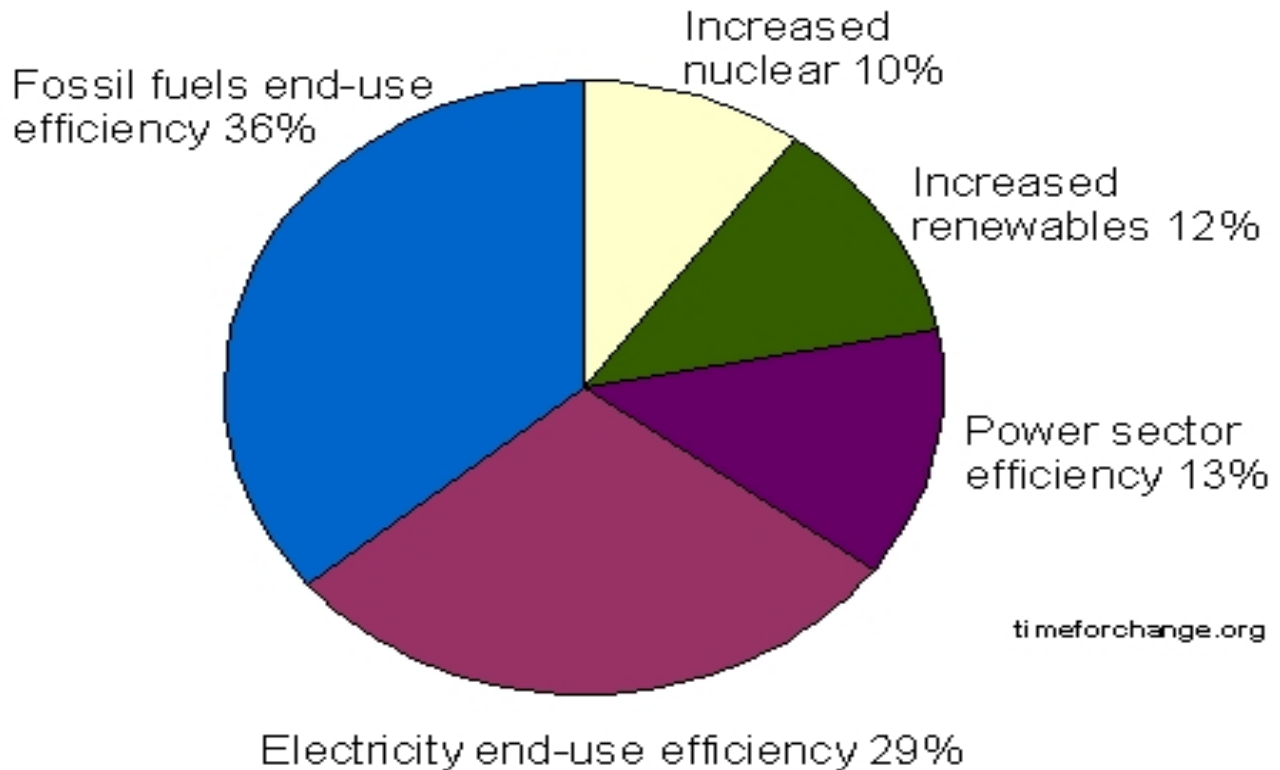
How much can nuclear energy reduce the main cause of global warming?

The International Energy Agency (IEA) records the energy consumption world-wide and produces a forecast for the next 25 years. In their last energy outlook published in autumn 2006, IEA predicts a strong increase of the carbon dioxide emissions by the year 2030 as a consequence of the increasing demand for energy world-wide.

Additionally, IEA investigated to which extent the above mentioned emissions of CO₂ could be prevented if politics applied rigorous measures. One of many measures investigated was massive facilitations and incentives for building additional nuclear power plants.

From all measures proposed, nuclear energy was found to have a 10% effect . The chart below shows the effects of each proposed measure to reduce the main cause of global warming, the emission of carbon dioxide:

CO₂ reduction share by fuel type



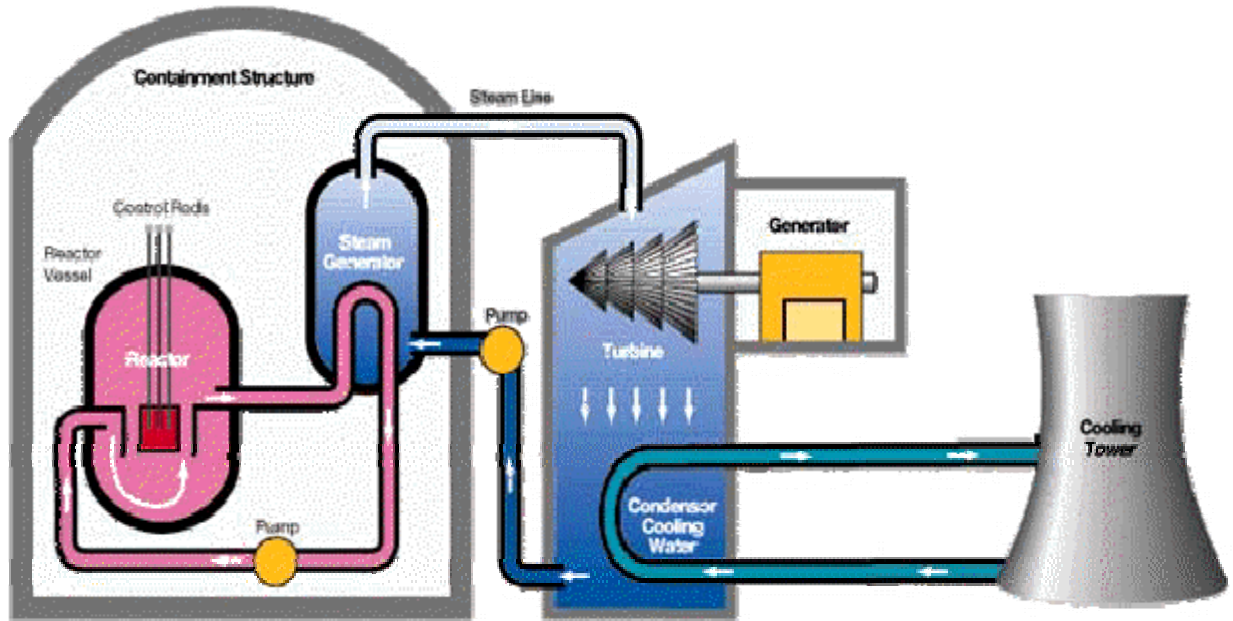
Graph1: Proportional effect of measures to mitigate the main cause of global warming, the emission of CO₂ by the year 2030. 100% = effect of all proposed measures together. Data source: International Energy Agency (IEA). <http://iea.org>

The following results attract attention:

- Almost 80% of the desired effects are due to increasing the energy efficiency (36% due to increasing the efficiency of the use of fossil energy, 29% due to increasing the efficiency of electrical appliances and 13% due to increasing the efficiency at the electrical power generation).
- 12% of the desired effects are due to furthering the generation and application of renewable energies.

- 10% of the desired effects are due to furthering nuclear energy.

Nuclear Power Generation



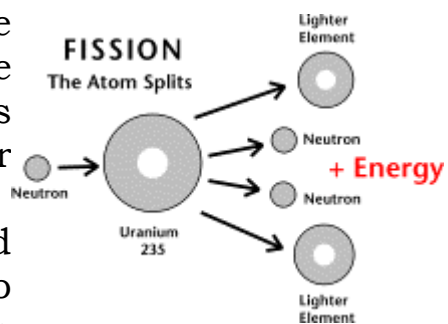
Nuclear

- **How is nuclear power produced?**

Nuclear energy is energy in the nucleus (core) of an atom. Atoms are tiny particles that make up every object in the universe. There is enormous energy in the bonds that hold atoms together. Nuclear energy can be used to make electricity. But first the energy must be released. It can be released from atoms two ways: nuclear fusion and nuclear fission.

In **nuclear fusion**, energy is released when atoms are combined or fused together to form a larger atom. This is how the sun produces energy.

In **nuclear fission**, atoms are split apart to form smaller atoms, releasing energy. Nuclear power plants use nuclear fission to produce electricity.



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The **fuel** most widely used by nuclear plants for nuclear fission is uranium. Uranium is nonrenewable, though it is a common metal found in rocks all over the world. Nuclear plants use a certain kind of uranium, U-235, as fuel because its atoms are easily split apart. Though uranium is quite common, about 100 times more common than silver, U-235 is relatively rare. Once uranium is mined the U-235 must be extracted and processed before it can be used as a fuel.

During nuclear fission, a small particle called a neutron hits the uranium atom and it splits, releasing a great amount of energy as heat and radiation. More neutrons are also released. These neutrons go on to bombard other uranium atoms, and the process repeats itself over and over again. This is called a chain reaction.

Most power plants burn fuel to produce electricity, but not **nuclear power plants**. Instead, nuclear plants use the heat given off during fission as fuel. Fission takes place inside the reactor of a nuclear power plant. At the center of the reactor is the core, which contains the uranium fuel.

The uranium fuel is formed into ceramic pellets. The pellets are about the size of your fingertip, but each one produces the same amount of energy as 150 gallons of oil. These energy-rich pellets are stacked end-to-end in 12-foot metal fuel rods. A bundle of fuel rods is called a fuel assembly.

Fission generates heat in a reactor just as coal generates heat in a boiler. The heat is used to boil water into steam. The steam turns huge turbine blades. As they turn, they drive generators that make electricity. Afterward, the steam is changed back into water and cooled in a separate structure at the power plant called a cooling tower. The water can be used again and again.

Different types of nuclear power plants have been developed, including boiling-water reactors (BWRs), and pressurized-water reactors (PWRs).

Nuclear reactors are basically machines that contain and control chain reactions, while releasing heat at a controlled rate. In electric

power plants, the reactors supply the heat to turn water into steam, which drives the turbine-generators. The electricity travels through high voltage transmission lines and low voltage distribution lines to end users.

Like all industrial processes, nuclear power generation has **by-product wastes**: spent (used) fuels, other radioactive waste, and heat. Because nuclear generated electricity does not emit carbon dioxide into the atmosphere, nuclear power plants prevent emissions of millions of metric tons of carbon dioxide.

Spent fuels and other radioactive wastes are the principal environmental concern for nuclear power. Most nuclear waste is low-level radioactive waste. It consists of ordinary tools, protective clothing, etc that have been contaminated with small amounts of radioactive dust or particles. These materials are subject to special regulation that govern their disposal so they will not come in contact with the outside environment. On the other hand, the spent fuel assemblies are highly radioactive and must initially be stored in specially designed pools resembling large swimming pools (water cools the fuel and acts as a radiation shield) or in specially designed dry storage containers.

What is reprocessing of fuel?

Fuel reprocessing recovers the useable uranium from fuel rods, to be used again in the reactor. This dramatically cuts down on the amount of waste from nuclear power plants.

Why the third Stage of our Nuclear Programme is still to take off?

The third stage of nuclear programme is based on Thorium (a by product of Uranium ore), of which we have substantial reserves. However, the technology to use thorium as fuel is still in its experimental stage. The present Agreement would not affect our ongoing thorium based programme.

What is Nuclear Fuel Cycle ?

All operations associated with the production of nuclear energy, including:(a) Mining and processing of uranium or thorium ores; (b) Enrichment of uranium; (c) Manufacture of nuclear fuel; (d) Operation of nuclear reactors (including research reactors); (e) Reprocessing of spent fuel; (f) All waste management activities (including decommissioning) relating to operations associated with the production of nuclear energy; (g) Any related research and development activities.

What is the separation plan and does it affect our programme?

The plan to separate civilian reactors from the military ones is called the Separation plan. As per the agreement only the civilian reactor would be subject to IAEA safeguards. Our Fast breeder Test reactor and the thorium based research programme have been placed on the military side, so the Agreement does not affect their progress.

What is meant by safeguards ?

It basically means that we would have to allow our civilian nuclear sites for inspection by the IAEA authorities essentially to confirm that there is no diversion of supplies received from the nuclear supplier for civilian nuclear use to our strategic programme.

What is Fission and Fusion technology?

Nuclear Energy is produced from Fission Technology. In this process, an atomic nucleus is broken up by neutrons, releasing energy in the process. In fusion, two smaller nuclei are fused together to make a larger one, producing energy in the process. This requires very high temperature. Fusion constantly takes place in the sun. We do have fusion based research programme but its scope is very limited at this point in time.

What is Fast Breeder Reactor ?

A Fast Breeder Reactor uses a much faster stream of neutrons in the reactor. This allows for more efficient generation, and produces a surplus of neutrons which can then be used to either a) break down

existing nuclear waste in to less harmful compounds, or b) create more fissile material for the reactor - a breeder reactor. This reactor is in experimental stage in India .

Common Nuclear Energy Terms

Uranium: A radioactive element with the atomic number 92 and, as found in natural ores, an atomic weight of approximately 238. The two principal natural isotopes are uranium-235 (0.72 percent of natural uranium), which is fissile, and uranium-238 (99.28 percent of natural uranium), which is fissionable by fast neutrons and is fertile. Natural uranium also includes a minute amount of uranium-234.

Enriched Uranium: Uranium containing a greater mass percentage of uranium-235 than 0.72%.

Low Enriched Uranium (LEU): Enriched uranium containing less than 20% of the isotope ^{235}U . LEU is considered a special fissionable material and an indirect use material.

High Enriched Uranium (HEU): Uranium containing 20% or more of the isotope ^{235}U . HEU is considered a special fissionable material and a direct use material.

Depleted Uranium: Uranium containing a lesser mass percentage of uranium-235 than in natural uranium.

Plutonium (Pu): A heavy, radioactive, manmade metallic element with atomic number 94. Its most important isotope is fissile plutonium-239, which is produced by neutron irradiation of uranium-238. It exists in only trace amounts in nature

Source Material :Uranium or thorium, or any combination thereof, in any physical or chemical form or ores that contain by weight 1/20 of one percent (0.05 percent) or more of (1) uranium, (2) thorium, or (3) any combination thereof. Source material does not include special nuclear material.

Fissile Material :Although sometimes used as a synonym for fissionable material, this term has acquired a more restricted meaning. Namely, any material fissionable by thermal (slow) neutrons. The three primary fissile materials are uranium-233, uranium-235, and plutonium-239.

Special nuclear material : Plutonium, uranium-233, or uranium enriched in the isotopes uranium-233 or uranium-235.

Byproduct : Byproduct is (1) any radioactive material (except special nuclear material) yielded in, or made radioactive by, exposure to the radiation incident to the process of producing or using special nuclear material (as in a reactor); and (2) the tailings or wastes produced by the extraction or concentration of uranium or thorium from ore.

Nuclear Fuel: Fissionable nuclear material in the form of fabricated elements for loading into the reactor core of a civil nuclear power plant or research reactor.

Spent nuclear fuel: Fuel that has been removed from a nuclear reactor because it can no longer sustain power production for economic or other reasons.

Fuel reprocessing : The processing of reactor fuel to separate the unused fissionable material from waste material.

Safeguards : Nuclear safeguards are measures to verify that civil nuclear materials are properly accounted for and are not diverted to undeclared uses. The measures include nuclear materials accountancy, containment and surveillance.

Protocol Additional to Safeguards Agreements (Additional Protocol) : Agreements with the IAEA made by States that specify the additional authority necessary for the IAEA to fully implement its obligations under comprehensive safeguards agreements pursuant to the NPT. Additional protocols contain measures to improve the efficiency and strengthen the effectiveness of the IAEA safeguards system. The main features of the additional protocol are the requirements that States provide (i) information beyond that required

for nuclear materials accountancy, e.g. on nuclear fuel cycle-related R&D, specified manufacturing activities (e.g. centrifuge manufacture) and exports and imports of certain non-nuclear material and equipment; and (ii) extended access to the IAEA to check this reporting.

The Nuclear Suppliers' Group

The NSG was created following the explosion in **1974** of a nuclear device by India. The NSG published their guidelines in **1978** as a document of the International Atomic Energy Agency , INFCIRC/254 (subsequently amended), to apply to nuclear transfers for peaceful purposes to help ensure that such transfers would not be diverted to unsafeguarded nuclear fuel cycle or nuclear explosive activities.

At the **1990** NPT Review Conference, a number of recommendations were made by the committee reviewing the implementation of Article III, which had a significant impact on the NSG's activities in the 1990s.

In **1992**, the NSG decided to establish Guidelines for transfers of nuclear-related dual-use equipment, material and technology (items which have both nuclear and non-nuclear applications) which could make a significant contribution to an unsafeguarded nuclear fuel cycle or nuclear explosive activity. These Dual-Use Guidelines were published as Part 2 of INFCIRC/254, and the original Guidelines published in 1978 became Part 1 of INFCIRC/254.

The endorsement at the **1995** NPT Review and Extension Conference (NPTREC) of the full-scope Safeguards policy already adopted by the NSG in 1992 clearly based on the principle that this nuclear supply policy would be a vital element in promoting the NSG's shared nuclear non-proliferation commitments and obligations.

- **Guidelines for Nuclear Transfers (INFCIRC/254, Part 1)**
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 therefor; (iii) non-nuclear material for reactors; (iv) plant and equipment for the 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 2)

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.

Q & A on the 123 Agreement

Q: Does the 123 Agreement affect our ability to conduct an independent foreign policy?

Answer: PM has said categorically that our foreign policy is determined solely by our national interests and that there is no question of India being bound by a law passed by a foreign legislature. Government remains committed to the pursuit of an independent foreign policy which is a legacy of our founding fathers. Our sole guiding principle in regard to our foreign policy, will be dictated entirely by our national interest and this agreement in no way affects our ability to conduct an independent foreign policy. The 123 Agreement is a voluntary agreement between two equal partners. It states specifically that both India and the US wish to develop cooperation in the civil nuclear energy on the basis of mutual respect for sovereignty, non-interference in each other's internal affairs. If anything, by contributing to India's energy security, the Agreement will increase our capacity to follow an independent foreign policy and our self-reliance.

Q: Will the 123 Agreement affect India's strategic programme?

Answer: No. The Agreement, as Prime Minister stated on 13 August 2007 in the Parliament, is about civilian nuclear cooperation. There is no provision in the Agreement which limits India's right to build future nuclear facilities, whether civil or military. On the other hand the Agreement includes a clause which explicitly ensures that the Agreement will neither be interpreted nor implemented in a manner that would adversely affect our independent and military nuclear activities. This Agreement therefore does not in any way impact on India's ability to produce and utilize fissile material for its current and future strategic needs.

Q: Does the Agreement affect our right to conduct nuclear explosive tests?

Answer: No. The Prime Minister has stated on 13 August in the Parliament that the Agreement does not in any way affect India's right to undertake future nuclear tests, if it is necessary in India's national interest. A decision to undertake a future nuclear test would be our sovereign decision, one that rests solely with the Government of the day. There is nothing in the Agreement that would tie the hands of a future Government or legally constrain its options to protect India's security and defence needs.

Q: Will the Agreement have any adverse impact on our indigenous three stage nuclear programme?

Answer: Our rights to pursue our three-stage nuclear power programme remain undiluted. The Agreement fully preserves our right to use for our own purposes our independent and indigenously developed nuclear facilities. It also provides for non-hindrance and non-interference in our activities involving use of nuclear material, non-nuclear material, equipment, components, information or technology and military nuclear facilities produced, acquired or developed independently for our own purposes. Our three stage nuclear programme holds immense promise for the future. However the thorium based technology, which would constitute the third stage, would become economically viable over a period of time following sequential implementation. Since our uranium supplies are inadequate we need to source it from elsewhere. While our three stage programme continues, using our own uranium resources, this Agreement, opens the door for international cooperation and would allow us to increase the share of nuclear energy. By separating our indigenous facilities from those that are imported our own programmes will continue to grow.

Q: Does the Agreement provide for fuel supply assurances for safeguarded reactors?

Answer: The Agreement provides for US support for an Indian effort to develop a strategic reserve of nuclear fuel in order to guard against any disruption of supply

for the lifetime of India's reactors. This is in accordance with the provisions of the Separation Plan of March 2006. The US has also agreed that in case a disruption of fuel supplies occurs, it would jointly convene with us a group of friendly supplier countries, including countries such as Russia, France and the United Kingdom to undertake such measures which would restore fuel supply to India. India also retains its right to take corrective measures in the event of disruption in the supply of foreign nuclear fuel.

Q: The Agreement states that it will be implemented by both sides according to their national laws and regulations. The Hyde Act will be one of the laws which the US will need to follow in implementing this Agreement. How will it then fulfill its assurances?

Answer: As far as India is concerned we are committed to the terms and provisions of the 123 Agreement only. The 123 Agreement does not mention Hyde Act anywhere. There is no provision of the Hyde Act in the 123 Agreement which is undesirable from our point of view. The Hyde Act is an enabling legislation to permit the US Administration to negotiate bilateral nuclear cooperation agreement with India. It contained certain extraneous provisions and commitments on US and Indian foreign policy which we have rejected.

The US Administration has categorically assured that the Hyde Act enables it to fulfill all of the commitments it made to India in the July 18 and March 2 Joint Statements. President Bush has also made it clear while signing the Act on December 18, 2006 that that he would consider certain provisions of the Hyde Act as only advisory.

Q: Why should Parliament not approve this Agreement?

Answer: India follows a parliamentary model, as specified in our Constitution, wherein treaty making powers rest with the Executive. No past bilateral treaty and

agreement has ever been approved by the Parliament. For instance the NDA Government had agreed with the US “Next Steps in Strategic Partnership” in January 2004 but this was never even made public. Even a major treaty such as the 1971 Indo-Soviet Union Treaty of Friendship was not brought to Parliament. Despite this Government has kept Parliament fully in the picture at various stages of our negotiations with the United States.

Advantages of the Agreement

- The Agreement could be a major contributor to our energy security. For India it is critical that we maintain our current economic growth rate of 8 to 10% per annum if we are achieve the goal of eradicating poverty. Inadequacy of energy supply is one of the primary constraints on accelerating India's growth rate. We are trying to expand all forms of energy production in a manner which takes care of concerns about environment. Nuclear energy is a logical choice in this context and can make a larger contribution to our overall energy mix. At present its share is only about 3%. We have an ambitious programme to increase our nuclear energy generating capacity to 20,000 MWe by 2020. While our domestic three stage programme continues, using our own uranium resources, this Agreement, by adding additional capacity quickly, would help us to reach that target soon.
- The Agreement also opens the door for cooperation in civil nuclear energy with other countries. We are already discussing with France and Russia similar bilateral cooperation agreements on civil nuclear energy. Once the NSG adopts an exemption to its Guidelines we hope to operationalise all these agreements.
- In the longer term, it would also help us to remove restrictions imposed on India by various technology denial regimes and help us to access high technology in various sectors important for our economic development. This Agreement can thus lead to major spin-offs for the development of our industries and expansion of high technology trade with the US and other technologically advanced countries.
- It will also create opportunities for our scientists to participate in the international exchange of ideas and technical know-how.

Main features of the 123 Agreement

- (i) The Agreement is “between two States possessing advanced nuclear technology, both parties having the same benefits and advantages”.
- (ii) The Agreement provides for full civil nuclear energy cooperation covering nuclear reactors and aspects of the associated nuclear fuel cycle including enrichment and reprocessing.
- (iii) The Agreement provides for nuclear trade, transfer of nuclear material, equipment, components, and related technologies and for cooperation in nuclear fuel cycle activities.
- (iv) The Agreement contains a full reflection of the March 2, 2006 supply assurances, its linkage to safeguards in perpetuity and the provision for corrective measures.
- (v) The Agreement provides for the development of a strategic reserve of nuclear fuel to guard against any disruption of supply over the lifetime of India’s reactors.
- (vi) The Agreement provides for the application of IAEA safeguards to transferred material and equipment. There is no provision that mandates scrutiny of our nuclear weapons programme or any unsafeguarded nuclear facility.
- (vii) The Agreement explicitly provides that it will not affect the unsafeguarded facilities of either party and that it shall be implemented in a manner so as not to hinder or otherwise interfere with any military nuclear facilities or nuclear material produced, acquired or developed independent of this Agreement.
- (viii) The Agreement grants prior consent to reprocess nuclear material, transfer nuclear material and its products. To bring this into effect, India will establish a national reprocessing facility to reprocess safeguarded nuclear material. Consultations on arrangements and procedures will begin within six months of a request by either party and will be concluded within one year.
- (ix) The Agreement does not affect India’s right The 123 Agreement does not affect India’s right to test in any manner.
